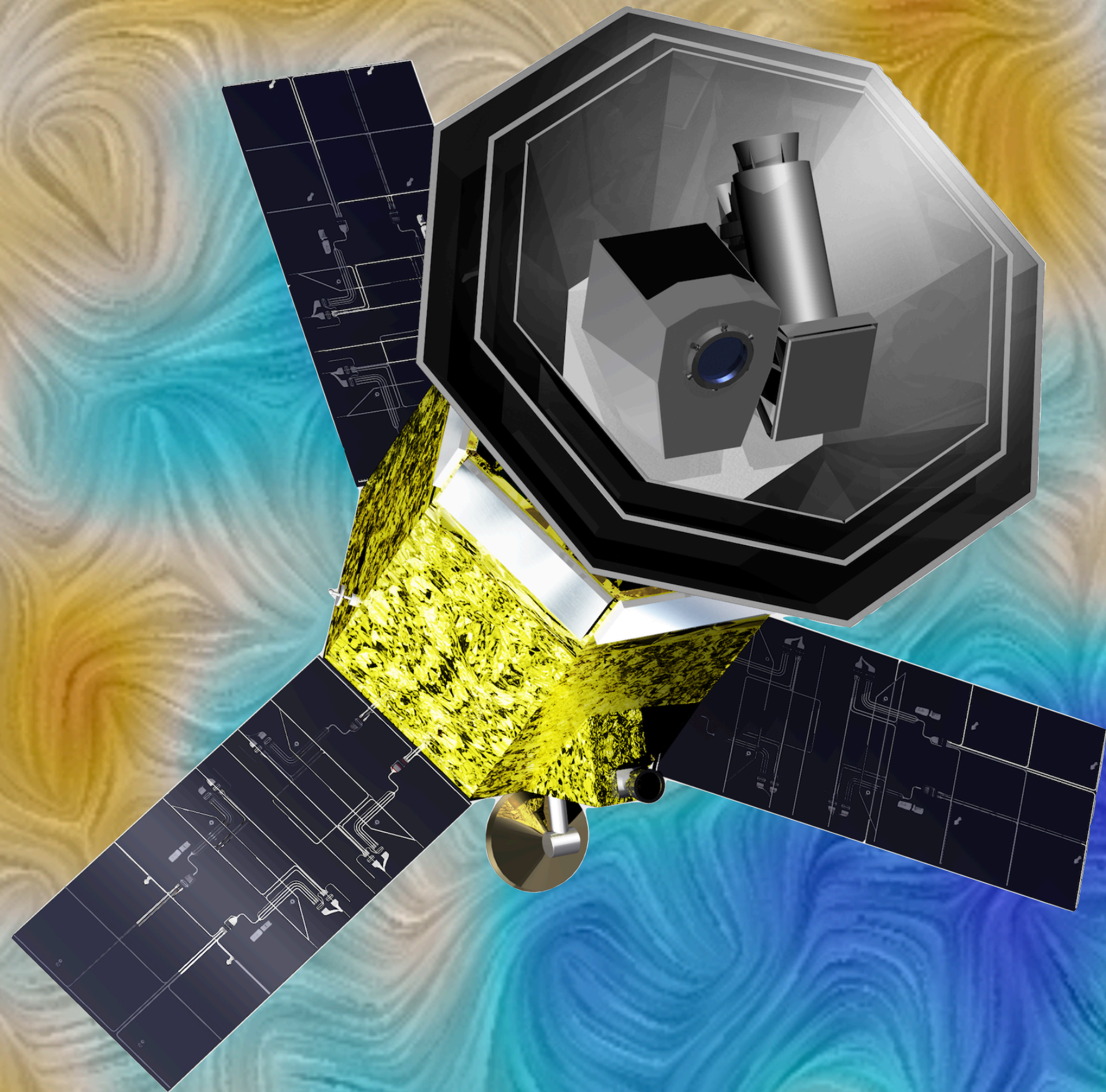


LiteBIRD Status

L. Montier
S. Henrot-Versillé
B. Maffei
B. Mot
G. Patanchon
M. Tristram

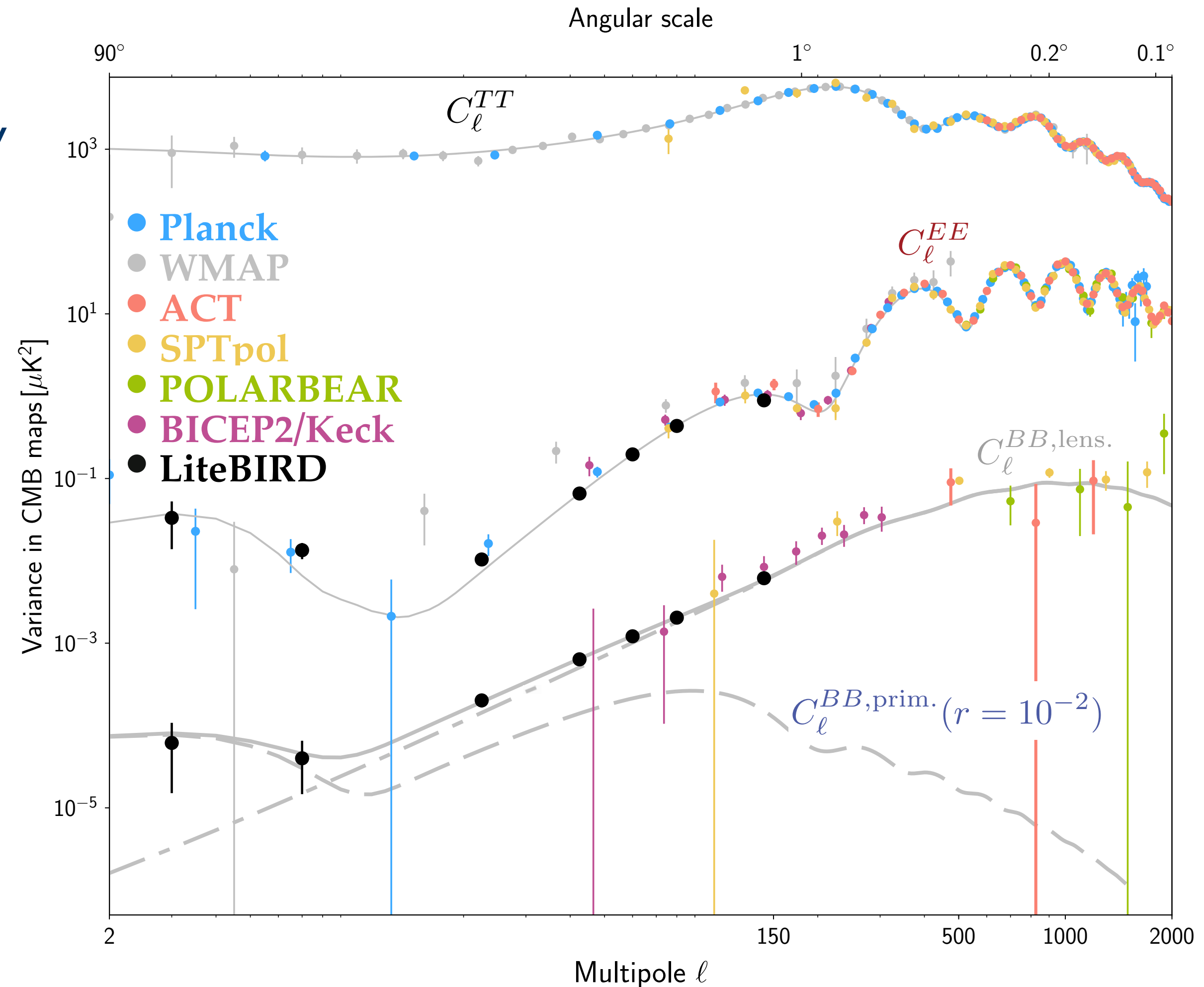
on behalf of LiteBIRD Collaboration





Main Scientific Objectives

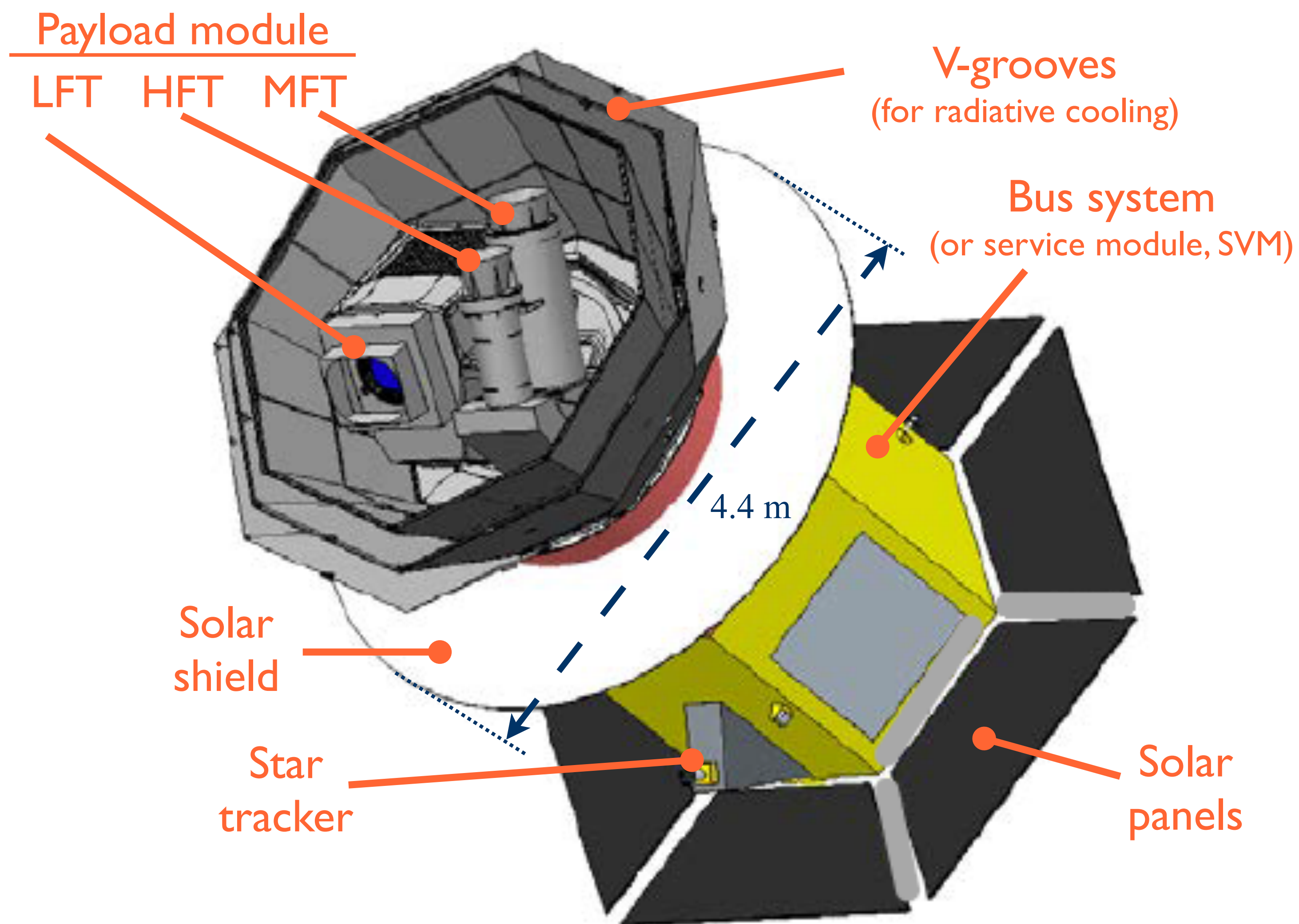
- Definitive search for the **B-mode signal** from **cosmic inflation** in the CMB polarization
 - Making a discovery or ruling out well-motivated inflationary models
 - Insight into the quantum nature of gravity
- The inflationary (i.e. primordial) B-mode power is proportional to the **tensor-to-scalar ratio, r**
- Current best constraint: $r < 0.032$ (95% C.L.)
(Tristram et al. 2021, combining BK18 + Planck PR4 data)
- LiteBIRD will improve current sensitivity on r by a factor ~ 50
- Science requirements (no external data):
 - For $r = 0$, **total uncertainty of $\delta r < 0.001$**
 - For $r = 0.01$, 5- σ detection of the reionization ($2 < \ell < 10$) and recombination ($11 < \ell < 200$) peaks independently
- Huge discovery impact (evidence for inflation, knowledge of its energy scale, ...)



