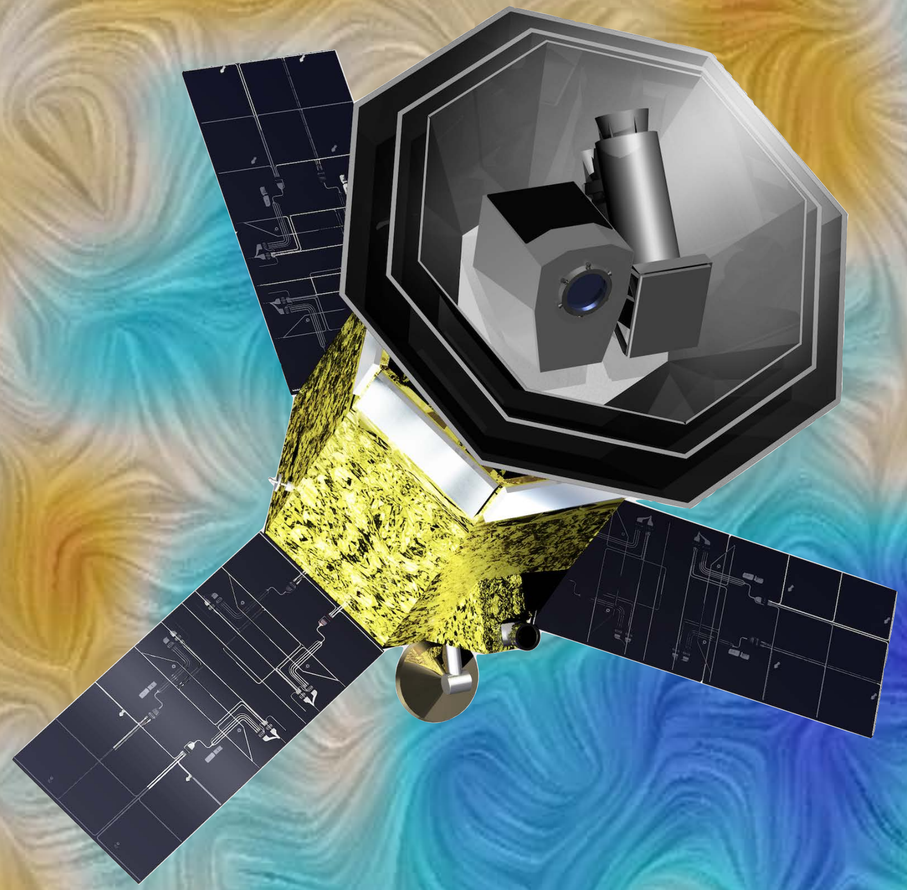


LiteBIRD MHFT Overview

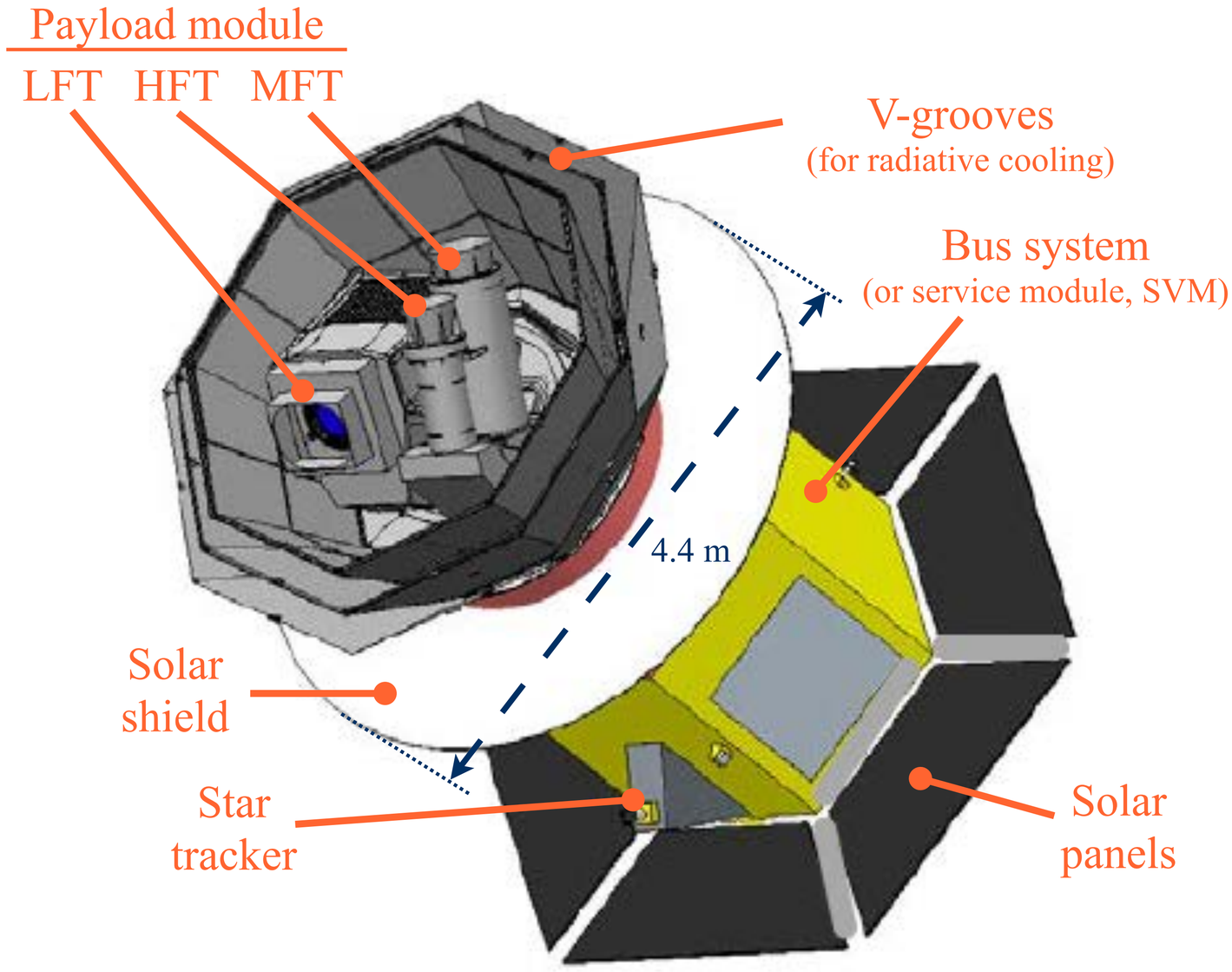
Baptiste Mot
on behalf of LiteBIRD collaboration

