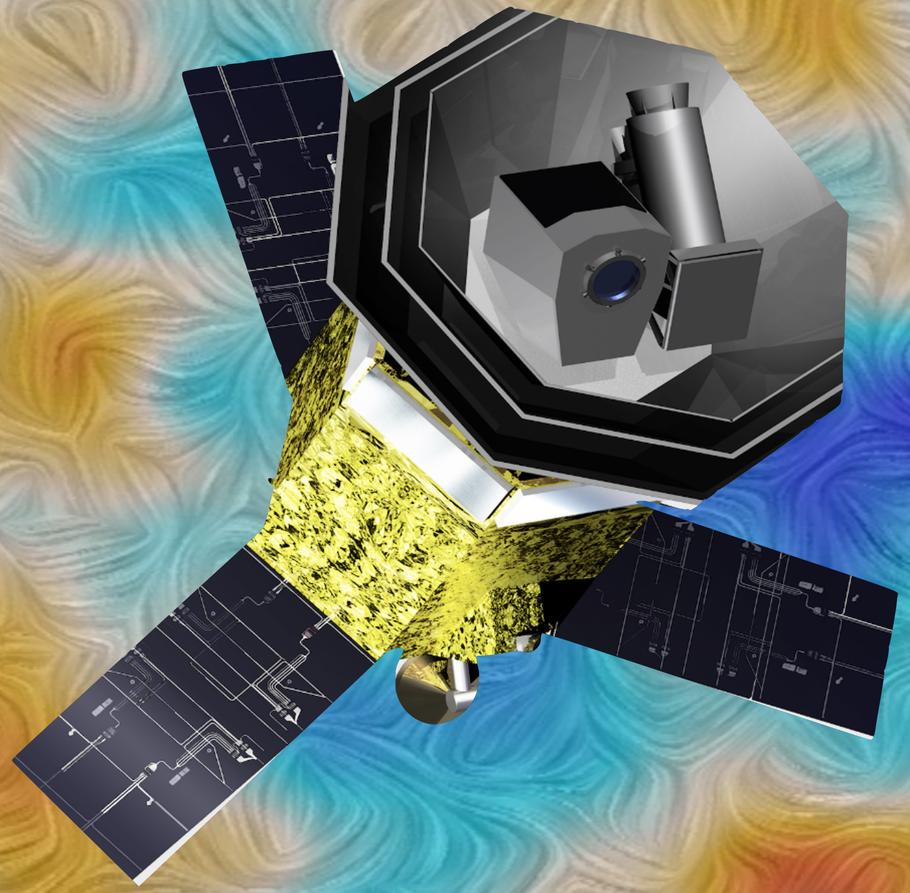


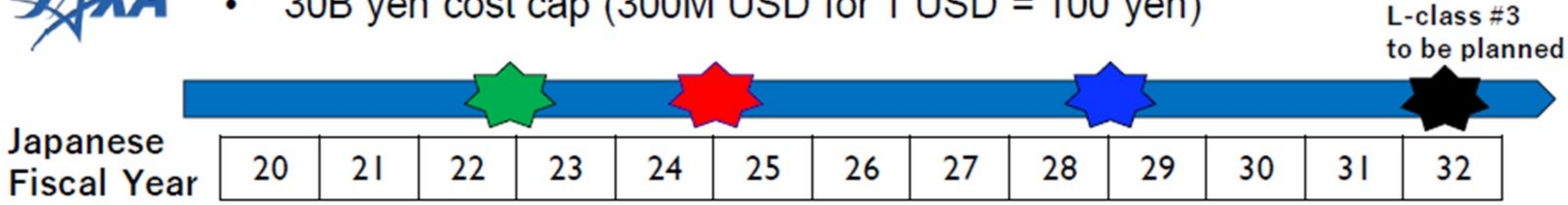
Panel Report of the LiteBIRD MHFT Phase A2 preparation Key Point

CNES-JAXA KP - 05 May 2023

LiteBIRD MHFT Context

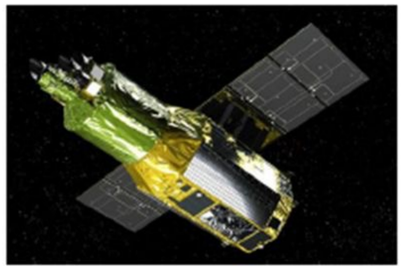
LiteBird is the JAXA L-Class #2 mission to be launched in January 2031 with an H3 launch vehicle for three years of observations at the Sun-Earth Lagrangian point L2.
LiteBIRD : Lite (Light) satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection

- Flagship science mission with HIIA/H3 vehicle
- 30B yen cost cap (300M USD for 1 USD = 100 yen)

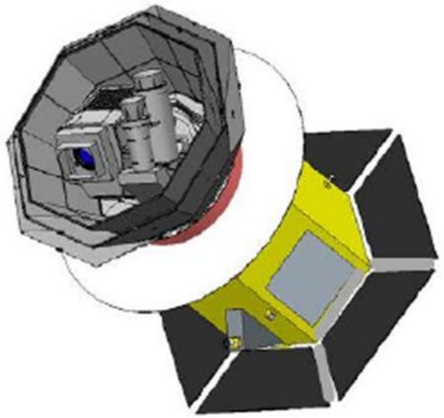


HIIA

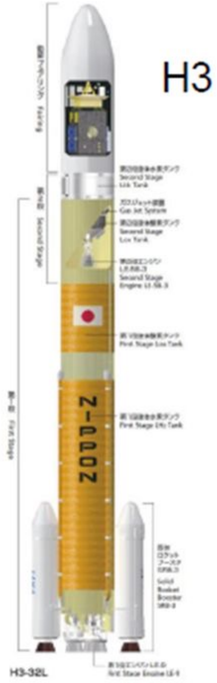
XRISM
(recovery of Hitomi)



L-class #1
Martian
Moons
eXploration
(MMX)