Spacecraft Overview

- **3 telescopes** are used to provide the **40-402 GHz** frequency coverage
 1. **LFT** (low frequency telescope)
 2. **MFT** (middle frequency telescope)
 3. **HFT** (high frequency telescope)
- Multi-chroic transition-edge sensor (TES) **bolometer arrays** cooled to **100 mK**
- Polarization modulation unit (PMU) in each telescope with **rotating half-wave plate** (HWP), for $1/f$ noise and systematics reduction
- Optics cooled to **5 K**

- Mass: 2.6 t
- Power: 3.0 kW
- Data: 17.9 Gb/day

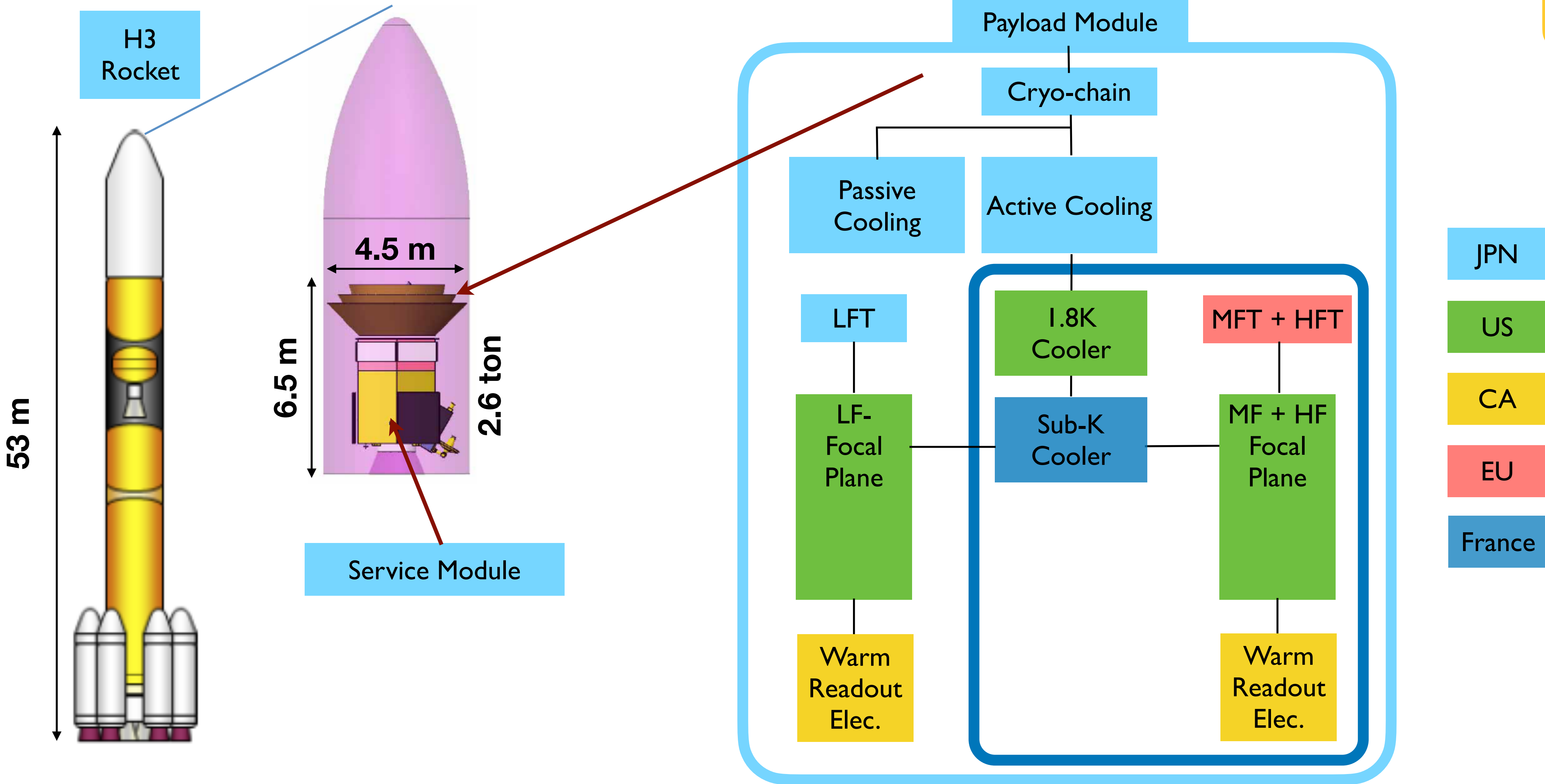


Procurement Update



Jun 2021

International Task Sharing

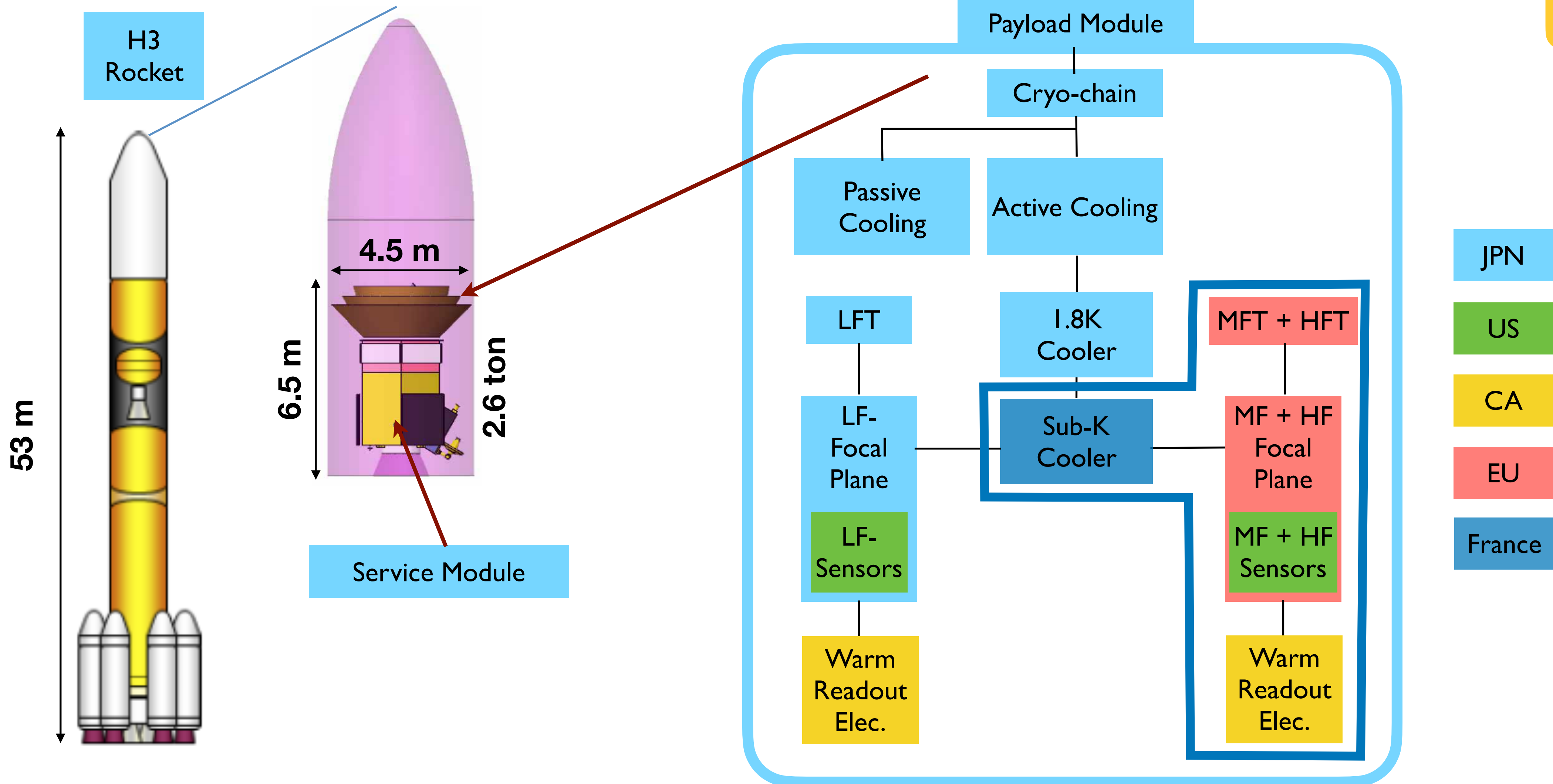


Procurement Update



Nov 2022

International Task Sharing



Re-organisation after NASA no-commitment

Feb 2020

US Opportunity Call is rejected by NASA

➔ Looking for a back-up plan of the 3 Focal Planes...

but hopes remained that NASA could change its mind and commit later by Mid 2022

Procurement Update

Re-organisation after NASA no-commitment

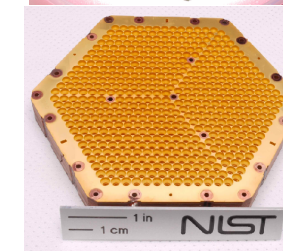
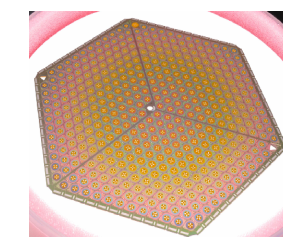
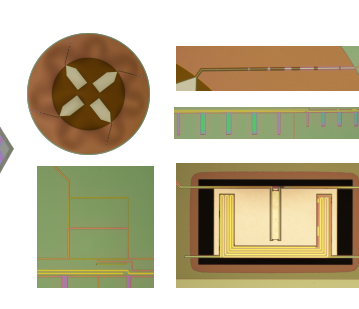
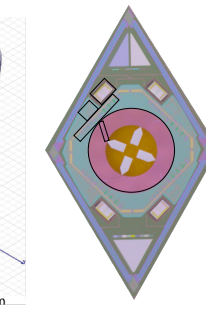
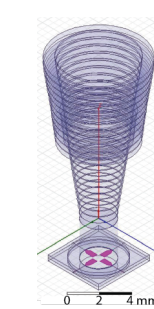
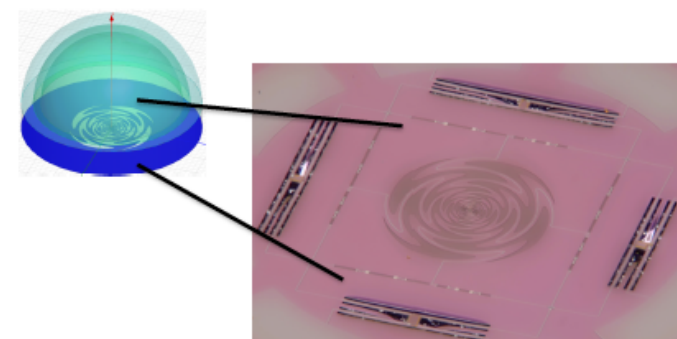
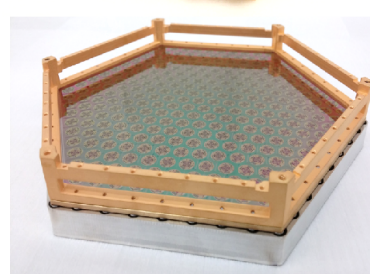
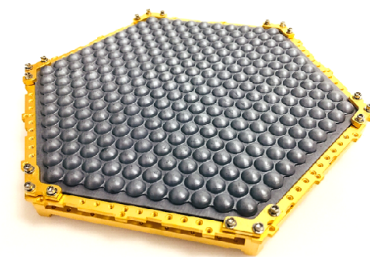
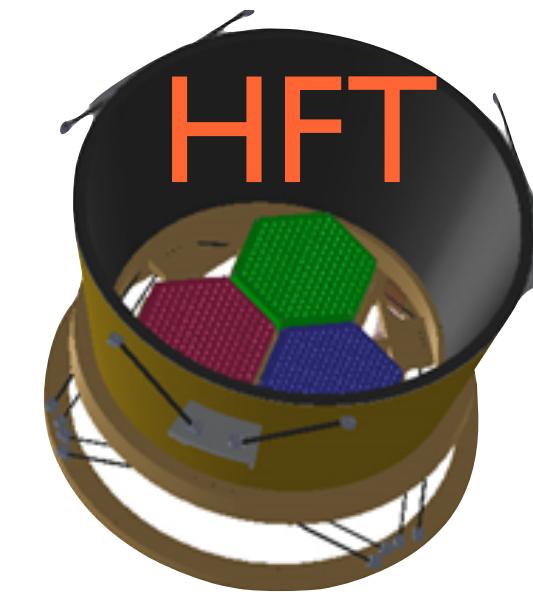
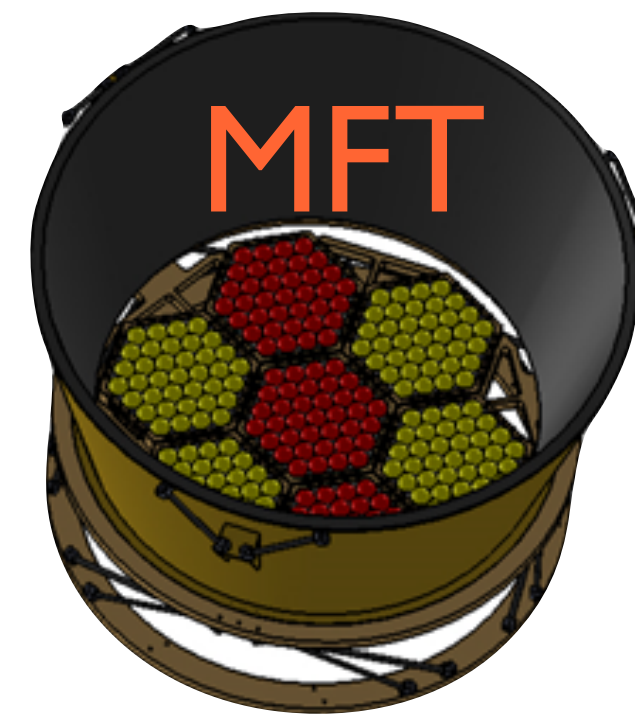
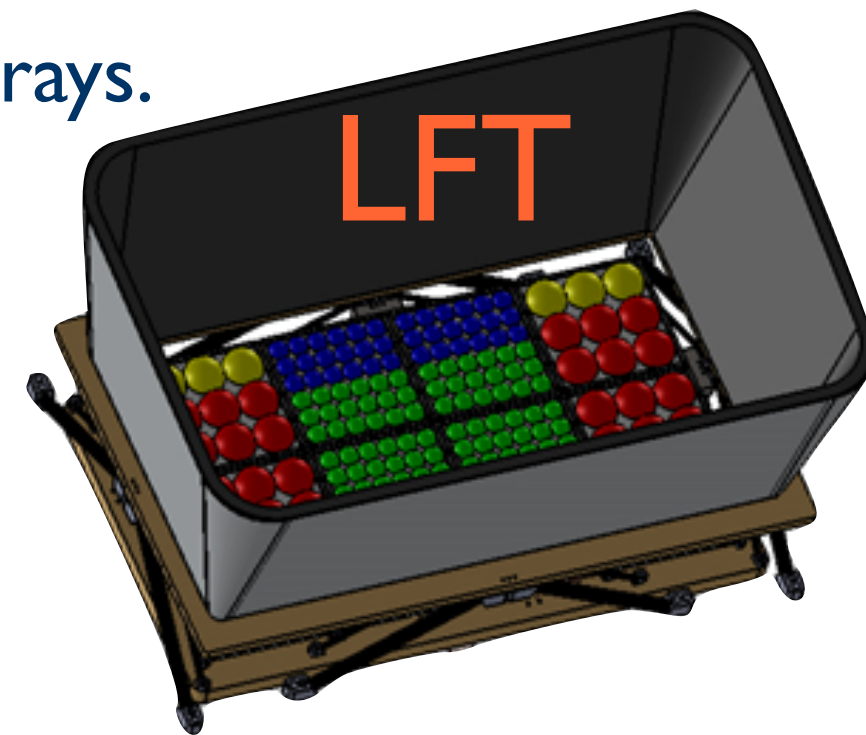
Feb 2020