LBIRD Day - 13 May 2024

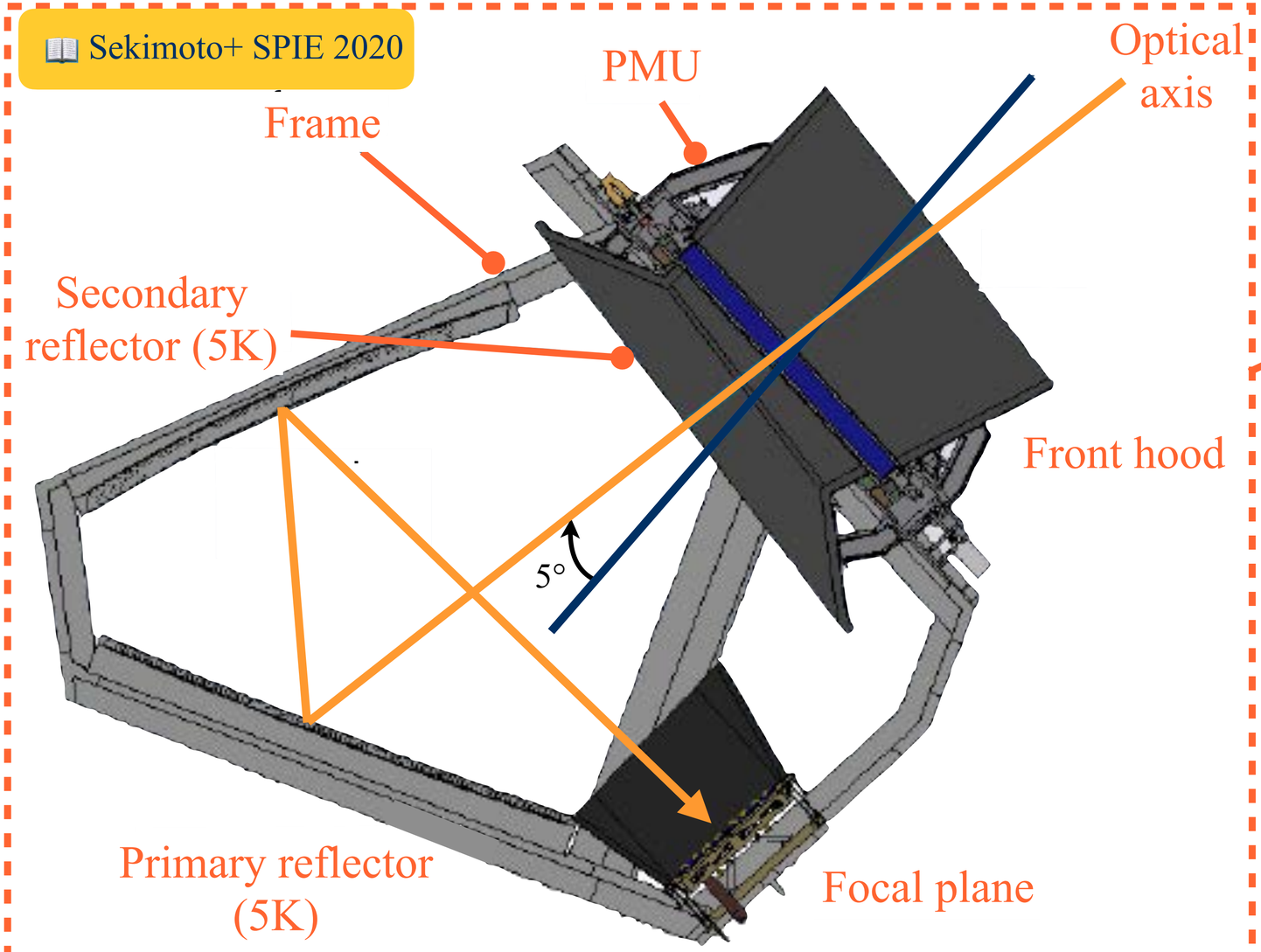
LiteBIRD spacecraft overview

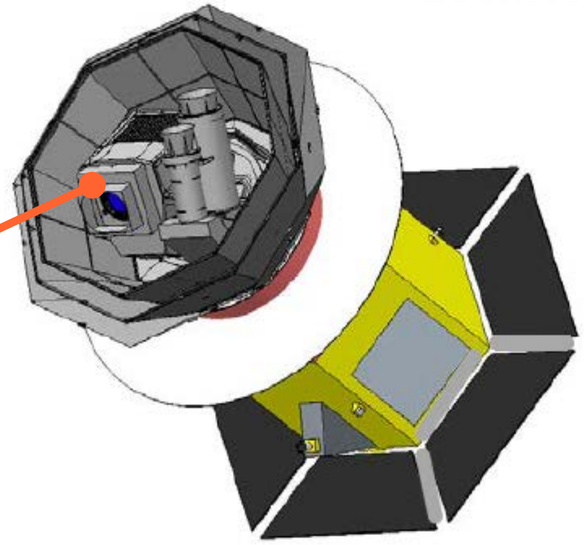
- **3 telescopes** are used to provide the **40-402 GHz** frequency coverage
  1. **LFT** (low frequency telescope)
  2. **MFT** (middle frequency telescope)
  3. **HFT** (high frequency telescope)
- Multi-chroic transition-edge sensor (TES) **bolometer arrays** cooled to **100 mK**
- Polarization modulation 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



Low Frequency Telescope (LFT)