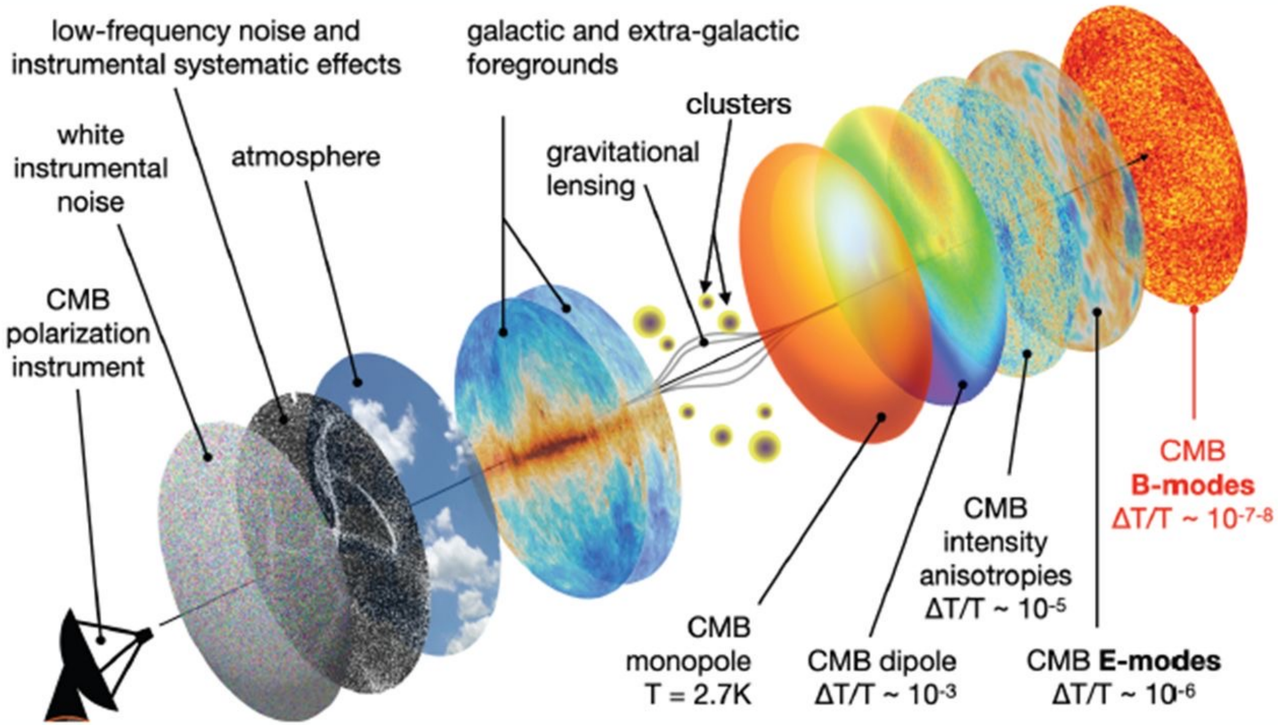
L-class #2
LiteBIRD
(selected in
May 2019)

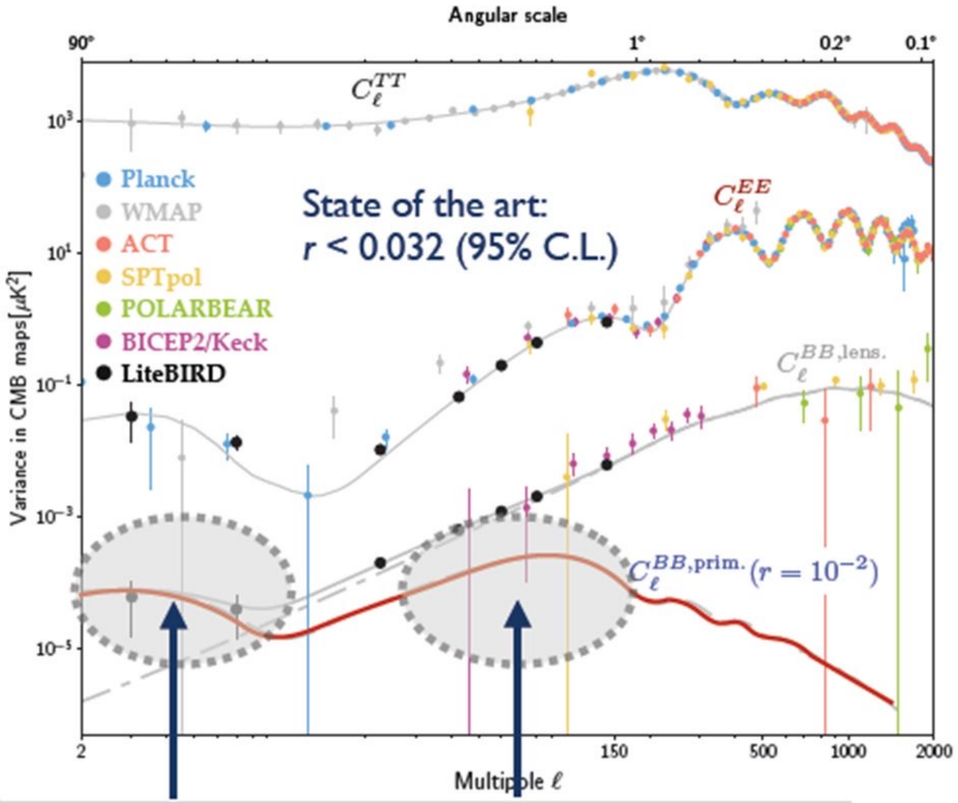


H3

LiteBIRD MHFT Context

What is our target on 'r' ?