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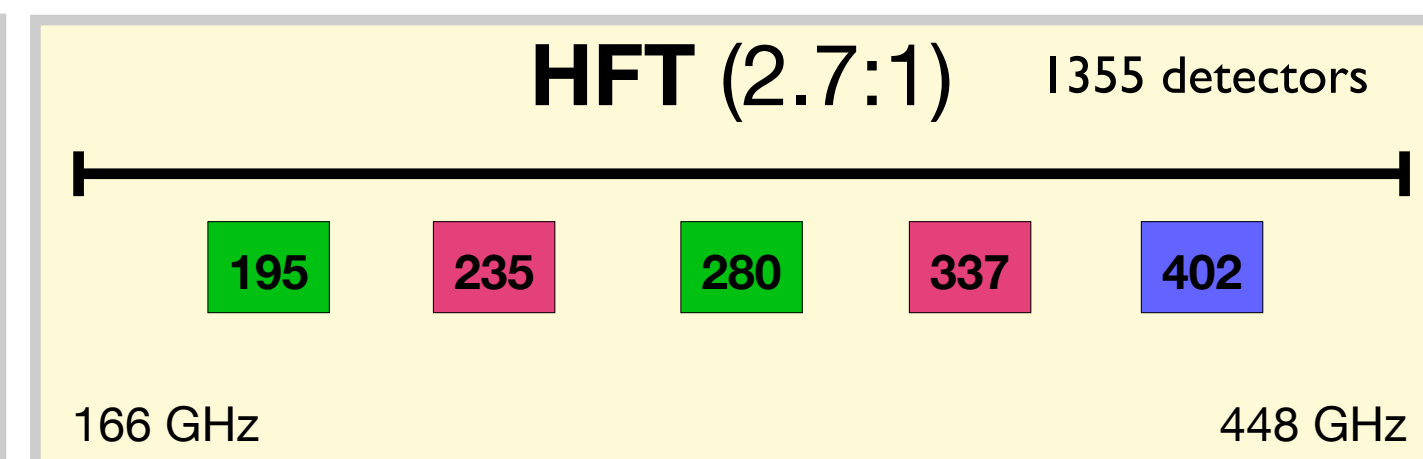
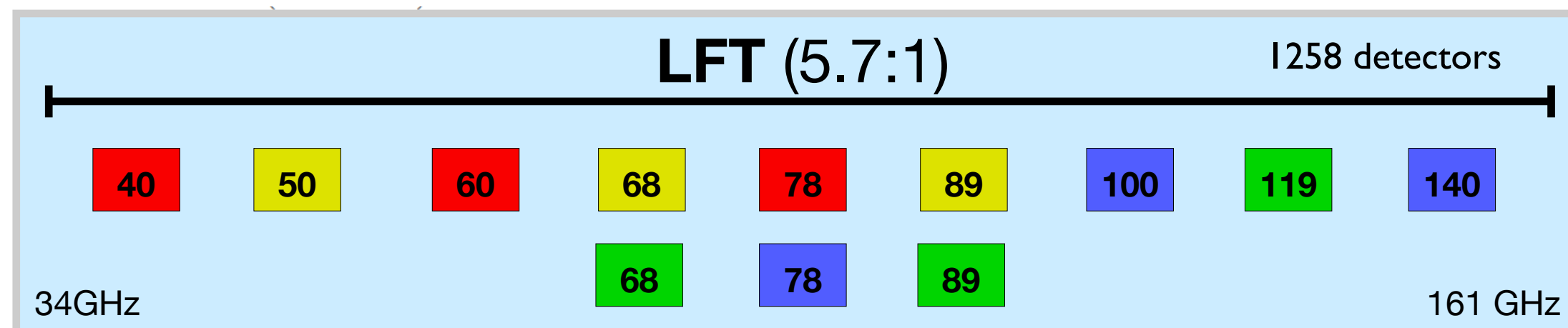
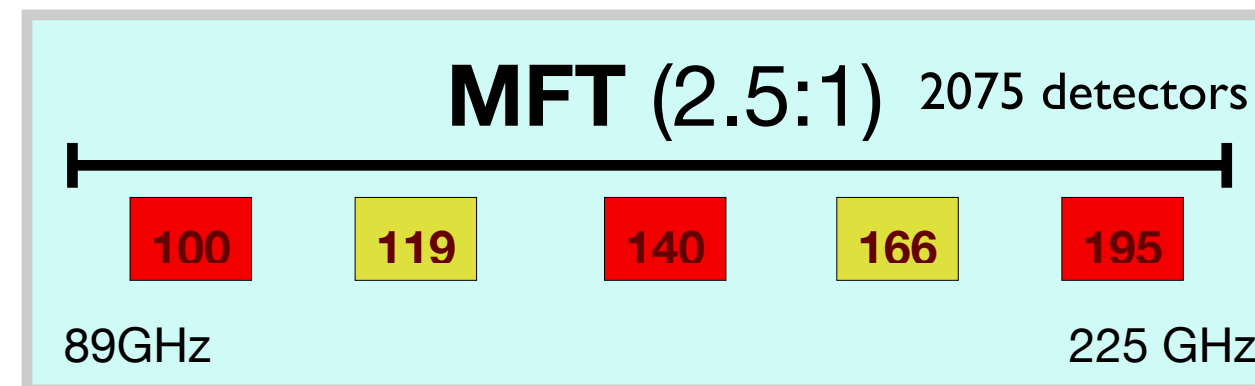
but hopes remained that NASA could change its mind and commit later by Mid 2022

- Transition-Edge Sensor (TES) arrays.
- Multichroic detectors.
- Number of sensors: 4508
- 15 bands including overlap between instruments.



Lensed coupled detectors
Lenslets

Horn coupled detectors
Platelets



Procurement Update

Re-organisation after NASA no-commitment

Feb 2020

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2020

European partners look for back-up solutions in Europe

Jan 2021

ESA opens Feasibility Study on Detectors in UK & Italy

Oct 2021

Outcomes of UK & Italian Feasibility Studies

➔ Feasible but 2-3 years of delay...

⋮
Waiting for US
Decadal Survey
Astro2020
⋮
↓

Re-organisation after NASA no-commitment

Feb 2020

US Opportunity Call is rejected by NASA

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⋮
Waiting for US
Decadal Survey
Astro2020

Nov 2021

JAXA Space Sub-Committee puts some pressure on schedule !

NASA officially rejects any commitment to LiteBIRD

End 2021

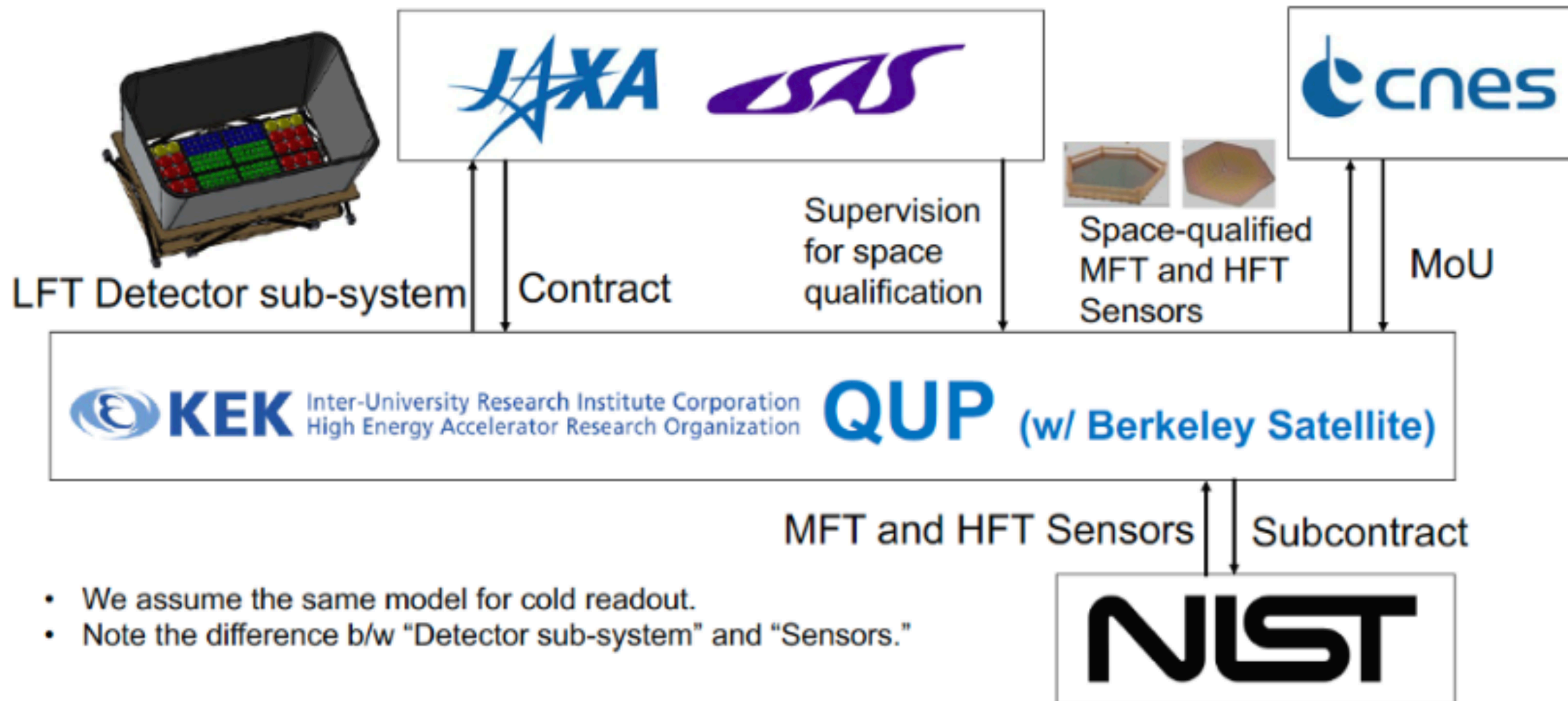
A new institute QUP is created at KEK in Japan by Masashi Hazumi, the LiteBIRD PI

Procurement Update



Re-organisation with QUP and JAXA

Focal Planes

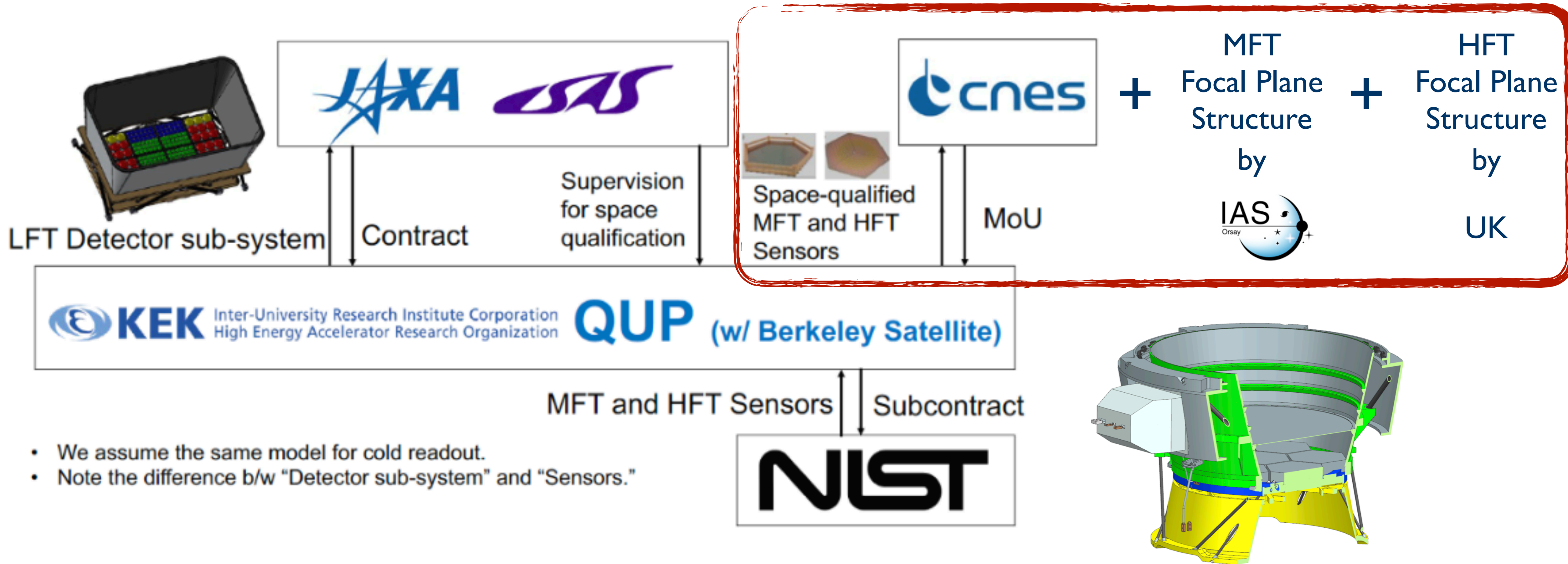


- We assume the same model for cold readout.
- Note the difference b/w "Detector sub-system" and "Sensors."