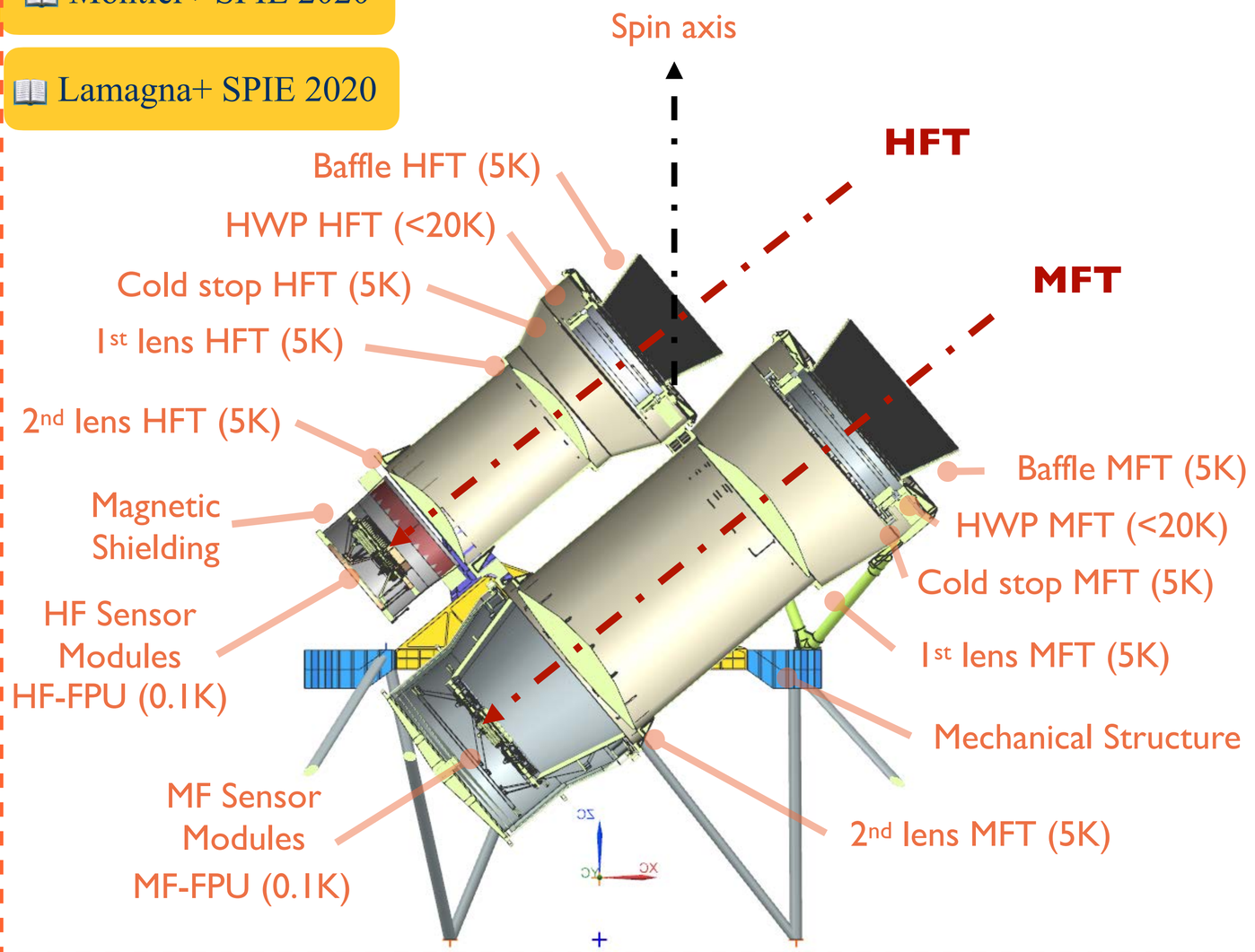


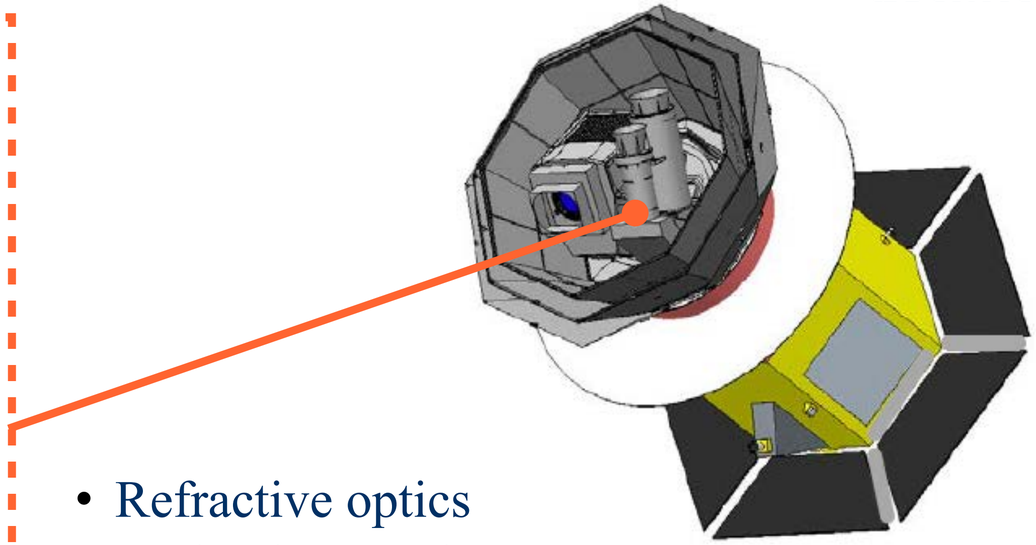
- **Crossed-Dragone** design
- Field of view: **18° × 9°**
- **Polarization Modulation Unit (PMU)**
- Aperture diameter: **400 mm**
- Frequency range: **40-140 GHz**
- Angular resolution: **70-24 arcmin**
- Weight < 200 kg

Middle-High Frequency Telescopes (MFT/HFT)

📖 Montier+ SPIE 2020

📖 Lamagna+ SPIE 2020

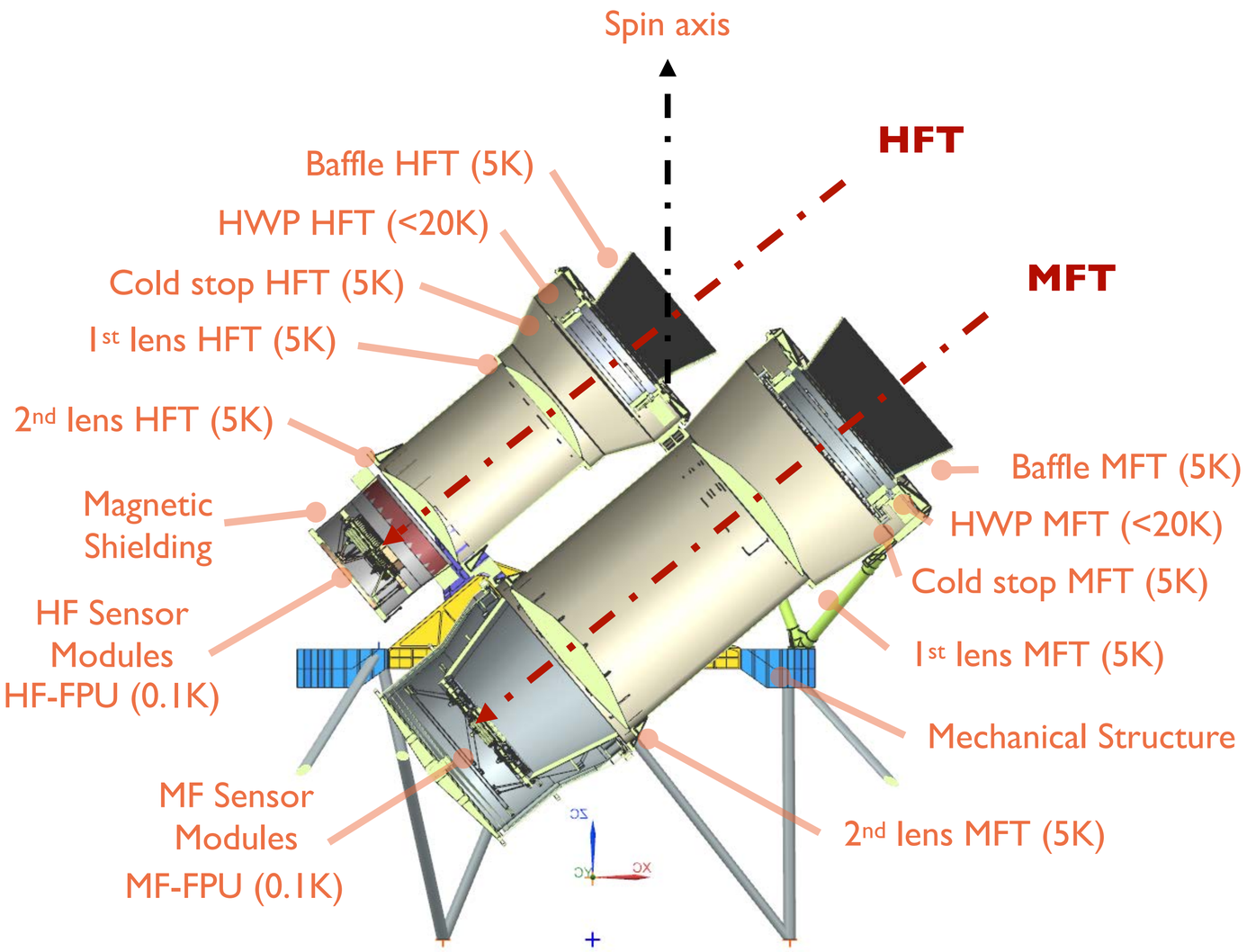




- Refractive optics
- Each telescope has PMU
- Optics at **5 K**
- Field of view: **28°**
- High heritage from ground experiments
- PP lenses + ARC
- Weight 180 kg

	MFT	HFT
ν (GHz)	**100-195**	**195-402**
Ap. diameter (mm)	**300**	**200**
Ang. res. (arcmin)	**38-28**	**29-18**