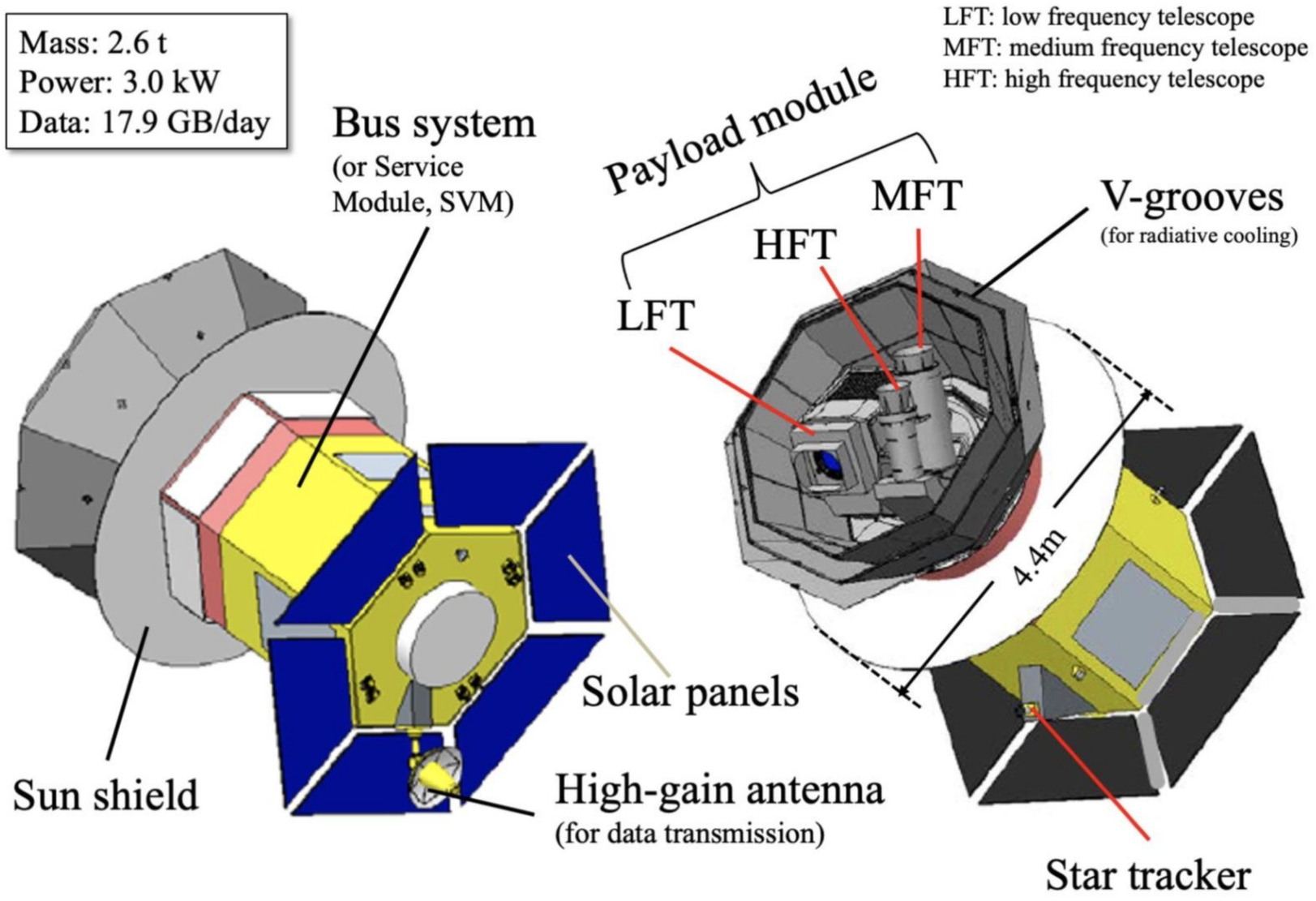


L1.01: $\delta r < 10^{-3}$

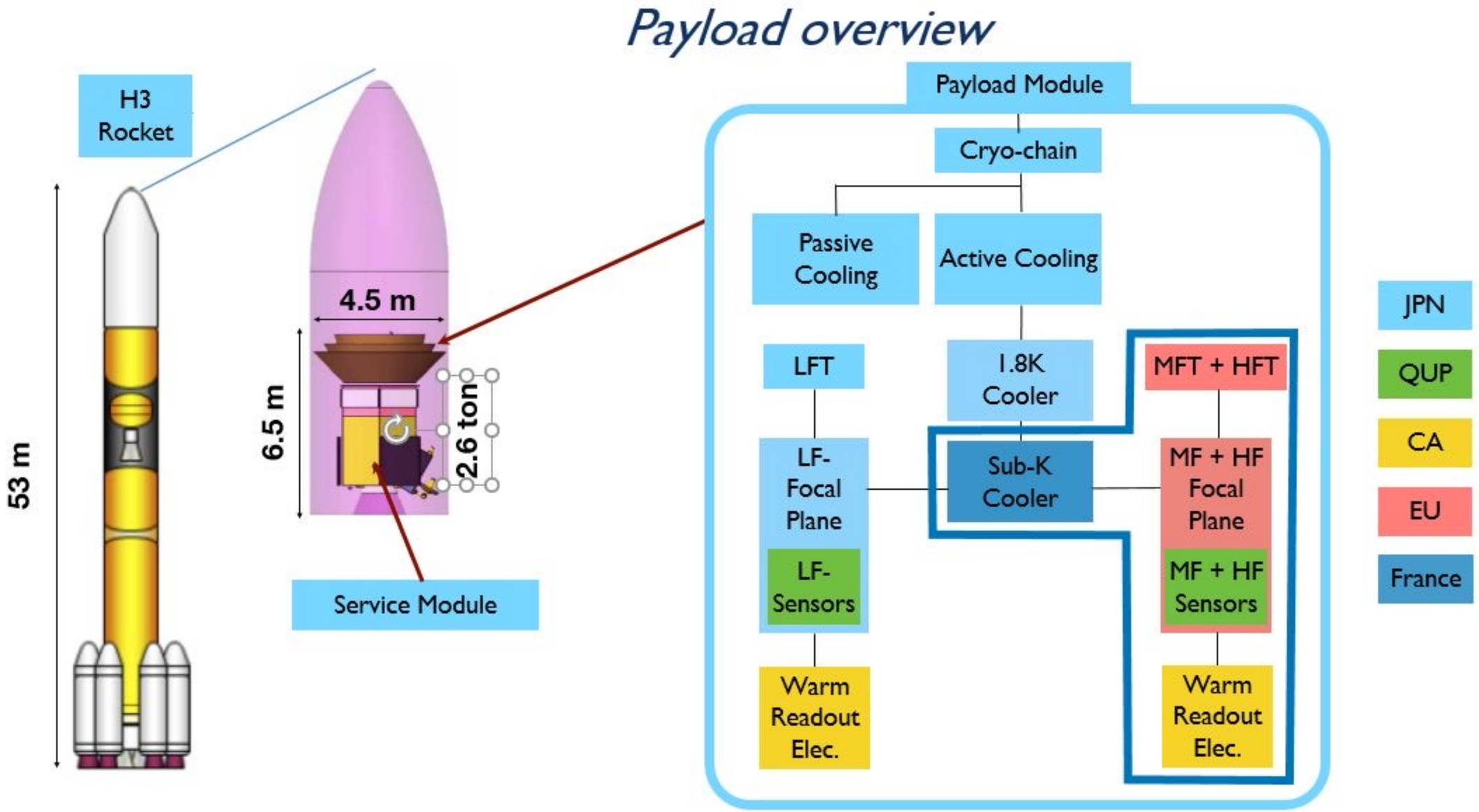
L1.02: On $2 \leq l \leq 10$ & $11 \leq l \leq 200$