Procurement Update

Re-organisation with QUP and JAXA

Focal Planes



- We assume the same model for cold readout.
- Note the difference b/w "Detector sub-system" and "Sensors."

Procurement Update

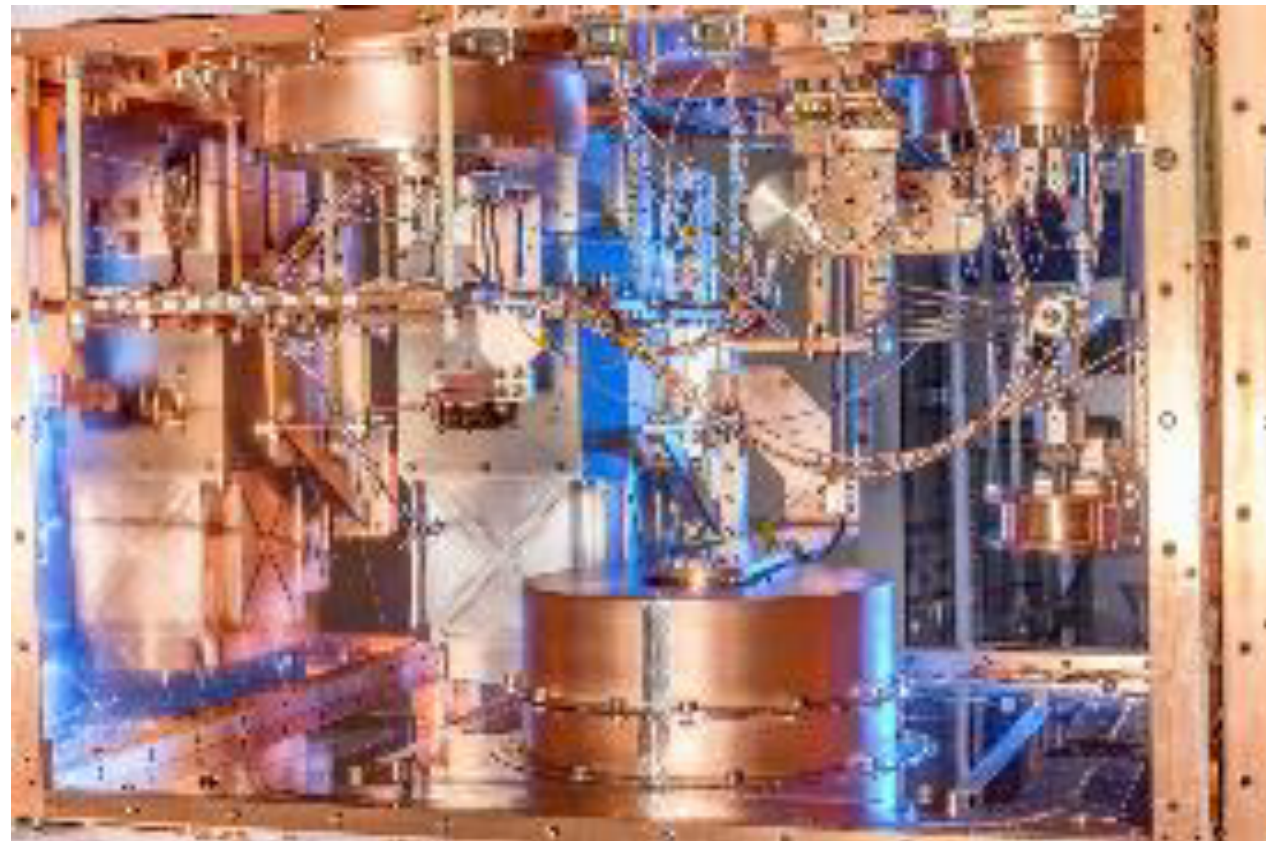
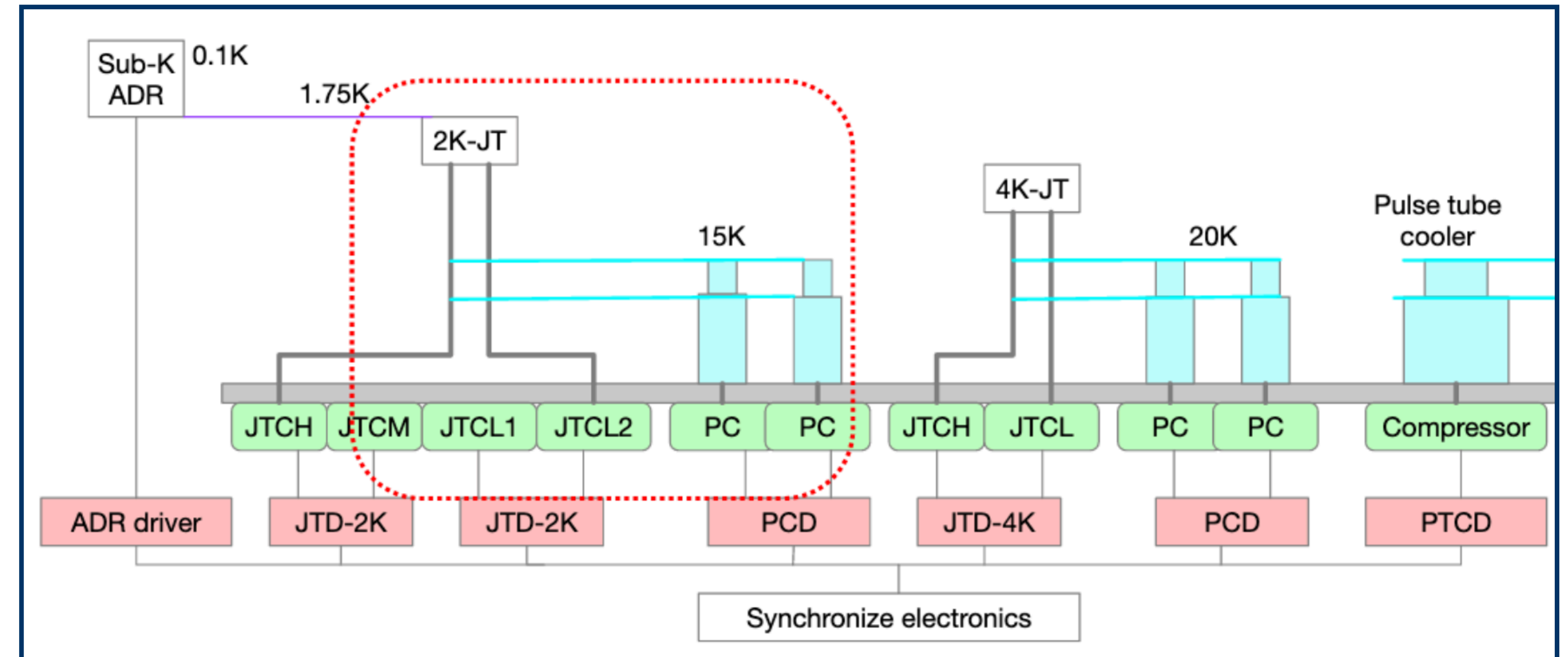
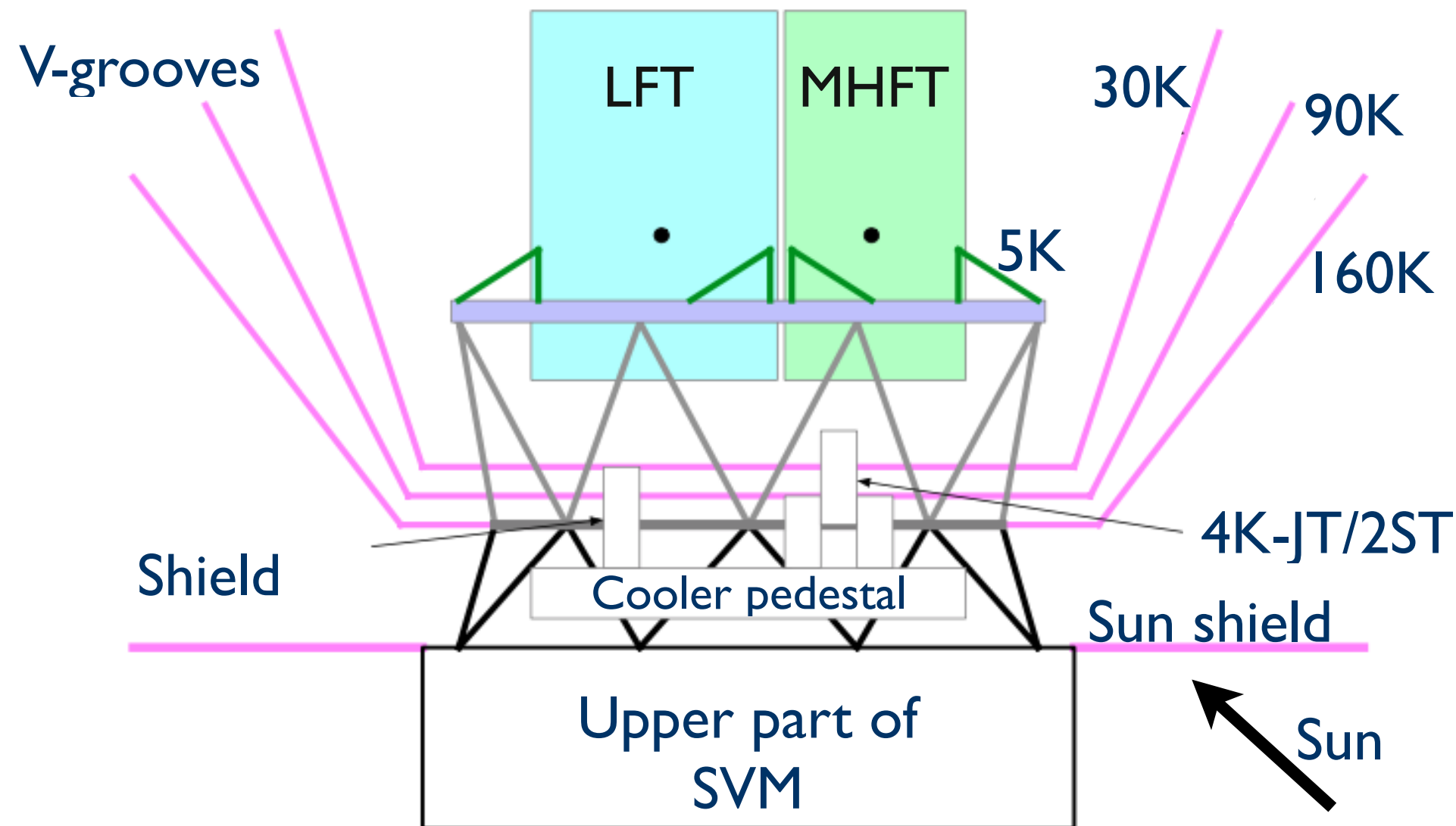
Re-organisation with QUP and JAXA