MFT/HFT main contributions



- 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

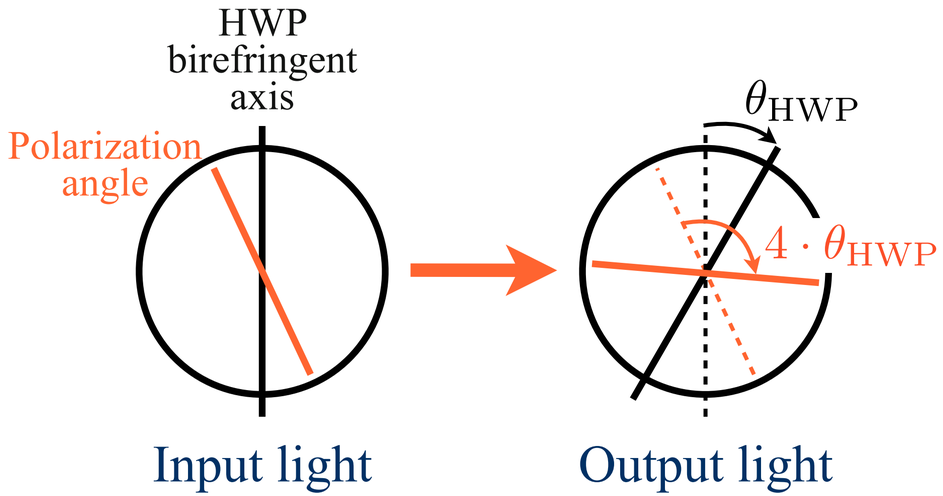
- Warm Readout Electronics

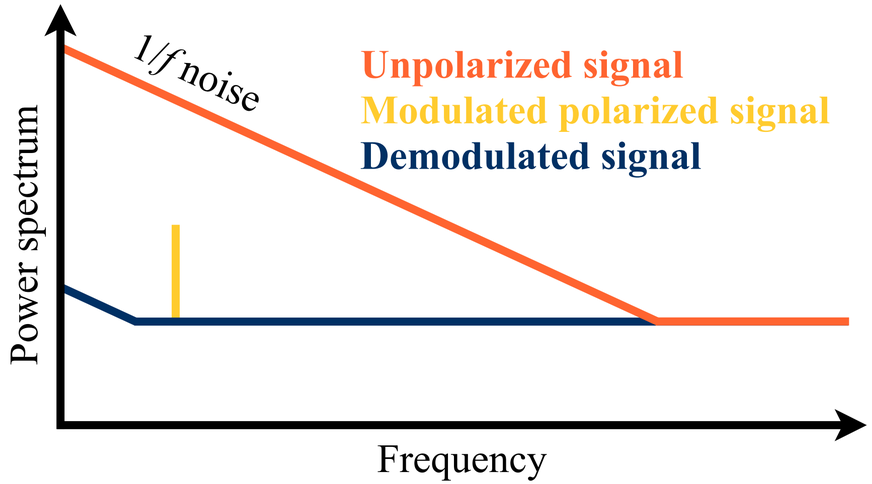
- European MoE driven by CNES
- System Responsibility
- Mechanical Structure 5K
- Focal-Plane Structure + FPU Integration
- DPU
- Sub-K cooler
- AIT + Calibration

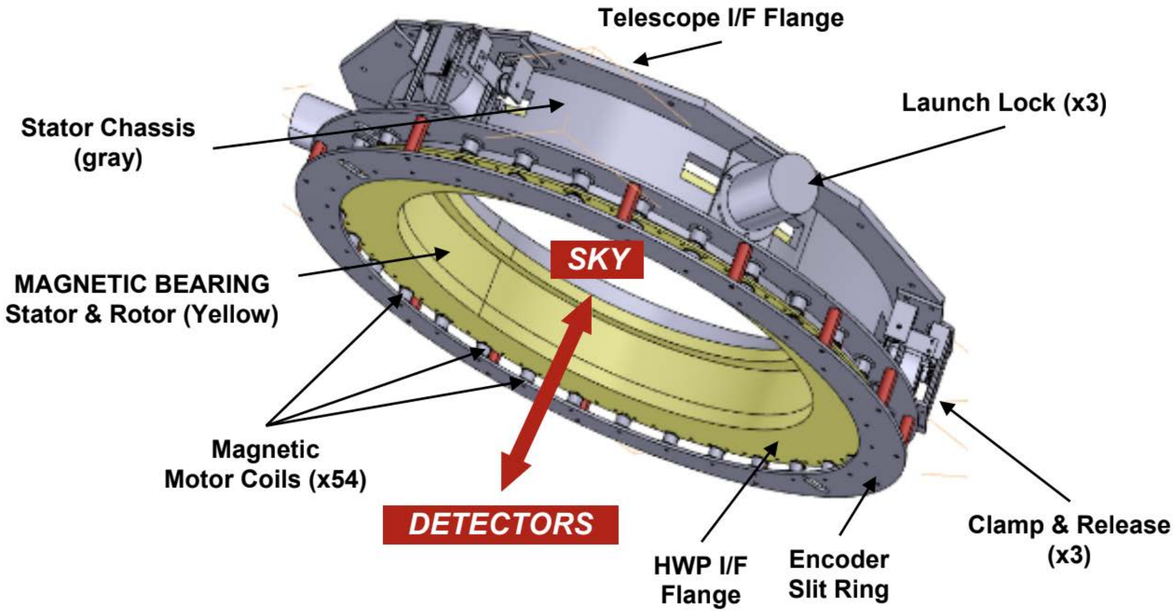
- Calibration

Polarization Modulation Unit (PMU)

- Rotating a birefringent plate to modulate polarization
- The first sky-side optical element

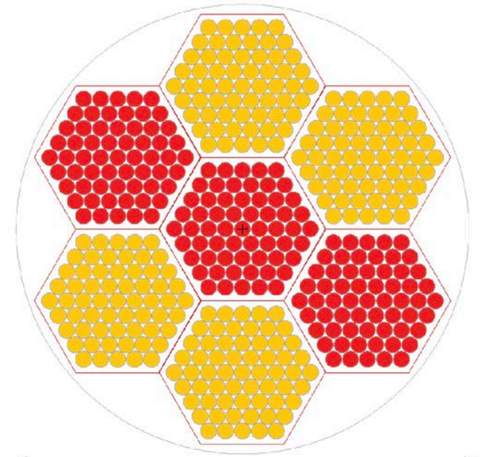


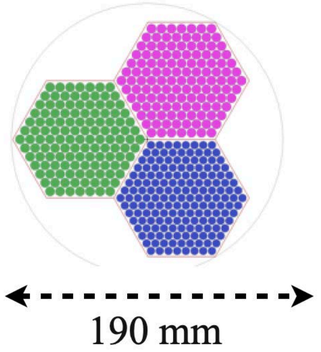




- Rotation test of superconducting magnetic bearing system in the 4K cryostat
- Stable rotation at cryogenic temperature (< 10 K)

Focal plane Sensor Modules



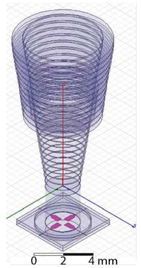


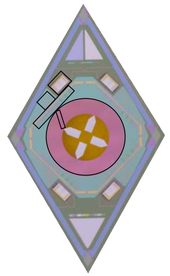
MFT (2.5:1)

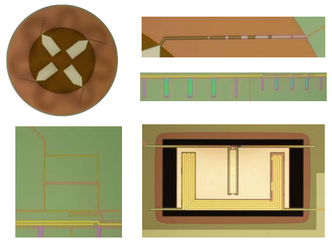
89GHz — 225 GHz

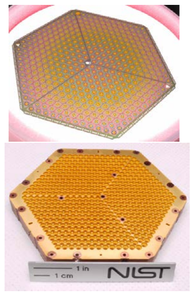
2074 detectors
2 x 183 Trichroic TES
2 x 244 Dichroic TES

100 | 119 | 140 | 166 | 195

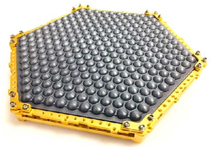


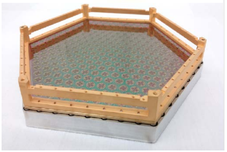


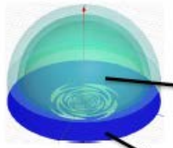


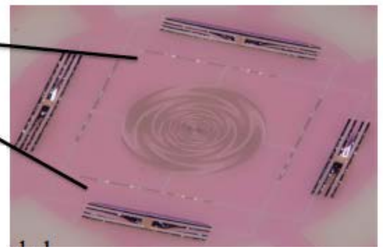


Lensed coupled detectors
Lenslets









HFT (2.7:1)