Detection @ 5σ , assuming $r = 10^{-2}$, $\tau = 0.05$

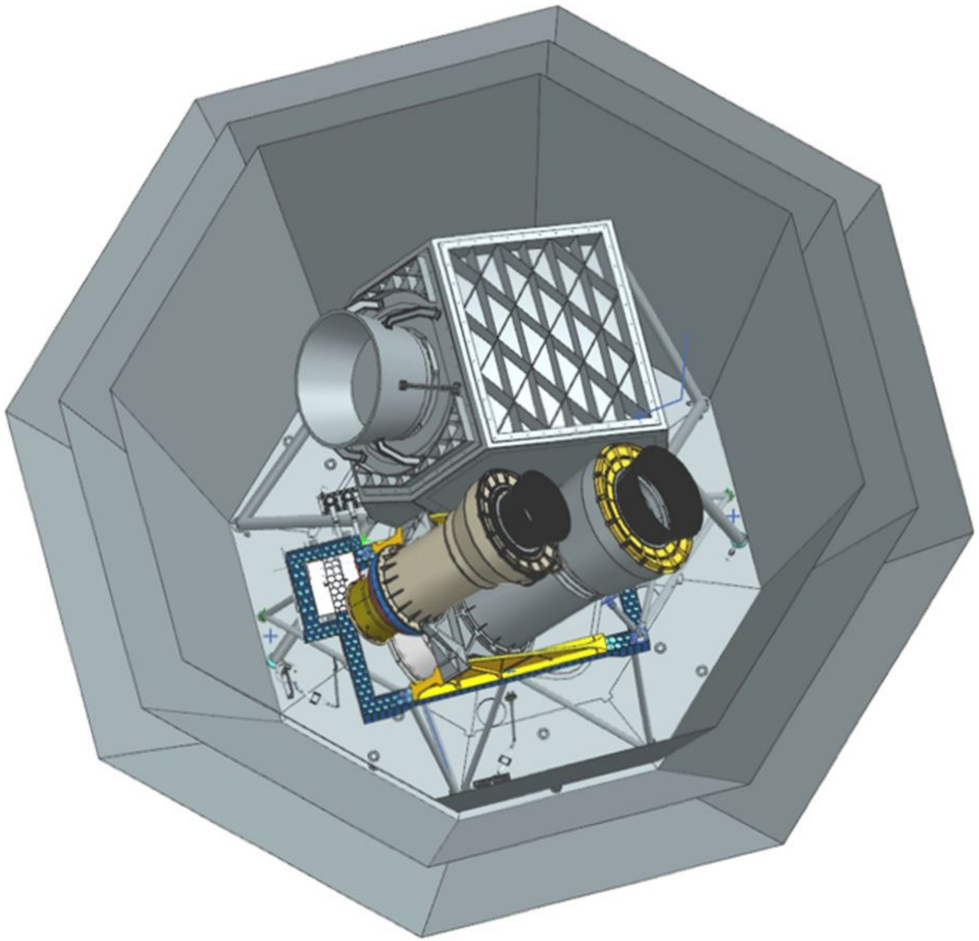
LiteBIRD Satellite Overview

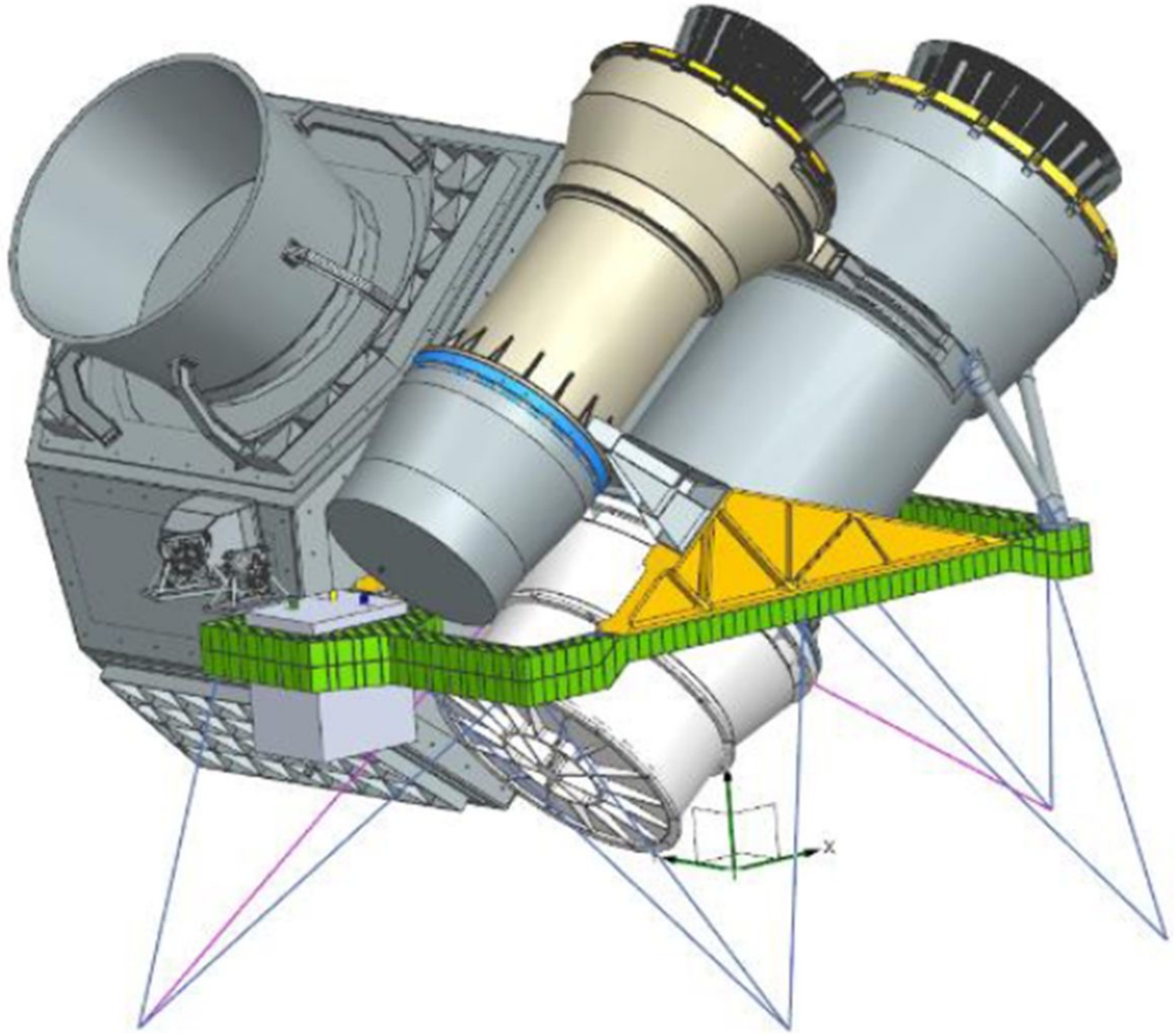


PLM Overview



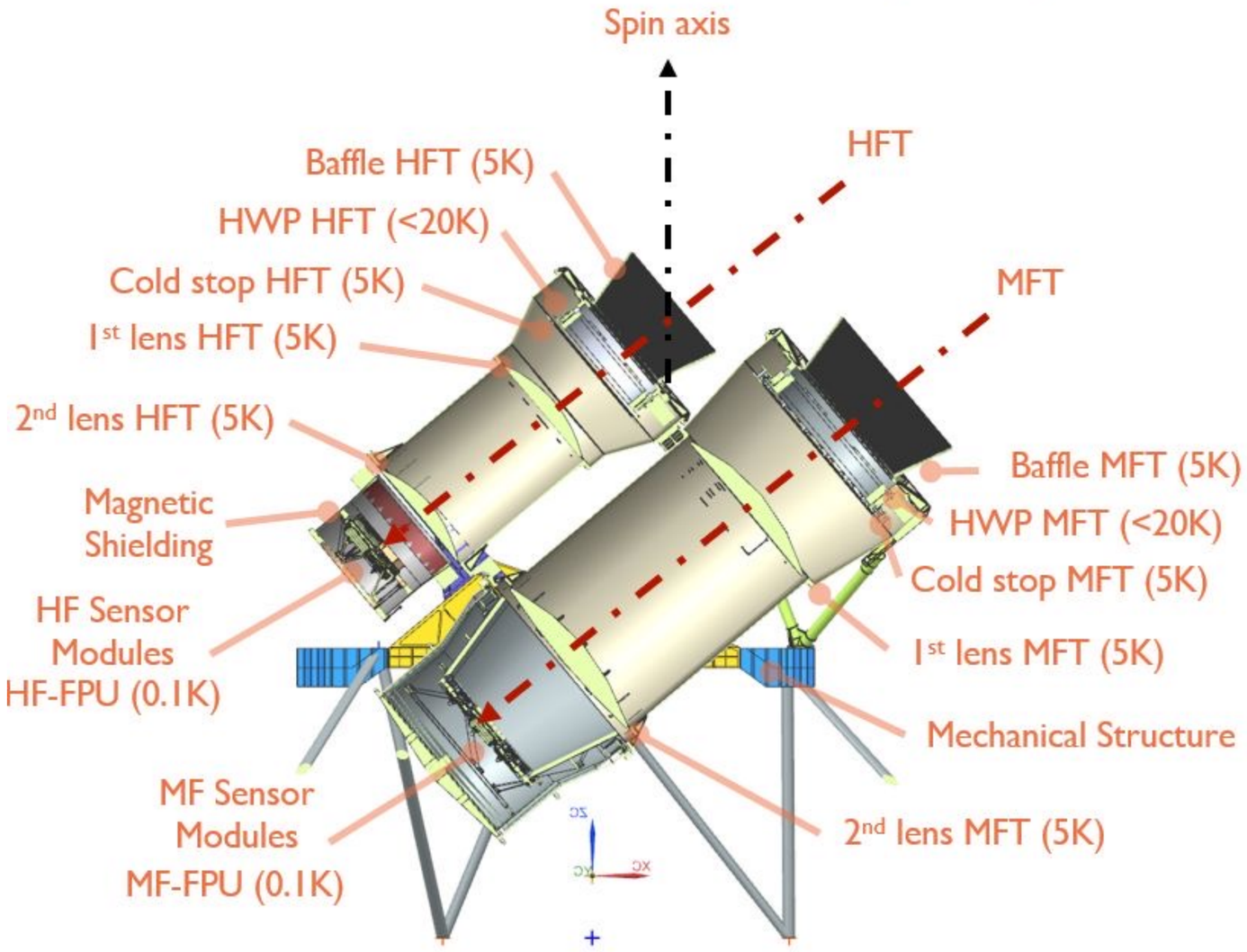
Payload Current Design





MHFT Design Overview

Mid-High Frequency Telescopes (MFT / HFT)



- HWP Mechanism
- Cold Aperture Stop
- FPGA Warm Readout Electronics
- HWP

- Front Baffles
- Lenses / Filters

- Sensor Modules
- Delivered by QUP Japanese
- Collaboration with US teams

- Magnetic Shielding

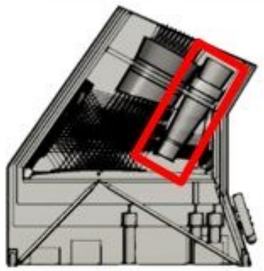
- Thermometers readout electronics

- Warm Readout Electronics

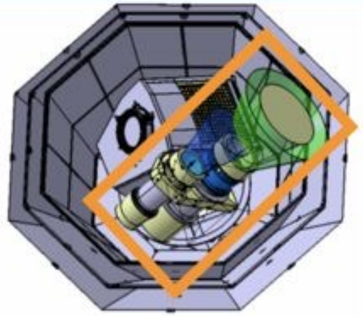
- System Responsibility
- Mechanical Structure 5K
- Focal-Plane Structure + FPU Integration
- DPU
- AIV + Calibration