1.8 K Stage

1.8 K ADR
by
NASA

replaced
by

2 K JT Cooler
by
JAXA



Continuous cooling at all stages

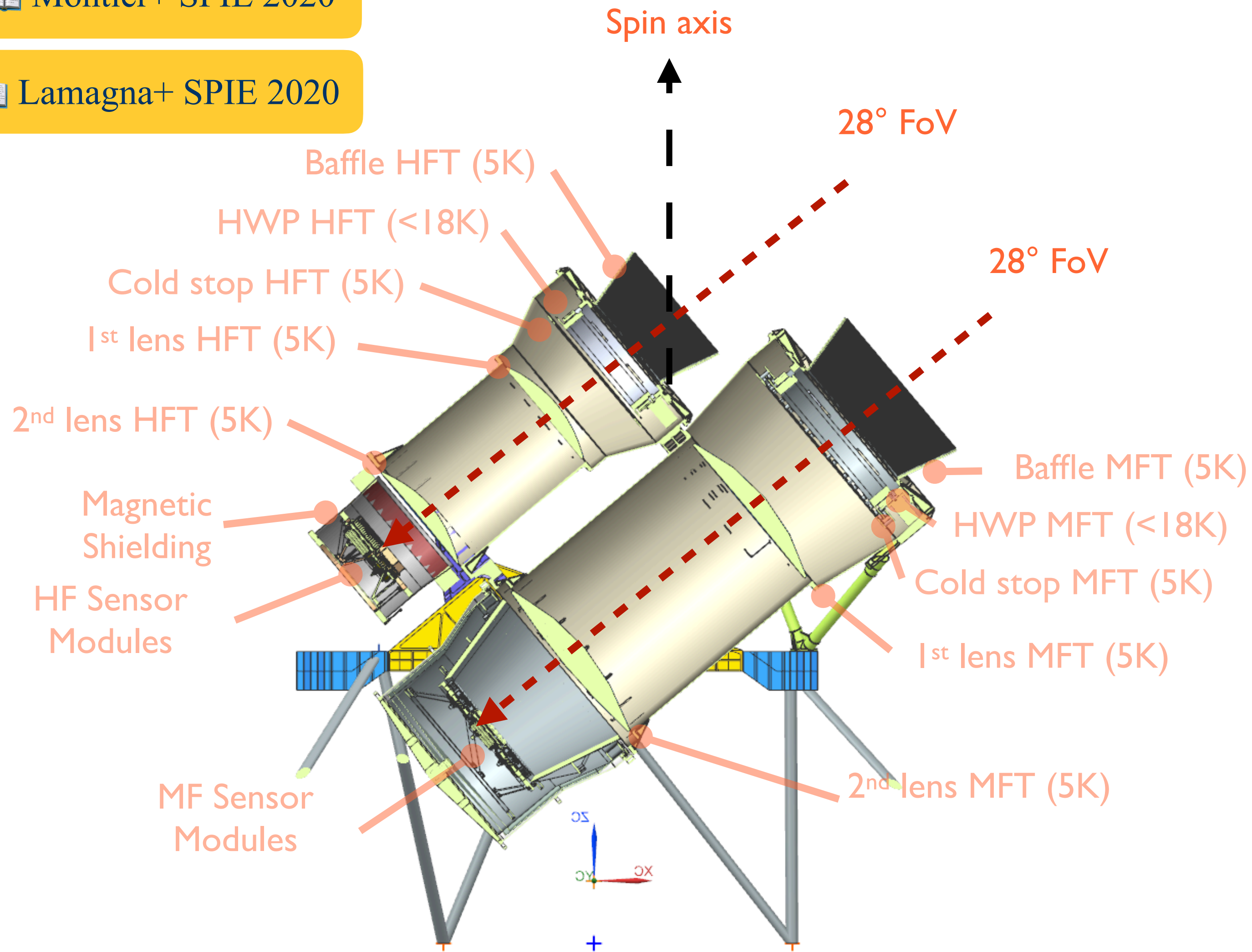
High stability on telescopes at all stages

Procurement Update

Mid-High Frequency Telescopes (MFT / HFT)

Montier+ SPIE 2020

Lamagna+ SPIE 2020



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



- Front Baffles
- Lenses / Filters
- HWP



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



- Magnetic Shielding



- Thermometers readout electronics



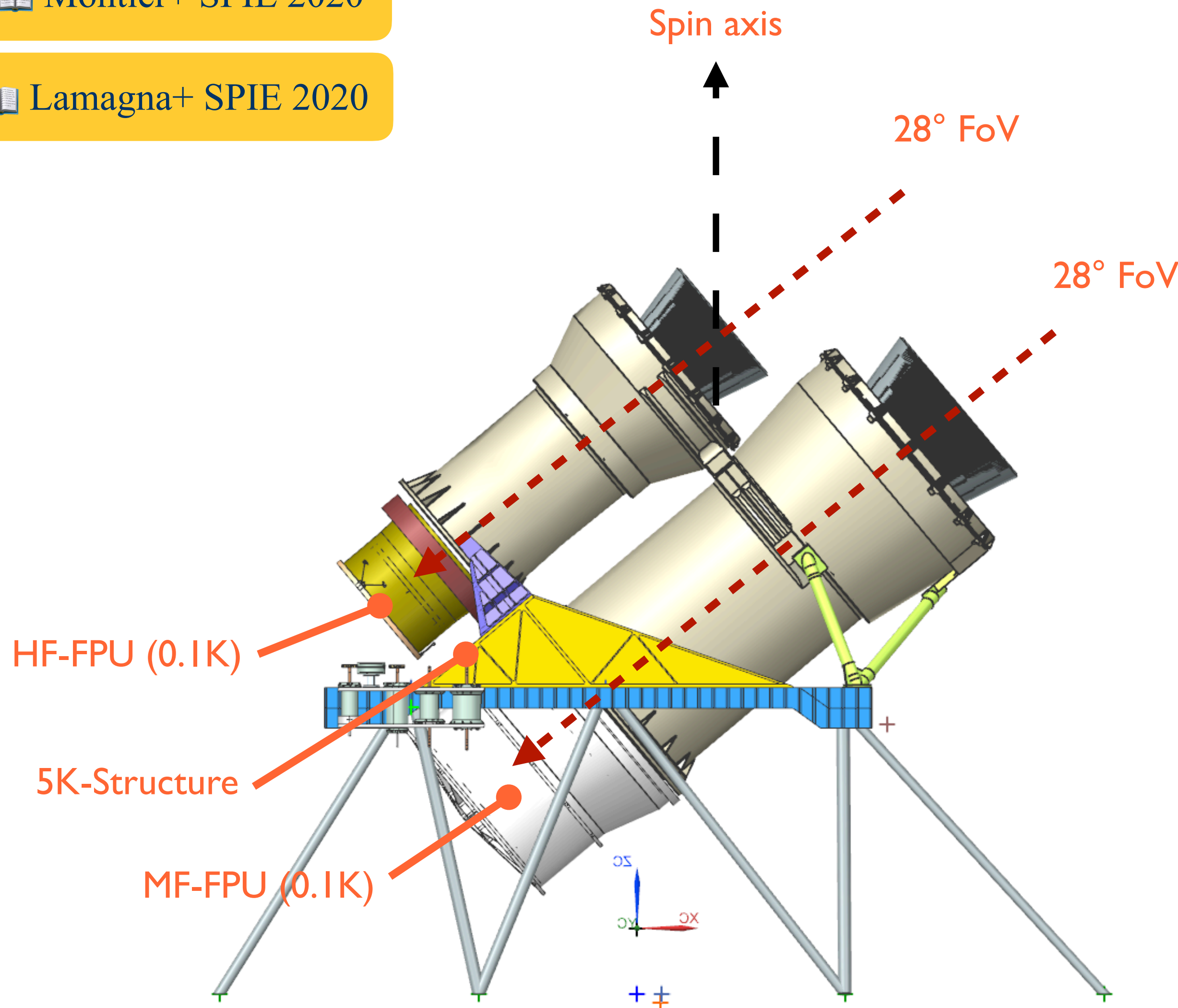
- Warm Readout Electronics

Procurement Update

Mid-High Frequency Telescopes (MFT / HFT)

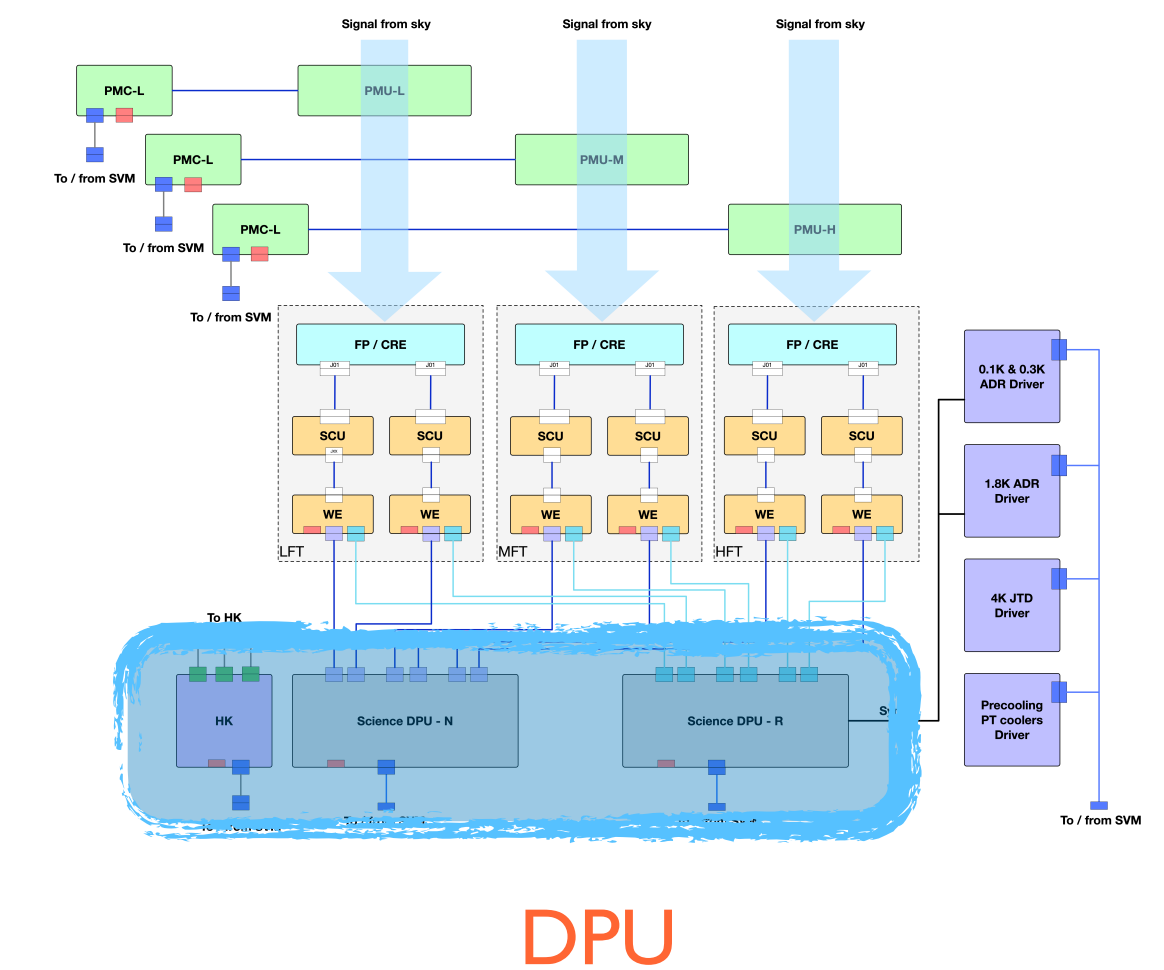
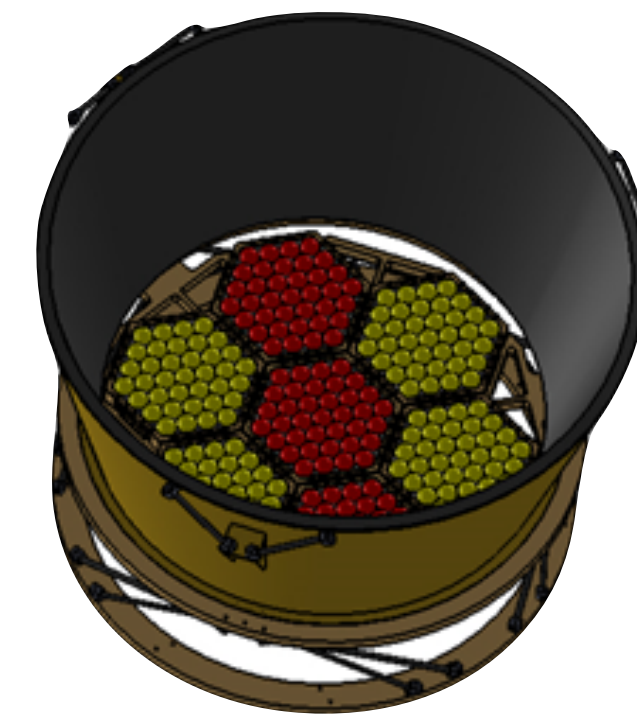
Montier+ SPIE 2020