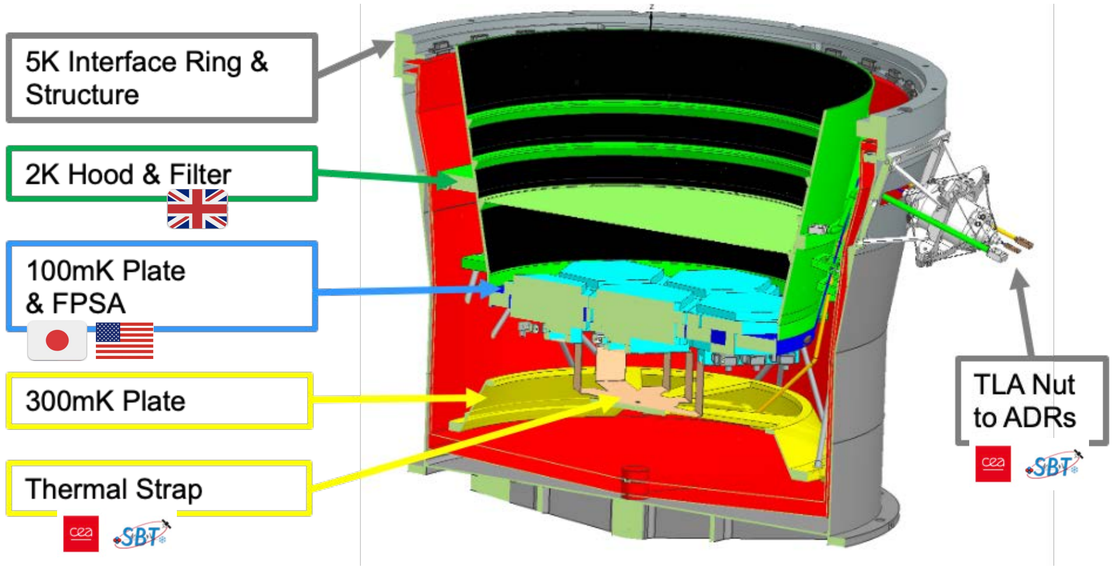
195 | 235 | 280 | 337 | 402

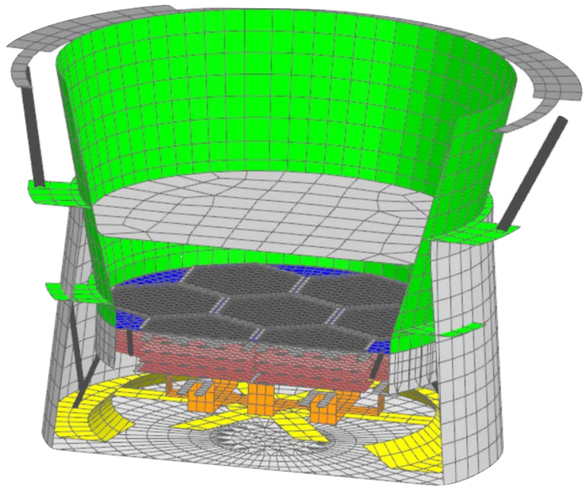
1354 detectors
2 x 254 Dichroic TES
2 x 169 Monochromatic TES