- Calibration

Phase A Timeline Overview



2017



2018

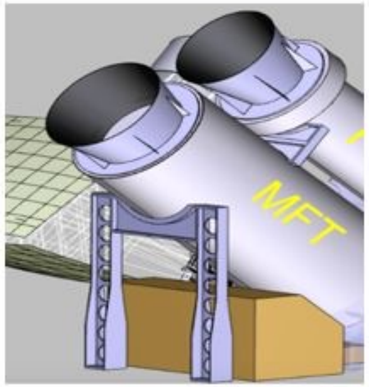
Main evolutions on HFT

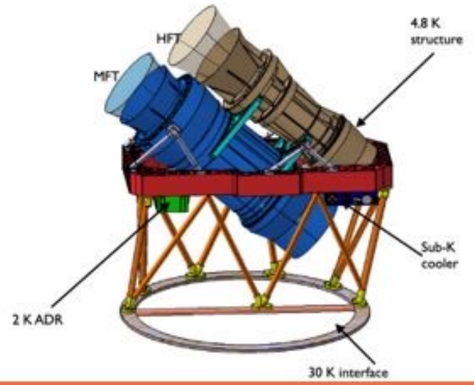
- Single telescope (HFT)
- 238 - 558 GHz
- 3 Channels
- 385 detectors
- 21 kg

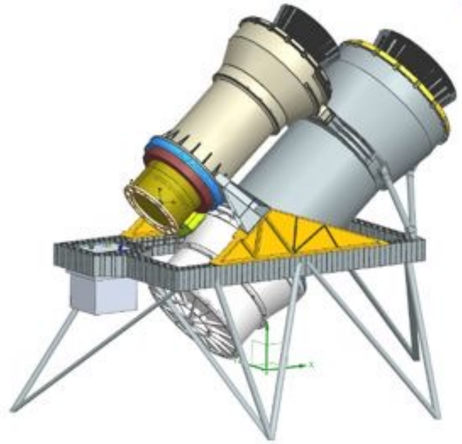
→

- Two telescopes (M-HFT)
- 89 - 448 GHz
- 5 + 5 channels
- 3528 detectors
- 100 kg

Boundaries conditions







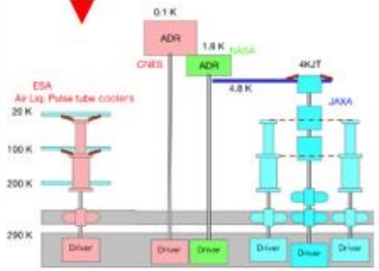
CNES Phase A1 | CNES Phase A2

2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

ESA CDF

CDR

HFT Frequency coverage: 9 bands from 89GHz to 448GHz
HFT resolution: from 10' to 30' maximum
HFT Volume: a 1700 x 1400 x 750 mm^3 5K envelope
HFT continuously rotating HWP
HFT Mass limit: 100kg (margins included)
Sub-K cooler: 100mK stage common to LFT and HFT



- ✚ JAXA down select.
- ✚ CNES Eu lead
- ✖ 2 K JT
- ✚ 2 K ADR
- ✖ US MO
- ✖ US FPU
  - ✚ QUP
  - ✚ FR FPU
- ✖ 5 K IF Ring
- ✚ 30 K IF Ring
- ✖ 30 K Central beam
  7pt => 4pt
  30 K => 38 K
- ✖ 2K ADR
- ✚ 2 K JT
- ✖ 30K IF?
- ✚ 5 K IF ?

LiteBIRD MHFT KP Objective and Agenda

The main goal of this KP is to get an MHFT progress status, to determine when the MHFT PO could be ready to have the MHFT phase A2 final review and to propose recommendations.
In particular, it is expected to have presented and discussed the work plan and organization implemented towards reaching end-of-phase A maturity level. This PK will then propose recommendations to the board with the aim to consolidate the remaining of phase A2 work.
The main objective of the phase A2 is to demonstrate the MHFT technical and programmatic feasibility.

KP agenda:

Documentation (best effort)	2023/03/15 (one week before the KP)
MHFT PO presentation	2023/03/23; one full day 9h00 – 19h00 (CET) Location : Toulouse (IRAP) + Paris (CNES) + ZOOM
Review group meeting	2023/03/24; half day 9h00-12h00 Location : Paris (CNES) + Toulouse (CNES) + ZOOM
RID's batch	2023/03/30; One week after the KP presentation
RID's answer by MHFT PO	2023/03/30
RID's discussion	2023/04/06 Location : Toulouse (IRAP) + ZOOM
Review Group Report	2023/05/05
Decision Board Meeting	Date TBD; Location : Paris (CNES) + Toulouse (CNES) + ZOOM

LiteBIRD MHFT KP Panel

Chair: Yves André	CNES/DOA/ACP
Co-Chair: Tadayasu Dotani	JAXA
Members:	
Gilles Hervet	CNES
Patrice Gonzalez	CNES
Florent Gant	CNES
Lorenzo Marelli	CNES
Yutaro Sekimoto	JAXA
Keisuke Yoshihara	JAXA
Eric Priéto	LAM/CNRS/INSU

In addition to the KP review group, some people are invited as observers at the KP presentation and RID's discussion:

Masashi Hazumi (JAXA PI), Adrian T. Lee (US PI), Matt Dobbs (CANADA PI), Juliette Lambin (CNES/DOA/SU), Carole Larigauderie (CNES/DOA/SU), Olivier La Marle (CNES/DS/DAP/SUE), Didier Massonnet (CNES/DS/DAP/SUE), Thierry Bret-Dibat (CNES/DS/DAP/SUE) + All Space agency representatives: ASI, BELSPO, CSA, DLR, UKSA, SPAIN, Norway, Sweden, The European Steering Comity

Findings and Recommendations

37 RIDs have been issued: 21 are closed, 11 with actions and 5 with recommendations. See 2023_04_24_PK_RIDs.xlsx.

In this report we will evaluate the preparation of the end-of-phase A2 review, considering its objectives.

The objectives of this review are:

1. Release of preliminary management plan, system engineering plan and product assurance plan for the project.
2. Release of the technical requirements specification including the interface requirements.
3. Demonstration of the technical feasibility technical and programmatic feasibility of the instrument:
   - 3.1 Demonstration of the technical feasibility in accordance with the mission objectives and the interface requirements
   - 3.2 Identification of the main risks, the critical technologies and their level of TRL and release of a plan for increasing the TRL.
   - 3.3 Items with a long lead time are identified and their delivery schedule compatible with the development schedule.
   - 3.4 Demonstration of the compliance with the needs expressed by JAXA in terms of model delivery, schedule with acceptable risk.
   - 3.5 Confirmation by all the partners that the required financial and human resources for the full development will be put in place.
4. Selection of system and operations concept(s) and technical solutions, including model philosophy and verification approach.