Lamagna+ SPIE 2020



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

MFT Focal Plane Unit



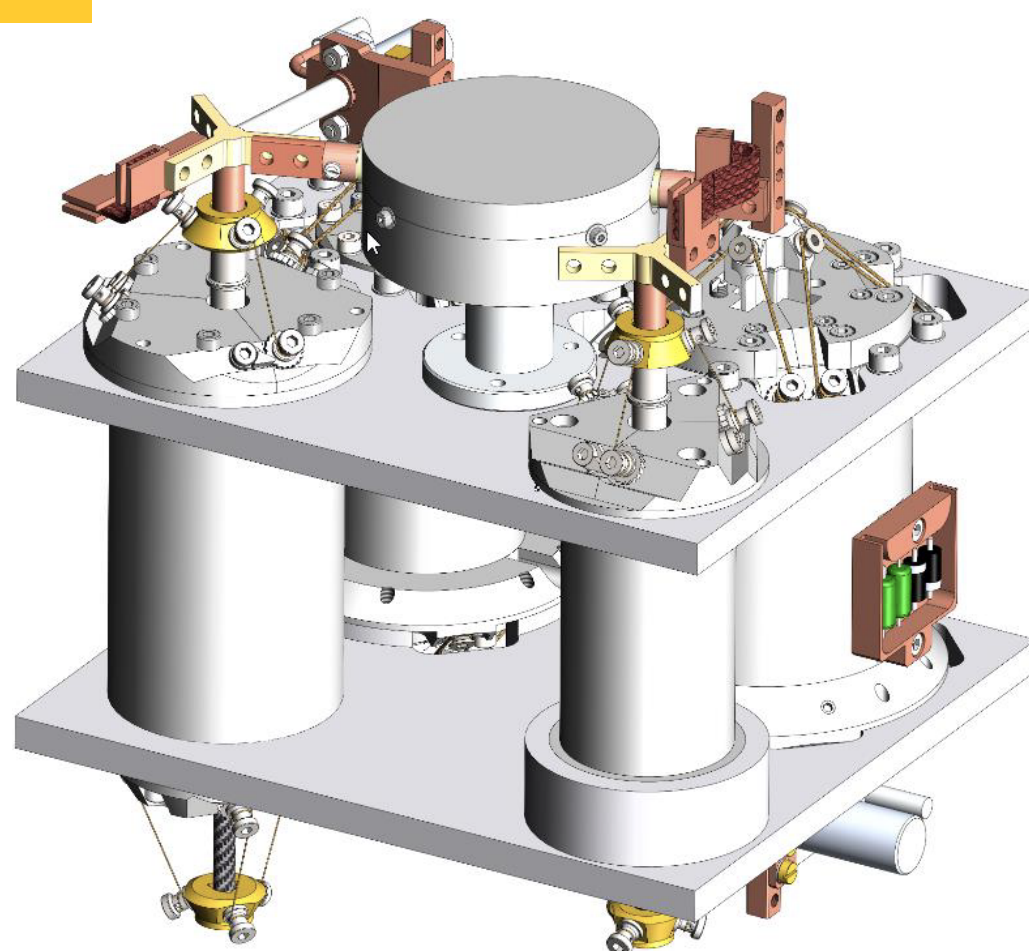
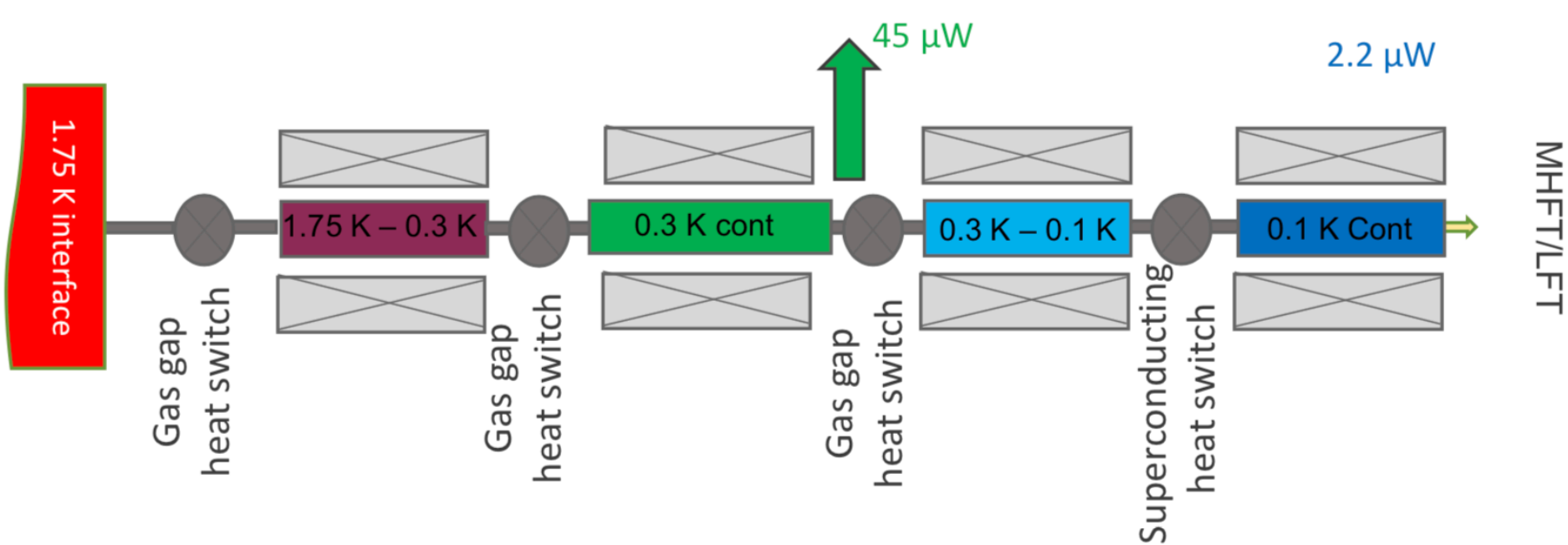
Procurement Update



Sub-K Cooler & Thermal links

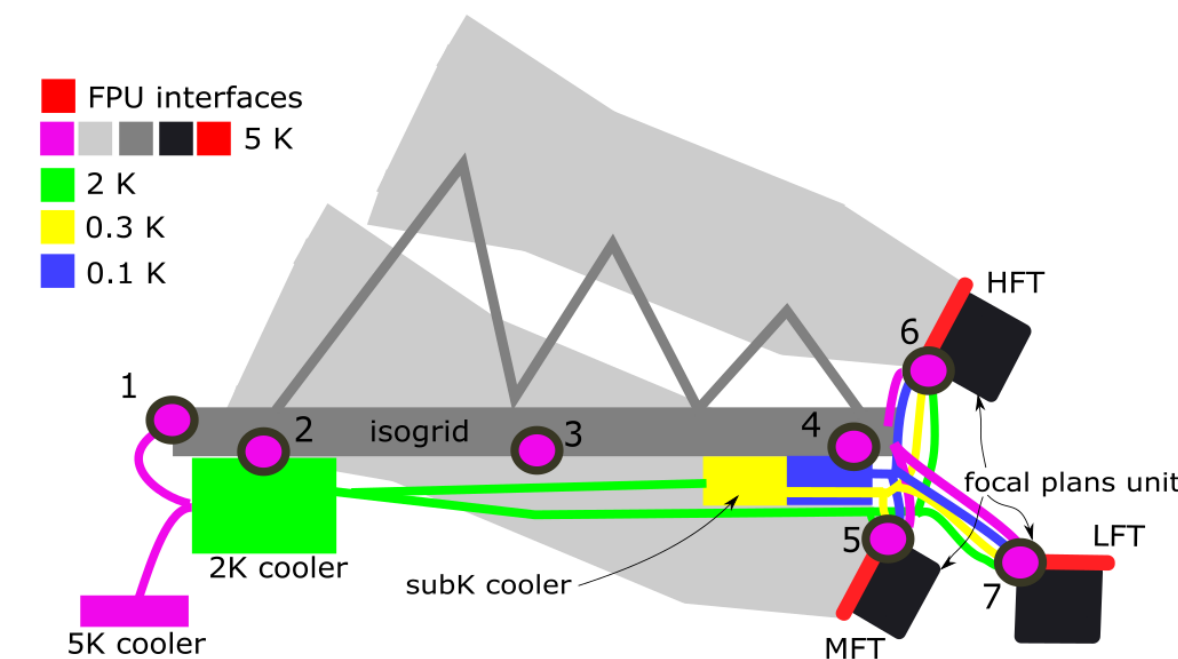
Sub-K Cooler

- Continuous cooling at 100mK
- 4 ADRs in series
- Common for all LB focal planes

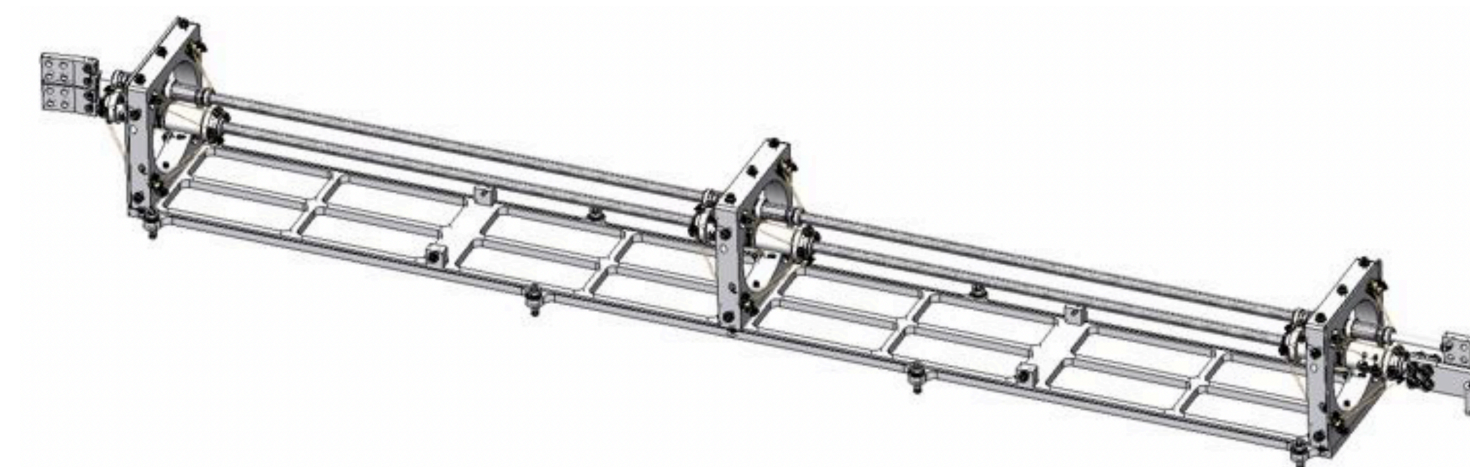


4 hours cycles
2.7 K interface

Thermal links



Thermal model of cryomodule includes thermomechanical IF at 5K with MHFT and 5K to 0.1K IF with the FPU



- Kevlar sustained
- High maturity

Programmatic in Europe



Jun 2021

European Collaboration



Committed in Phase-A2 leading the MHFT since 2020

France ✓

APC (Paris)
CEA-DAp (Saclay)
CEA-SBT (Grenoble)
ENS-LERMA (Paris)
IAP (Paris)
IAS (Orsay)
Institut Néel (Grenoble)
IPAG (Grenoble)
IRAP (Toulouse)
LAL (Orsay)
LAM (Marseille)
LESIA (Paris)
LPSC (Grenoble)

Italy ✓

Università di Roma "Tor Vergata"
Università di Milano
Sapienza Università di Roma
INAF/IASF, Bologna
INAF/OATS, Trieste
Università di Milano-Bicocca
Università di Genova
INFN-Sezione di Pisa
Università di Ferrara
Università di Padova
SISSA – Trieste

UK

Cardiff University
University of Cambridge
Imperial College London
University of Manchester
University College London
University of Oxford
University of Portsmouth
University of Sussex

Germany

Max Planck Society (MPA, MPE, MPIfR)
Ludwig-Maximilians-Universität München
Universität Bonn
RWTH Aachen Universität

Phase-A commitment:

- France:
 - Phase A I 2018
 - Phase A2 (MHFT leadership) 2020
- Italy: 2018

Spain

IFCA, IDR/UPM, DICOM/UC
ICCUB, IAC
Universidad de Oviedo
Universidad de Salamanca
Universidad de Granada
CEFCA

Holland

SRON
RuG

Norway

University of Oslo

Sweden

Stockholm University

Ireland

Maynooth

Belgium

CSL
University Louvain

~200 scientists, including experts on instrument and data analysis:

Programmatic in Europe



Nov 2022

European Collaboration



Committed in Phase-A2 leading the MHFT since 2020

France ✓

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Italy ✓

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Università di Ferrara
Università di Padova
SISSA – Trieste

UK ✓

Cardiff University
University of Cambridge
Imperial College London
University of Manchester
University College London
University of Oxford
University of Portsmouth
University of Sussex

Germany ✓

Max Planck Society (MPA, MPE, MPIfR)
Ludwig-Maximilians-Universität München
Universität Bonn
RWTH Aachen Universität

Phase-A commitment:

- France:
 - Phase A I 2018
 - Phase A2 (MHFT leadership) 2020
- Italy: 2018
- Spain: 2021
- Germany: 2022
- Belgium: 2022
- UK 2023 ?