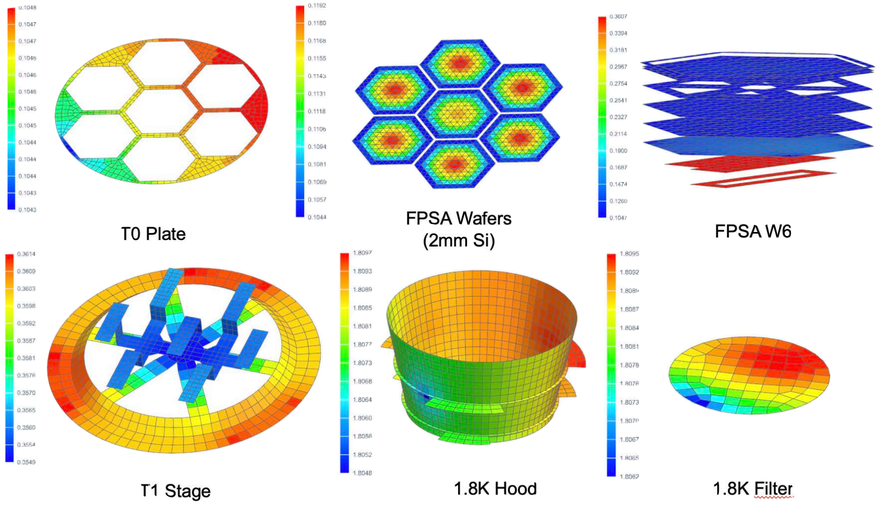
166 GHz — 448 GHz

Horn coupled detectors
Platelets

Focal Plane Assembly

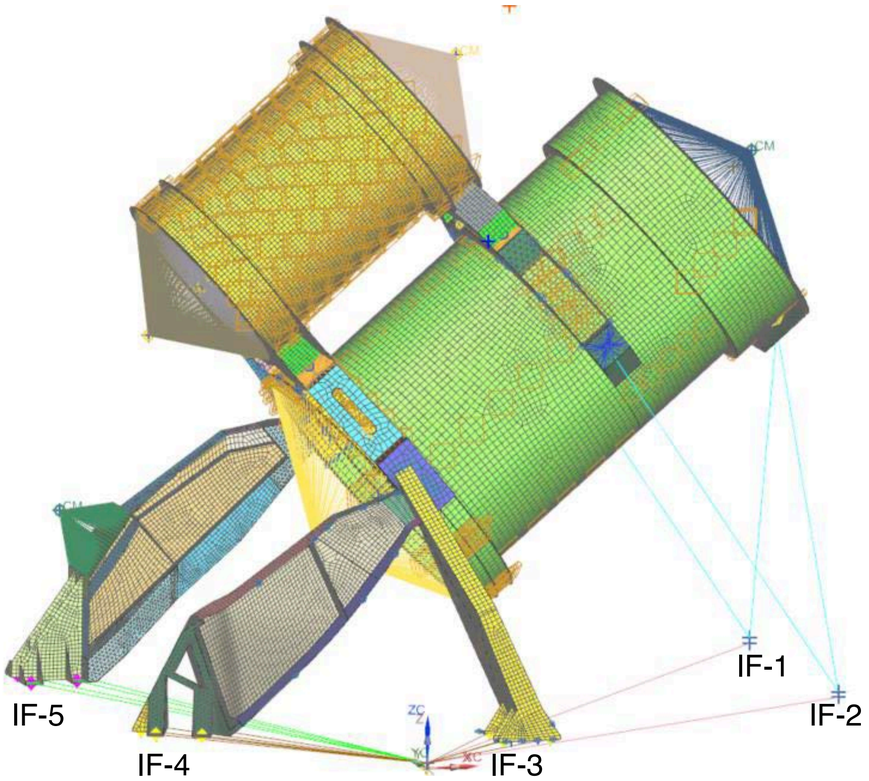


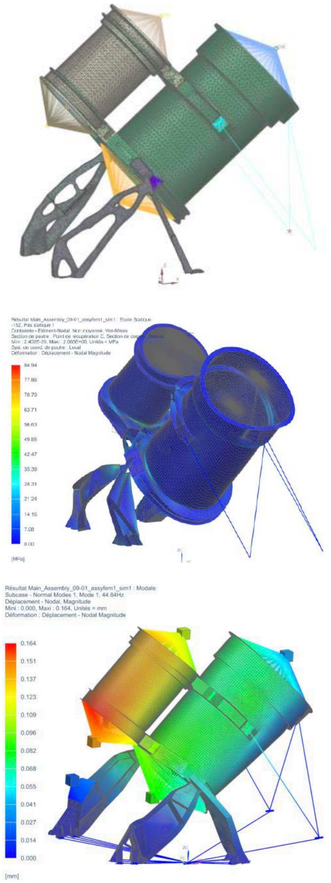


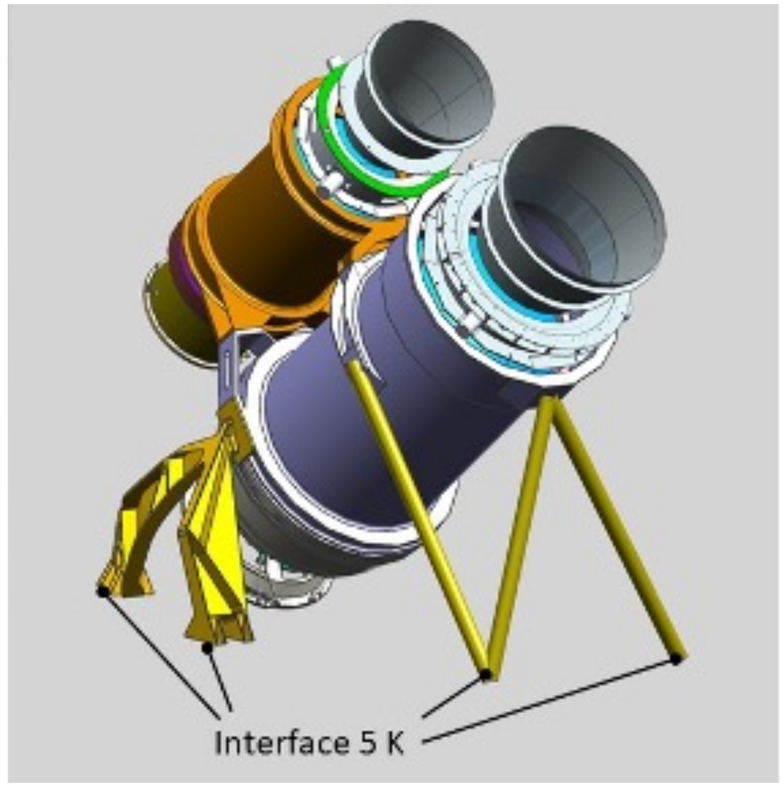


- Mechanical & Thermal modeling
- CAD design
- AIT

Mechanical Structure

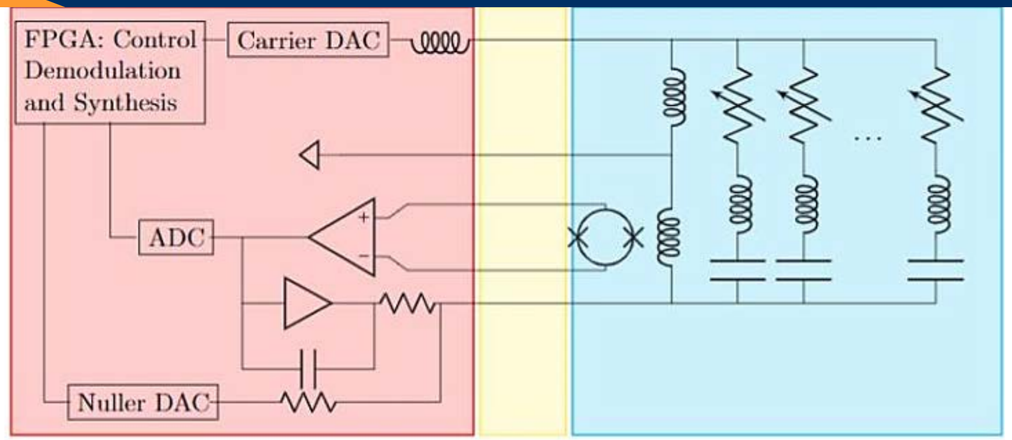


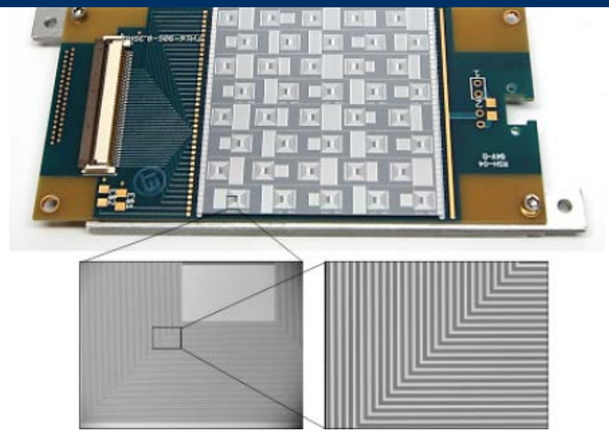


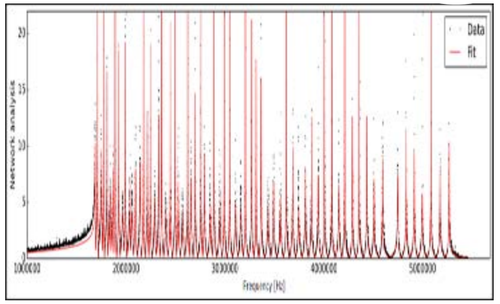


- Mechanical modeling
- CAD design
- AIT

LiteBIRD readout system







Cold Readout LC filters for MUX

- Digital frequency multiplexing (**DfMux**) readout technology enables the readout of many Transition Edge Sensors (TES) with fewer components and a low wire count, with no increase of system noise (⇒ **photon noise limited** detector performance)
- Superconducting resonators are used to assign unique frequency channels to the **TES sensors**.
- The signal is read out using a low-noise **SQUID amplifier** and an **FPGA controller**.