Findings and Recommendations

Objective 1 of the end-of-phase A2 review : Release of preliminary management plan, system engineering plan and product assurance plan for the project.

The management of this project is a major risk, assessed as unacceptable, in the risk portfolio (MHFT_4):

Origin : LiteBIRD/ MHFT governance not defined / agreed for phase B/C/D

Risk : CNES is not able to guaranty its MHFT lead responsibility toward JAXA

The RID EPr08 points out that the WBs and WPs are not in place. This provide confusion and difficulties of management.

The RID Epr09 pointed also the statement in the MHFT Project Office Organization and Management Plan chapter §4.3.2: it is written : "The MHFT PM is the ultimate responsible for all the technical and managerial aspects of the MHFT instrument and is responsible for the arbitration in case of internal MHFT conflicts. But, in case of remaining disagreement to solve MHFT conflicts, the MHFT international steering committee shall be called.“ In practice the MHFT PM is not always informed and some decisions, compromises and discussions on the requirements were made without involving the CNES MHFT manager, even after the KP.

In addition, the CNES team, reduce to the manager, is not able to really pilot the instrument development considering the risk MHFT_2 : Some lack of experience of the MHFT PO team for space project development.

Recommendation #1:

The panel recommends that a group of senior project experts make an inventory and analysis of the management of the MHFT and suggest ways to improve the governance of the MHFT instrument. This group should be co-piloted by CNES and JAXA with a representative from each agency involved in the MHFT instrument.

Findings and Recommendations

System engineering plan

In the datapackage it was not planning to produce the system engineering plan as a document. Its contain is covered by different documents.

Product assurance plan

This point was discussed with the RID GH-02. This document will be provided using if necessary the PA plan of an instrument of the same type.

Objective 2 : Release of the technical requirements specification including the interface requirements:

The RIDs YA02, YA03, YA04, EPr01, EPr02 concerned the technical requirements specifications.

EPr01 indicate that the justification is part of the requirement flowdown, then links to the flow down shall be traced. YA02 indicate also the need to have a dedicated document providing all the requirement flow down in addition of the PTEP paper. The project took the following action: The justification of the L3 and L4 requirements shall be presented in dedicated documents with the availability of the technical notes (and not in the PTEP paper).

EPr02 The functional analysis and the product tree are missing. These parts needs to be in place to support the flow down of requirement. The project took the following action: The product tree description shall be provided more accurately.

In addition in order to meet this objective at the following review the panel propose the following recommendation:

Recommendation #2:

The panel recommends MHFT PO to closely collaborate with the JAXA team to revisit and to clarify L3 integrated system document in order to make a clear connection between L3 level + IRD and L4 MHFT requirements. Clear correspondence between L3 and L4 items has to be ensured to make sure the compliance can be checked.

The management plan shall describe how will be managed the requirements of the units in common between LFT and MHFT.

Findings and Recommendations

Objective 3 :Demonstration of the technical feasibility and programmatic feasibility of the instrument:

Objective 3.1: Demonstration of the technical feasibility in accordance with the mission objectives and the interface requirements

The interface requirements shall be completed. For example, the Mechanical random and sine vibration specifications used by the MFHT team shall be approved by JAXA (RID FG02). The technical feasibility should be demonstrate. In the portfolio risk, the highest risk is the MHFT_1 technical feasibility not demonstrated to respect the specification. The level of this risk shall be reduced at the review.

The LiteBIRD MHFT Phase A2 readiness status has been provided in the presentation 31_2023_03_23_MHFT_Main_open_point" (see annex of this report).

This presentation provide a detail list of the major open points to be resolved before the review. At least a way to manage this points shall be proposed.

Objective 3.2: Identification of the main risks, the critical technologies and their level of TRL and release of a plan for increasing the TRL

The TRA/TRL management was addressed in the RID GH-05. The TRL of the main technology or contributions has been addressed during the key point. But in the development plan or management plan it is not explained how the team tackles this topics in relation with the model philosophy and schedule. TRL demonstration plan shall be provided at the review in parallel with the development plan to illustrate how all the activities performed by each contributor are organized and coordinated with the model philosophy and schedule milestones. This document should also explain how the TRA sessions or reviews will be arranged. The project took the action to : Add a synthesis of TRL plans for all sub-systems in a single document for Phase-A2.

The CIL Critical Item List to release was addressed in the RID GH-06. By the end of Phase A2 a preliminary CIL shall be issued. This list has for purpose to consolidate the technical risks and should point out the missing activities to increase the TRL at the good level in phase B (typically to get TR6 at the PDRs for the CFIs) and so to reinforce the development plan for each contribution in accordance with their current maturity.

Findings and Recommendations

Objective 3.3 : Items with a long lead time are identified and their delivery schedule compatible with the development schedule

The preliminary LLI Long Lead Items shall be presented at the end-of-phase A2 review. The compatibility with the schedule should be assessed.

This point was addressed in the RID GH-06 and YS02.

Objective 3.4 Demonstration of the compliance with the needs expressed by JAXA in terms of model delivery, schedule with acceptable risk.

The RIDs YA06, YS02 concerned the schedule and the RIDs YA08, EPr05 concerned the model philosophy. These RIDs and also some items reported in the major open points list.

In the portfolio risk, the risk MHFT_2 point out that the phase A2 MHFT is progressing very slowly, because there is no global MHFT authority of conception. The credibility of the schedule is low.

In any case the model philosophy/schedule shall be reviewed because the MHFT current schedule is not in line with JAXA need.

Recommendation #3:

The panel recommends revisiting the model philosophy and the schedule, include in the schedule the delay between end of Phase A2 and beginning of Phase B for agencies decision process, plan contracting times, the procurement delays, considered the humans resources availability to perform all the parallel activities proposed in the development plans, include some margins for NC management and uncertainties. MHFT PO should work with the JAXA team to solve the schedule inconsistency.

Findings and Recommendations

Objective 3.5 : Confirmation by all the partners that the required financial and human resources for the full development will be put in place

Since the beginning of the phase A1 (see slide 8) the instrument HFT becomes 2 instruments MFT and HFT. The number of detectors increase by a factor 9 and the mass by a factor 5. The financial and human resources impact of the new design shall be assessed. A potential reduction should be evaluated if the increasing could not be supported by the agencies.