Spain ✓

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RuG

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Sweden

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Ireland

Maynooth

Belgium ✓

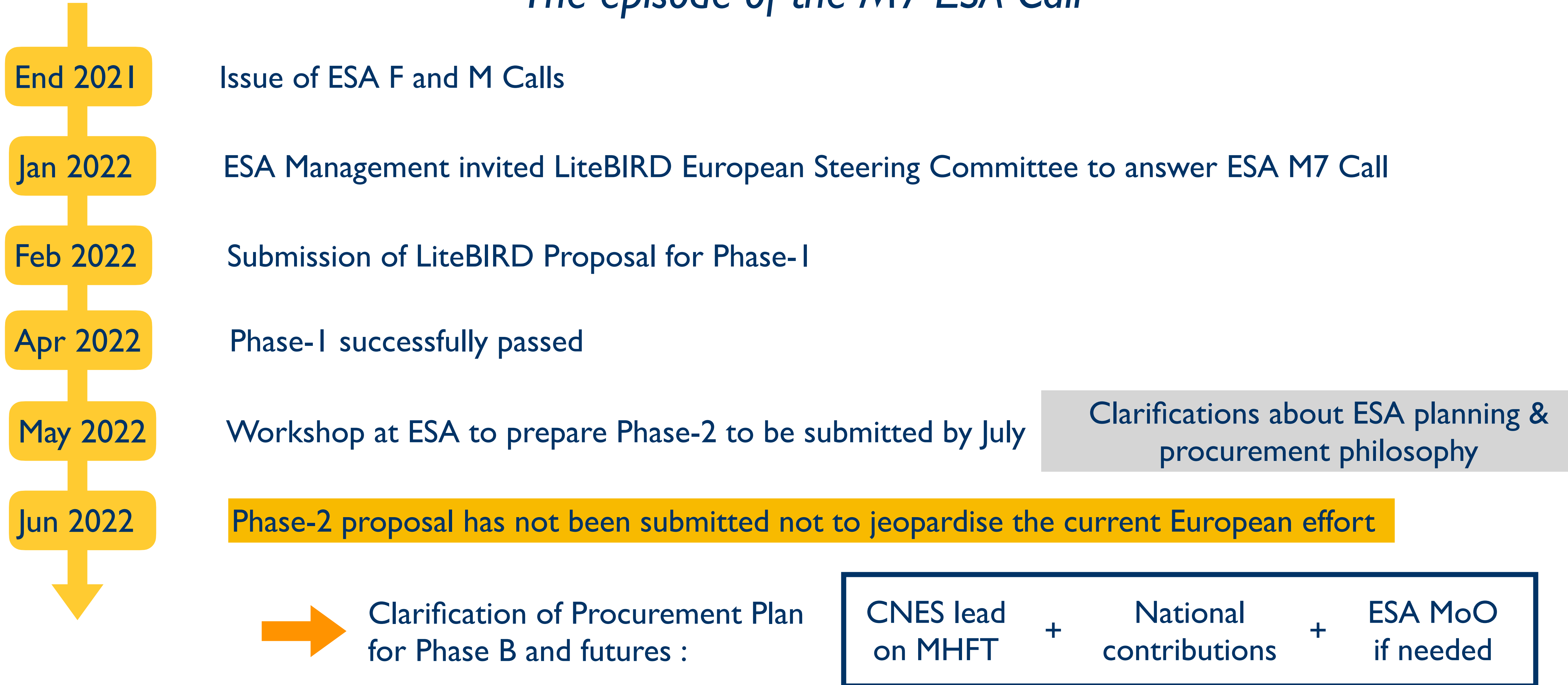
CSL
University Louvain

All European Partners
working with CNES toward
an ESA Mission of Opportunity
for LiteBIRD

~220 scientists, including experts on instrument and data analysis:

Programmatic in Europe

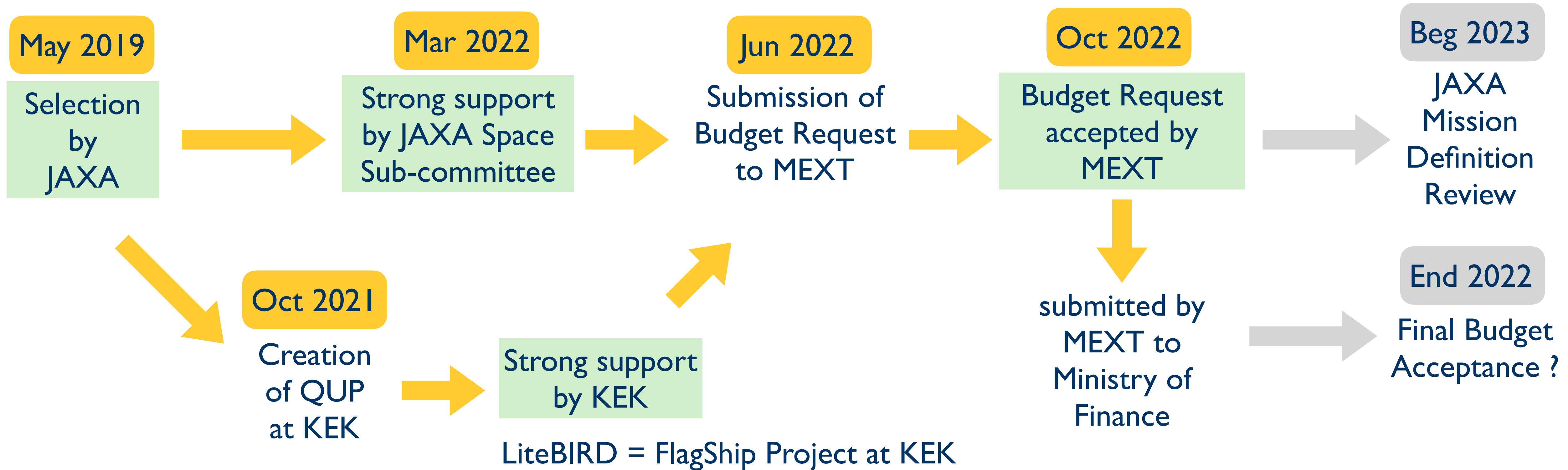
The episode of the M7 ESA Call



Programmatic in Japan



Toward the JAXA LiteBIRD Project Phase



MEXT = Ministry of Education, Science and Technology

Toward the MHFT Feasibility Demonstration



MHFT-Project Office

Since Jul 2021

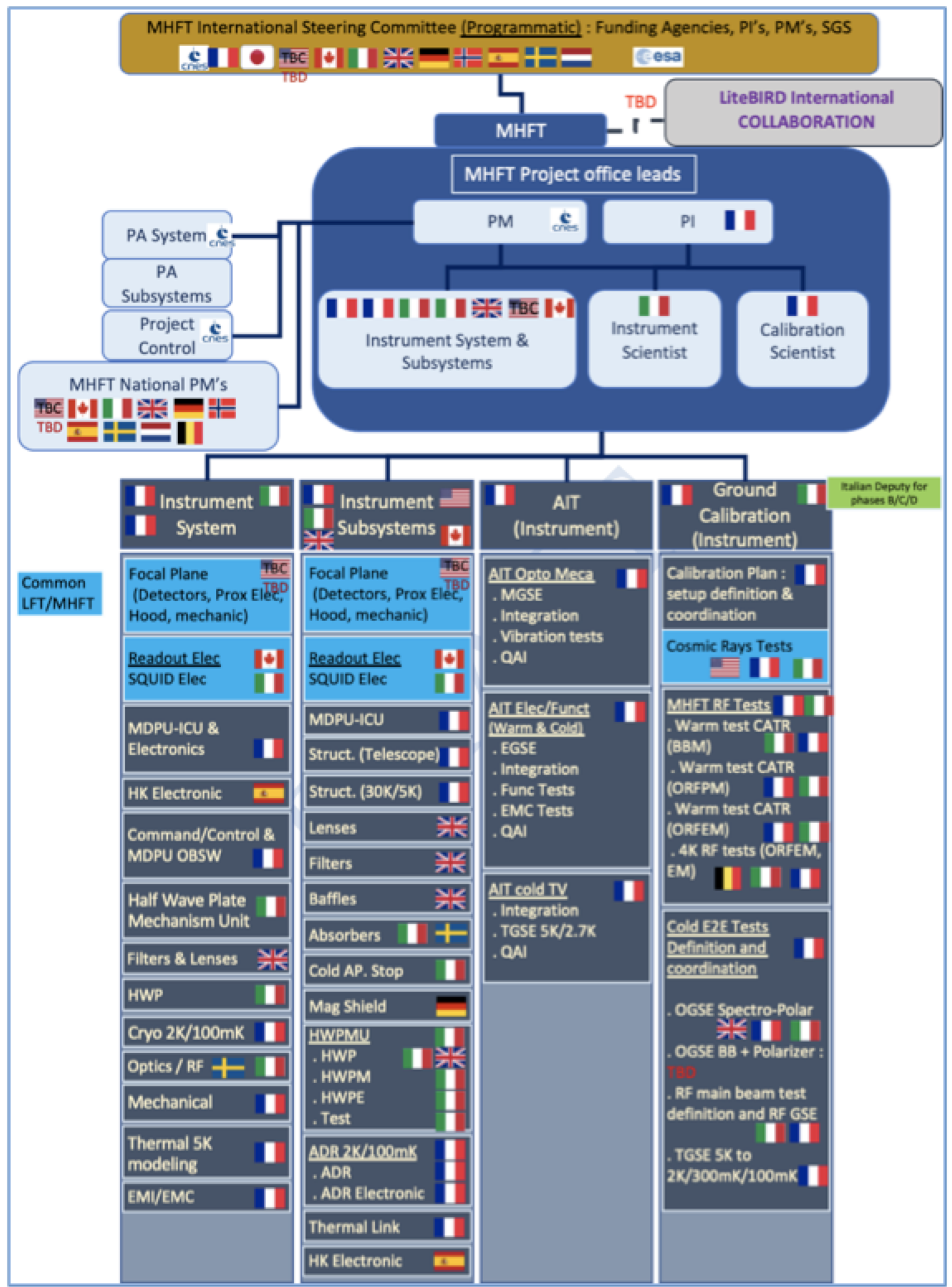
Role: Responsibility of the design, the development and the delivery of the MHFT instruments + sub-K chain

under CNES lead



Composition:
 Chaired by the CNES-PM
 co-Chaired by MHFT-PI

Mostly composed of people from the international collaboration.



Regular Progress Meetings
 Every 2 - 3 months

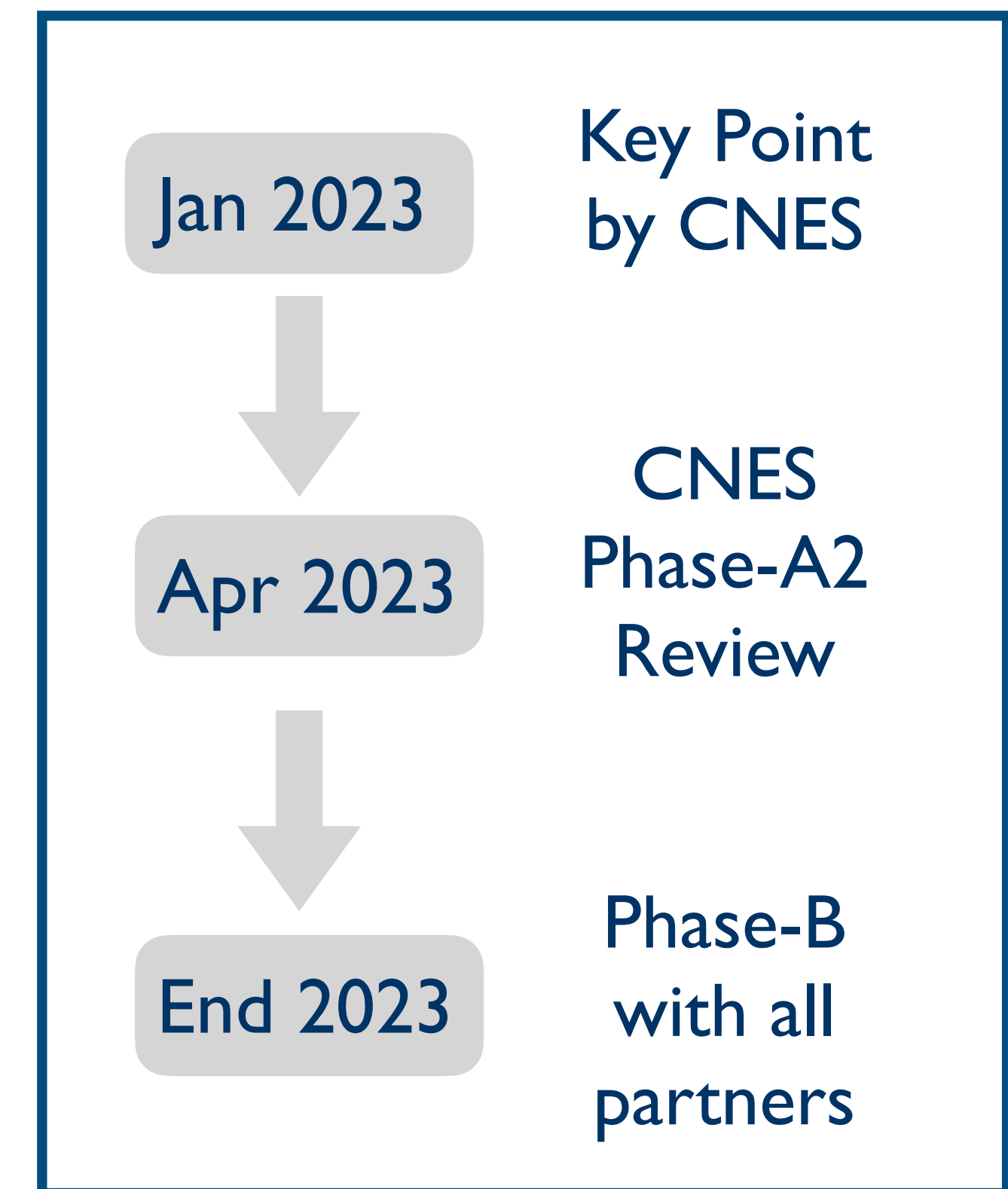
- 22-11-07,09: F2F Meeting @ Milano Bicocca
- 22-09-19,20: F2F Meeting @ IAS Orsay
- 22-06-13,16: F2F Meeting @ Sapienza
- 22-04-04,06: F2F Meeting @ IAC Tenerife
- 21-11-29,30: F2F Meeting @ INFN Pisa
- 21-10-08: F2F Meeting @ IJCLab
- 21-07-19: Kick-Off Meeting @ Sapienza