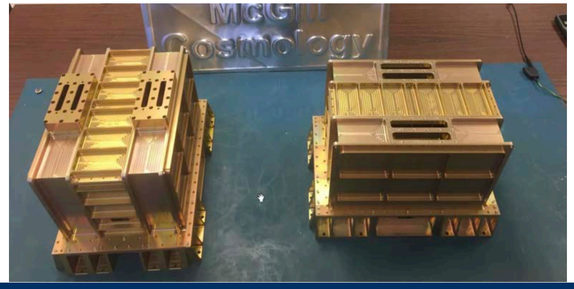
SQUID controller board

SQUID controller assembly

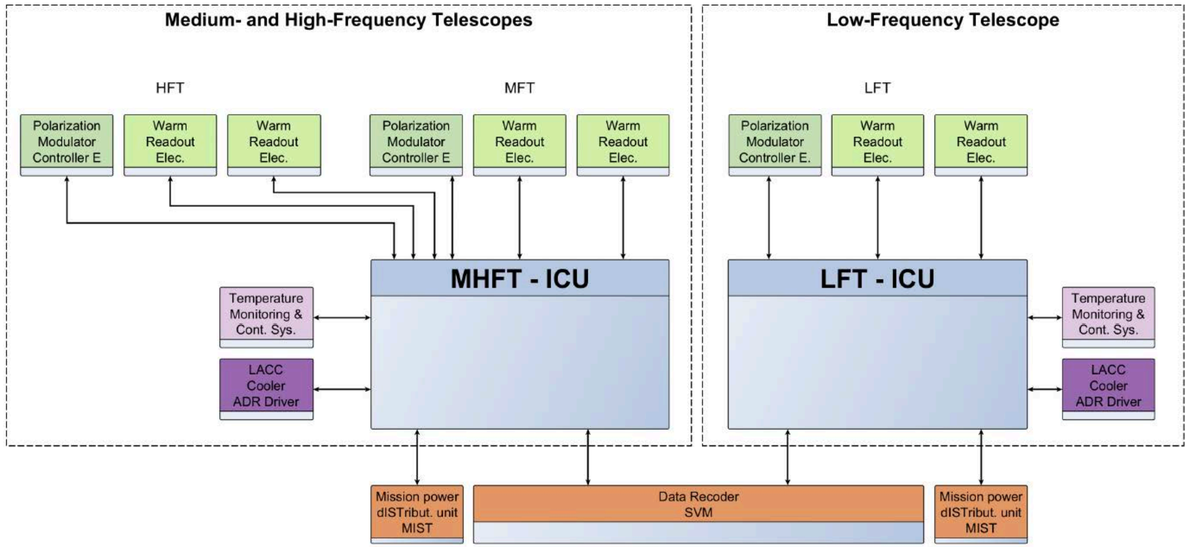
Digitizer assembly

Signal Processing Unit

Digitizer assembly



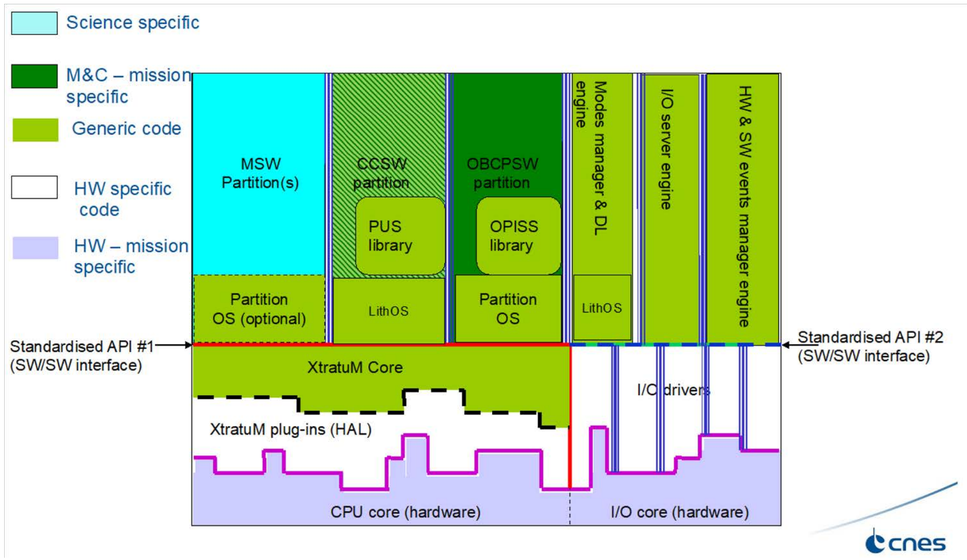
Data Processing Unit

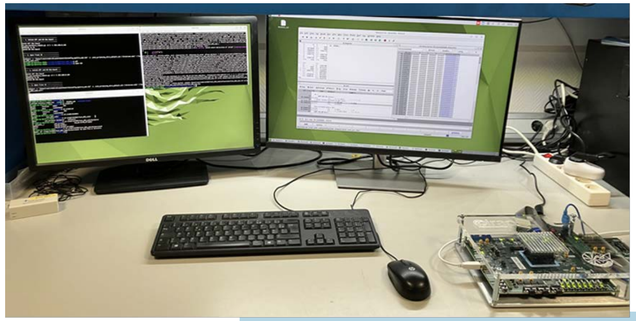


On-board software :

=> Hypervisor from Fentiss (XNG)

=> Generic payload generator (LVCUGEN) from CNES.

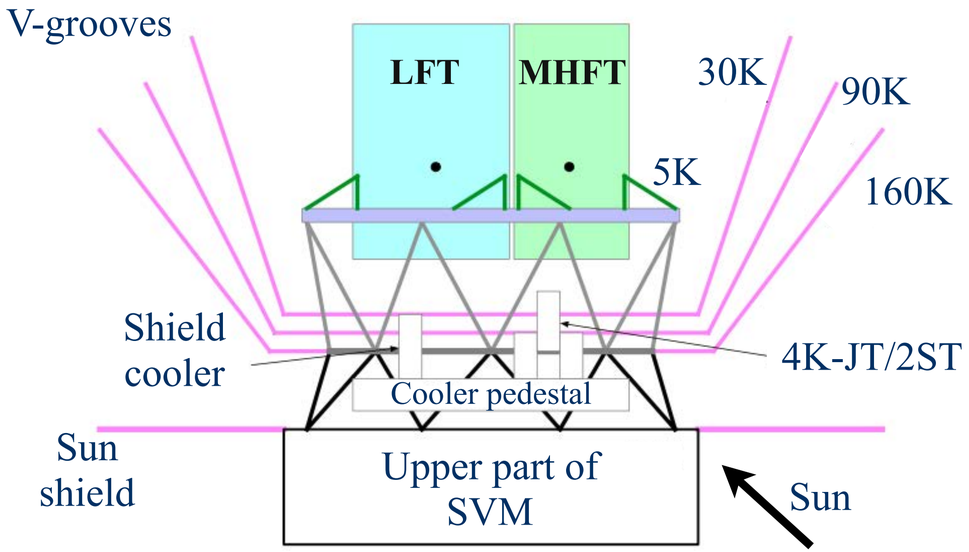


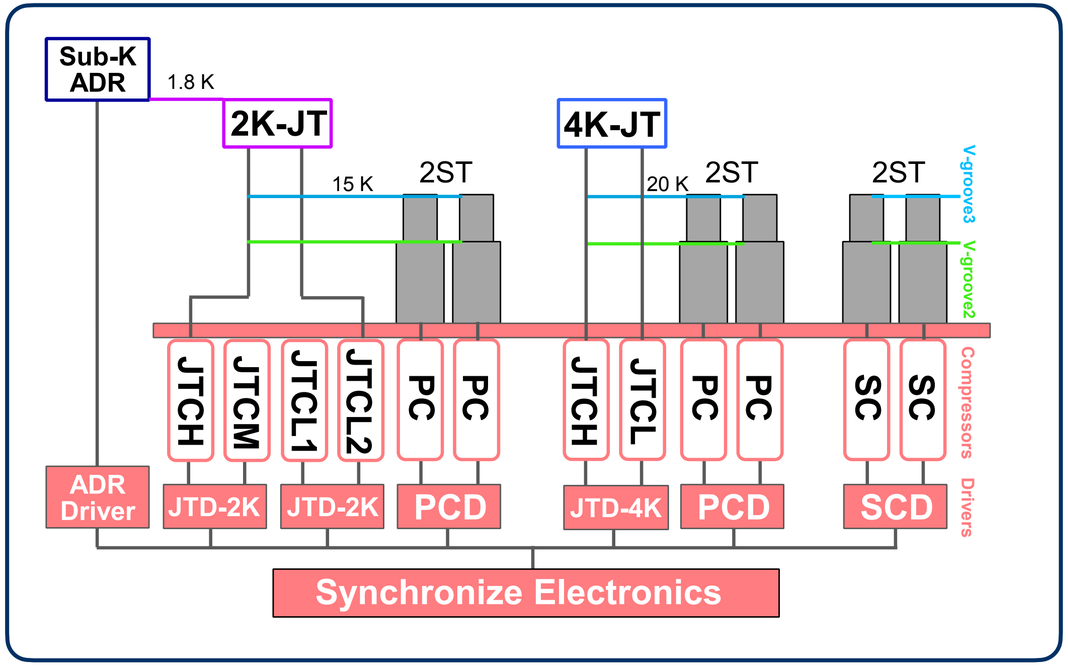


- NG-ULTRA component
- 4 cores, ARM processor at 600MHz
- 1M x 32 Static RAM
- 3 GBytes DDR3
- 8 GBytes Flash storage
- 6Spacewire links
- 5 Serial links
- 8 Warm Readout Electronic links