This activity must be completed prior to the Review Decision Committee meeting to obtain permission to proceed to the next phase.

Objective 4 : Selection of system and operations concept(s) and technical solutions, including model philosophy and verification approach.

Concerning the expected contribution to the Data Centers (RID YA01): the project took the following action: Provide a LiteBIRD SGS organization for the Phase-A2 review and a specific description of the French contribution with cost estimate.

The model philosophy and the verification approach have been presented, but the coverage of the verification approach shall be detailed (see YA05, YA08, YS02, YS03)

In particular the RID YS02 proposed the following action: Concerning the sensor modules tests and calibration with WRE (Warm Readout Electronics) EM, the interfaces, performances, verification accuracy and delivery schedule of the sensor modules shall be discussed with KEK QUP to prepare a mitigation plan to accommodate long lead-time to all sensor modules tests. This action has been accepted by the project. YS03 addressed the cryogenic verification plan.

Recommendation #4

The panel recommends MHFT PO to involve the JAXA team for the discussion of the mitigation plan with KEK QUP.

Way Forward

In order to prepare the data package of the end-of-phase A2 review the project should carry out all the actions taken during this key point and the recommendations decided by the Review Board Committee.

For each activity responsible shall be identify and he shall manage: the organization, objectives, milestones and the outputs definition. The activity plan shall be in line with the project plan and preparation of the review and approved by the MHFT project manager.

As presented in the chapter of the objective 3.1 All the major open points identify at the KP shall be closed or at least a way to closed this points shall be proposed.

Recommendation #5:
In order to limit the schedule delay, we recommend to plan the end-of-phase A2 review beginning of December .

CONCLUSION

LiteBIRD is a CMB mission succeeding to COBE (NASA, 1989), WMAP (NASA, 2001) et Planck (ESA, 2009).
This mission is a high priority for the French Scientific Programs Committee. This is a challenging project and the MHFT is a very complex instrument develop by a huge consortium.

The PK panel thanks the project team for the clarity of the presentations, the quality of the exchanges during the meeting of the responses to the RIDs. The panel recognizes good preparation in the organization of this Key Point. This clear vision allows us to propose actions and recommendations to optimize the chances of obtaining a successful end-of-phase A2 review.
A lot of work remains to be done but the proposed way forward should help the team.

ANNEX

MHFT Phase A2 Main Open points
23th 2023
MHFT CNES-JAXA KP

T. Maciaszek; CNES

LiteBIRD MHFT Phase A2 readiness status

Color code :

Green : Ready for phase A2 review

Yellow : Not fully ready for review but should be OK for phase A2 review; but the question is for **WHEN**

Orange : Not ready for the review and could be problematic for the phase A2 review

Red: Not ready and could be a major feasibility point for MHFT

System

- ✓ Litebird JAXA system Specification L3 :
  - Not yet fully established (mainly for the IRD spec)
- ✓ MHFT specifications L4 :
  - Not yet fully established, not correctly flowdown from L3 (except for the performances) and justified
- ✓ MHFT subsystem Main specifications L5 :
  - Not yet fully established, correctly flowdown from L4 and justified
- ✓ MHFT performances
  - Not yet fully established and justified for the current MHFT design
- ✓ MHFT optical and RF model :
  - No HWP, no 2K filters yet considered; straylight / ghost study and V-groove impact not finalized
- ✓ MHFT mechanical architecture and model :
  - Interfaces to be discussed and agreed soon with JAXA (come back to 5K interface instead of 30K is probable)
- ✓ MHFT Thermal model :
  - Sensitivity study to all parameters be done
  - Transient analysis considering realistic ADR, 2K, 5K thermal fluctuation, sky fluctuation and PI 100mK thermal control

LiteBIRD MHFT Phase A2 readiness status

Sub-System

- ✓ Detectors & cold electronic (QUP / US) :
  - Very huge work to demonstrate the performances, BUT no real consideration yet about space environment (except Cosmic Rays)
  - Lack of detector / cold electronic interfaces with the FPA (SQUID at 300mK linked to the 100mK TES could be a significant issue)
- ✓ Warm readout electronic (Canada / INFN)
  - Some update could be needed in case the redundancy scheme is modified (JAXA decision)
  - Very good level
- ✓ Structure with PLM Interface at 30K (IRAP)
  - OK (NOT OK with interface at 38K)
- ✓ Structure with PLM interface at 5K (IRAP)
  - To be done if JAXA decide to ask for a 5K PLM interface
- ✓ Focal plane (IAS)
  - Lack of detector / cold interfaces to go ahead
  - RF shield, Faraday cage not yet considered
- ✓ Lenses (UK, Cardiff)
  - TRP ESA on going but not finalized
  - Ageing degradation and radiation dose effect on the index (no spec but the index is critical for the beam shape)
- ✓ Filters (UK, Cardiff)
  - No Cardiff activity (large filter made with 1mm plastic ➔ frequency << 100Hz)

- ✓ Half Wave Plate mechanism (Univ Rome & Cardiff)
  - TAS-I study very well ongoing including electronic (end 2022)
  - HWP complete design including mechanical mount (Cardiff / Rome)
  - Expected cold performances tests soon on a representative breadboard to be done
- ✓ Magnetic shield (MPE)
  - Missing spec for periodic magnetic field sensitivity at detector level is missing; impact on the design ?
  - Mass much to high
- ✓ Absorbers (Univ Rome)
  - material well studied; mounting of the absorbers on the tubes TBD
- ✓ ADR 100mK (CEA)
  - OK for ADR; Elegant Breadboard continuous ADR 350mK (the most critical); new test expected in 2023 with a more MHFT representative breadboard
  - ADR electronic design proposed (similar XIFU)
- ✓ Thermal links (CEA)
- ✓ DPU-ICU (IRAP)
  - Representative tests expected Mid 23
- ✓ Harness between WRE and cold focal plane (length, characteristic, EMI); (JAXA)
- ✓ MHFT ORFPM
  - Definition and realization on going. Test in CATR CNES not yet done (expected mid 2023)
- ✓ **MHFT RF cold calibration**
  - Feasibility of the beam measurement (including polarization) on ground with the present required accuracy (-80dB) is not demonstrated; V-grooves impact ?
- ✓ **Schedule**
  - NOT in line with JAXA need; MHFT schedule credibility is TBD (when the phase B could start, …)
- ✓ MHFT governance and organization if stays as presently