The MHFT-Project Office Activity

Tasks:

- Consolidation of Requirements Flow-Down from Science to Instrument levels
 - ➔ Dedicated Task Force on Requirements & Performances
 - ➔ Close connection with JSG / DMG groups
- Check Compliance of design with specifications
 - ➔ Close connection with European sub-system teams
- Check technical feasibility of the design at System / Sub-System / Calibrations levels
 - ➔ Prototyping: HFT, DPU, WRE, HWP Mechanism, Sub-K, Beam Measurements
- Check consistency with planning and procurement plan
 - ➔ Discussions with JAXA / QUP / US

Expected Schedule:





LiteBIRD Collaboration

Same as Jun 2021

PI: Masashi Hazumi (JPN)
 PI-US: Adrian Lee (LBNL)
 PI-CA: Matt Dobbs (Mc Gill)
PI-EU: Ludovic Montier (IRAP)



Interim Governance Board

40 members
(7 French)

Joint Study Groups

systematics

G. Patanchon (APC)
 H. Ishino (IPMU)
 J. Borrill (LBNL)

foregrounds

N. Katayama (Japan)
 R. Flauger (US)
 C. Baccigalupi (Europe)

calibration

T. Matsumura (Japan)
 K. Arnold (US)
S. Henrot-Versille (IJClab)

Payload Module

Y. Sekimoto (Japan)
 K. Thompson (US)
B. Mot (IRAP)

Performance Team

Takashi Hasebe (Japan)
J. Errard (APC)

Data Management Group

Paolo Natoli (Italy)
M. Tristram (IJClab)

Instrument Model Team

Simulation Team

Production Team

Publication Board

A. Banday (IRAP)
 T. Matsumura (Japan)

Liaison:
J. Aumont (IRAP)

Speaker Selection

B. Barreiro (Spain)

Membership Board

M. Hazumi (Japan)
 A. Lee (US)
 E. Calabrese (UK)

Deep involvement of the French community in the LB collaboration and in the management levels



Science Exploitation

The Science Study Groups

Since Jul 2021

LiteBIRD PTEP Paper accepted in Nov 2022

A new set of Science Study Groups dedicated to science forecast with LiteBIRD.
Short term goal (1-2 years)

Scientific Forecasts Groups

- LiteBIRD: Isotropy and Statistics
- LiteBIRD: Tests of Cosmic Inflation
- LiteBIRD: Optical Depth, Reionization of the Universe, and Neutrino Masses
- LiteBIRD: Cosmic Birefringence
- LiteBIRD: Mapping the Hot Gas in the Universe
- LiteBIRD: Primordial Magnetic Fields
- LiteBIRD: Gravitational Lensing of the CMB
- LiteBIRD: Cross-correlation Science
- LiteBIRD: E-modes

A. Banday

M. Tristram M. Lattanzi

J. Errard A. Grupposo

Galactic Science Project Study (GSPS) J. Aumont Eirik Gjerlow

- 3D Galaxy
- Dust Properties / AME
- Foreground Separation techniques for Galactic Science

Science Forecast Activity is increasing
We have to put more resources on this

Opportunity to include new members on
dedicated forecast activities

The Science Ground Segment

Since Apr 2022

Task-Force:

- Prepare a document summarizing information and discussion at past LiteBIRD IGB meetings and global meetings on science ground segments (SGSs) and related collaboration governance.
- Identify differences between projects led by Europe, Japan, and the US.
- Study possible LiteBIRD SGS configurations(1). Evaluate, compare, and score them(2).

Members:

- Japan: Ken Ebisawa, Yuki Sakurai
- Europe: Paolo Natoli, Matthieu Tristram, Hans Kristian Eriksen
- North America: Renee Hlozek, Raphael Flauger

+ Ex officio members:

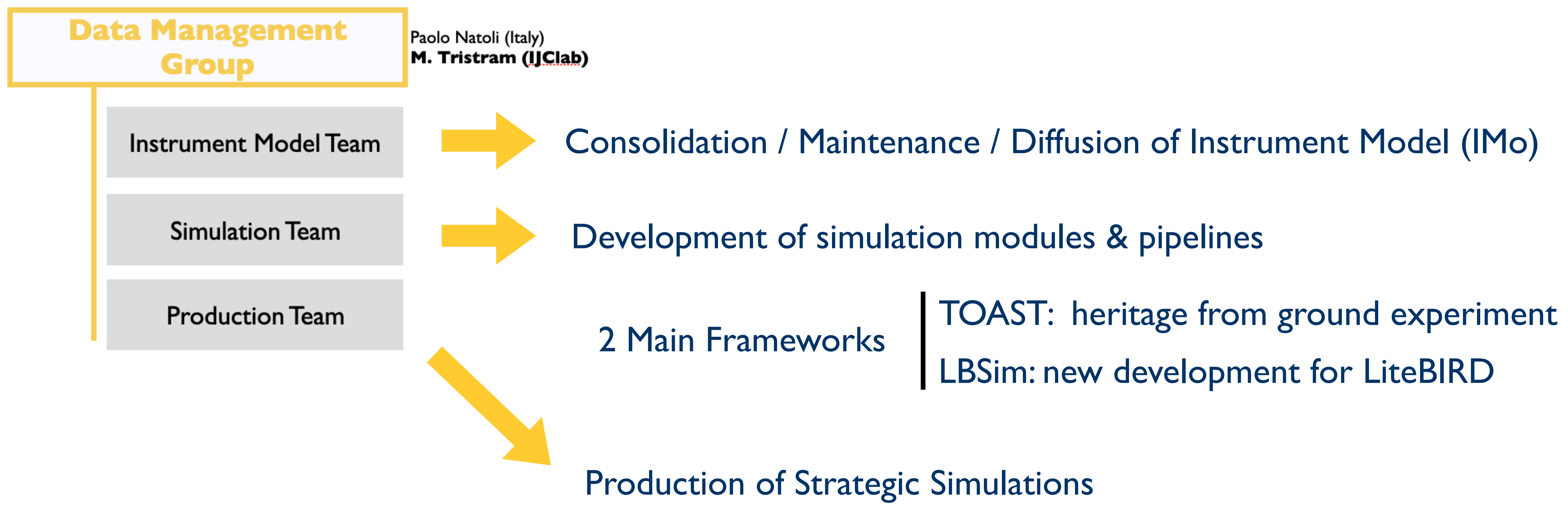
- Masashi Hazumi
- Adrian Lee
- Ludovic Montier

Data centers envisaged for LiteBIRD:

- NERSC (LBNL)
- KEKcc (Japan)
- Cineca (Italy)
- CC-IN2P3
- Germany ?



Simulation Pipeline Development / Production Effort



NASA TRL simulations w/ TOAST3

Full LB Focal Plane including plenty of systematics
Goal is to demonstrate TRL of NERSC

On-going

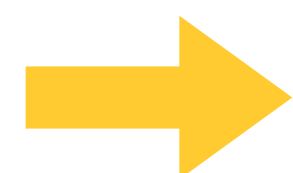
LBSim First Run

1/3 LB Focal Plane including 1/f noise x 50 sims
Goal is to provide material for post PTEP papers

On-going

Take-away Message

Lots of activities in the last 1.5 years

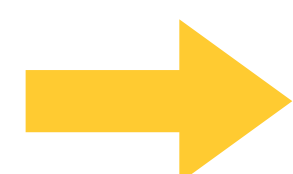


Consolidation of International Task Sharing:

Sensor Modules delivered by QUP (with US and JAXA)

+

Focal Plane Structures delivered by France & UK



Consolidation of European Procurement Plan for Phase-B and futures:

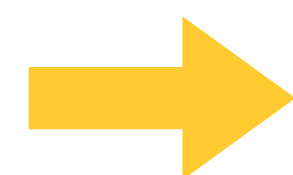
CNES lead on MHFT

+

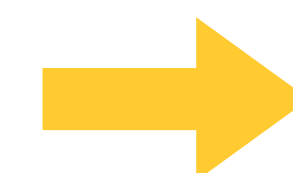
National contributions

+

ESA MoO if needed



Preparation of Science Exploitation has been initiated: Science Study groups / papers / SGS / Simulations



Next Steps:

Beg 2023

Mid 2023

JAXA Mission Definition Review

CNES Phase-A2 Review

Major Milestones

- 2023: Prototype HFT
- Mid-2023: End CNES Phase-A2
- End-2023: Selection for Phase B CNES
- 2026: EM Delivery
- 2028: FM Delivery
- 2030: Launch



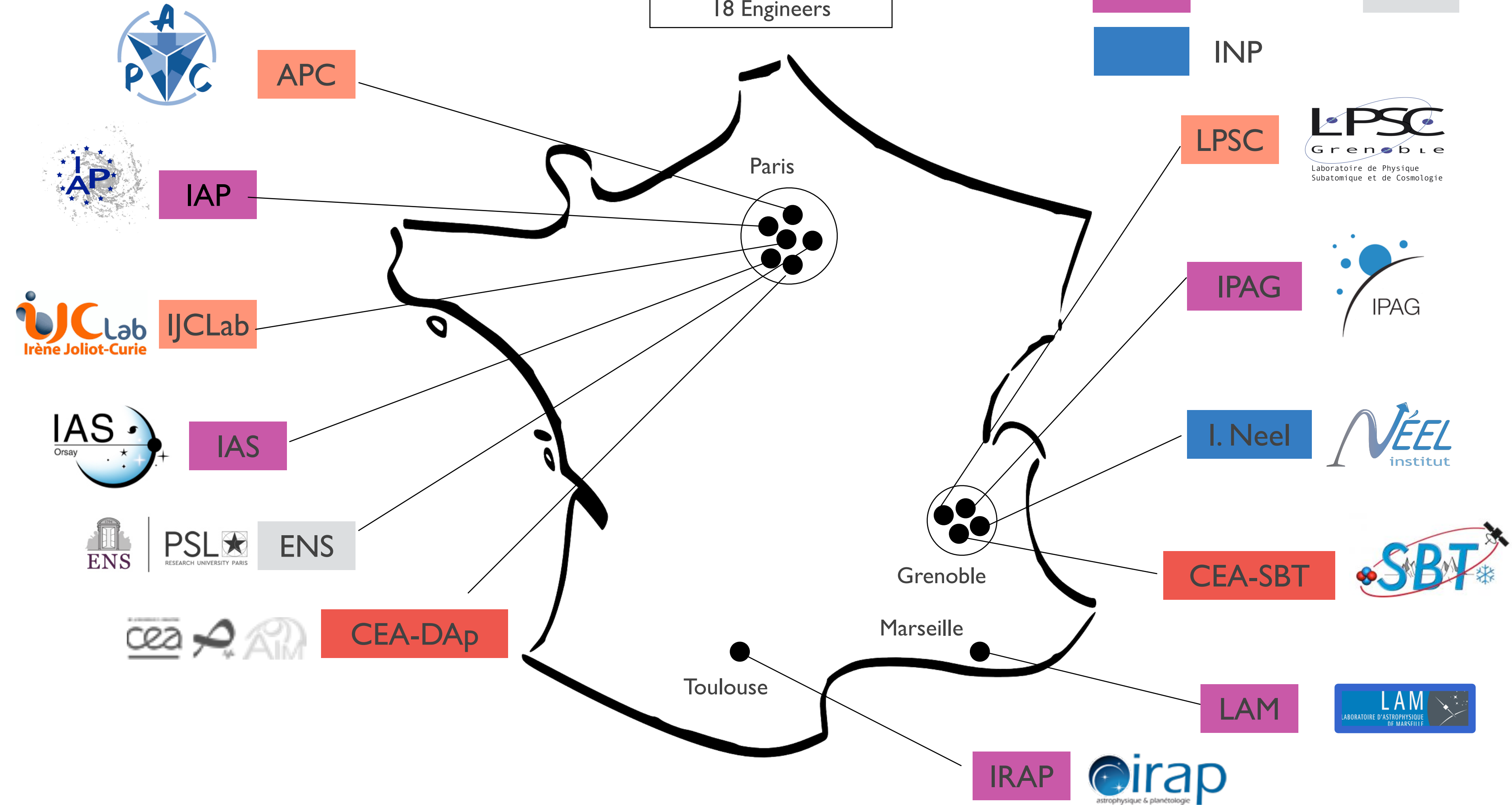
The LiteBIRD Collaboration



LiteBIRD France

37 Scientists
18 Engineers

- IN2P3
- CEA
- INSU
- ENS
- INP



The LiteBIRD Collaboration



LiteBIRD France

37 Scientists
18 Engineers

- IN2P3
- INSU
- INP
- CEA
- ENS