Bread Board model

LiteBIRD cryogenic system

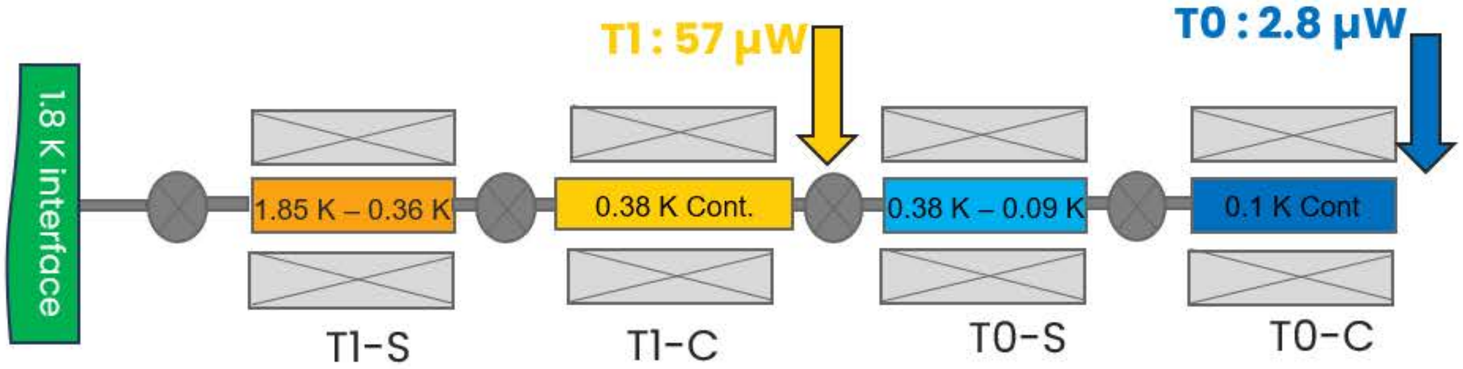


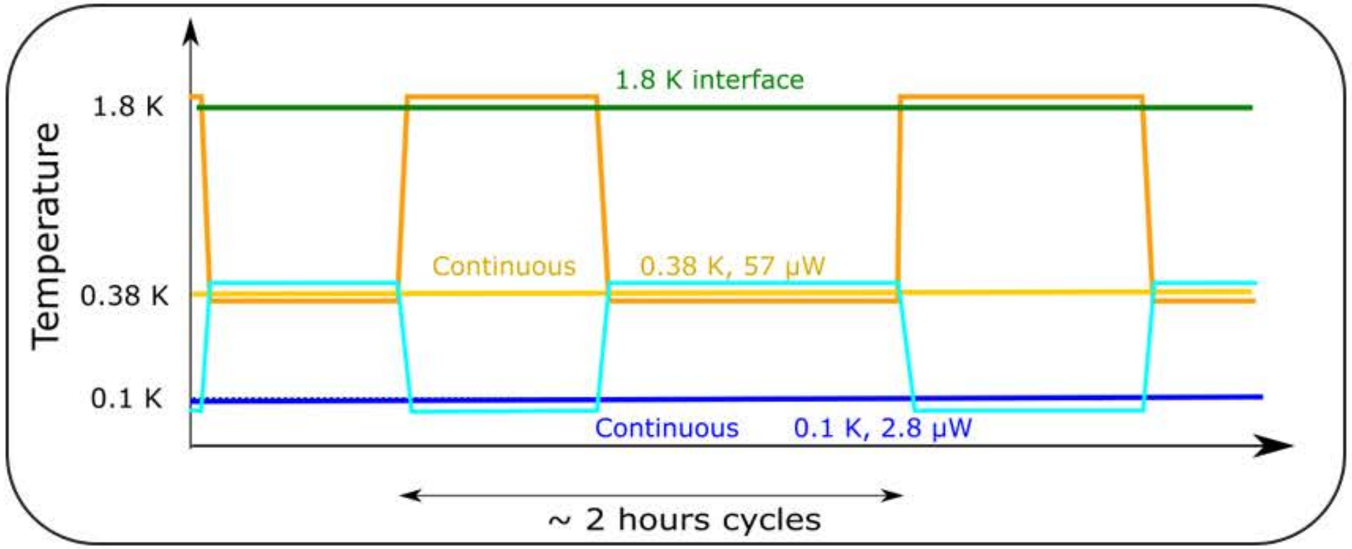


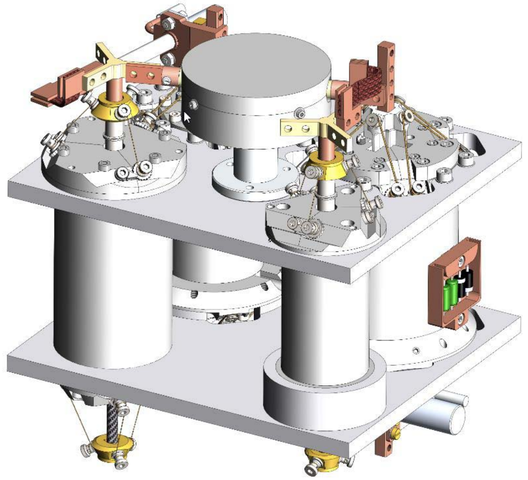
- Optimized to ensure **maximum stability** of the focal planes and of the optical elements of the telescopes
  - Radiative cooling to 30 K with V-grooves
  - Two 2ST are used for cooling V-grooves 2 and 3
  - A 4K-JT and two 2ST are used to cool the LFT and the MHFT
  - A 2K-JT, two 2ST, and a sub-K ADR are used for cooling the focal plane down to **100 mK**

Sub-K Cooler

4 ADR stages
2 intermediate stages
Mass < 10 kg



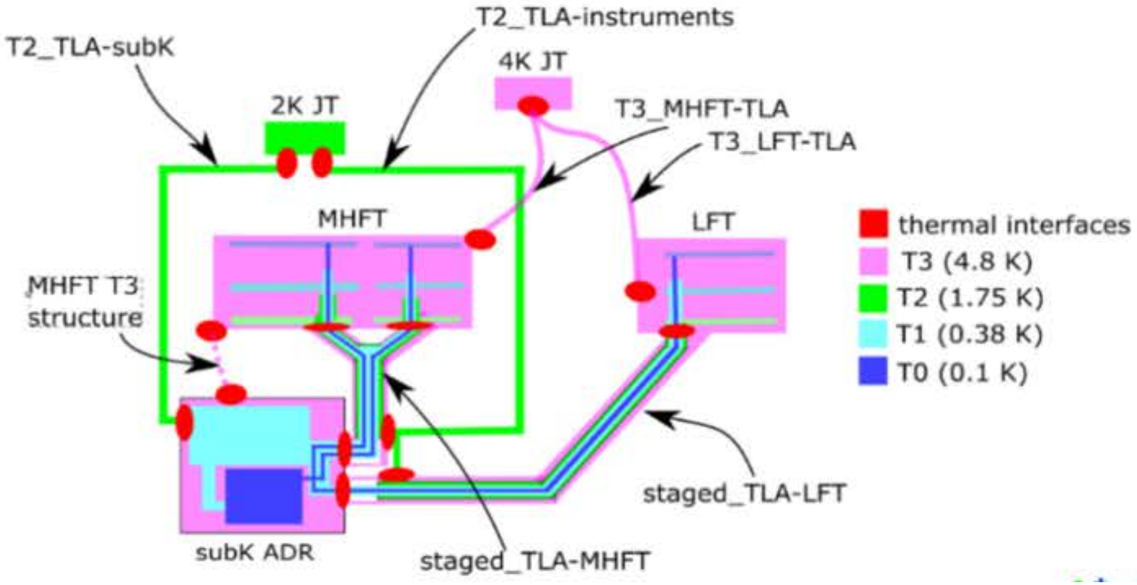


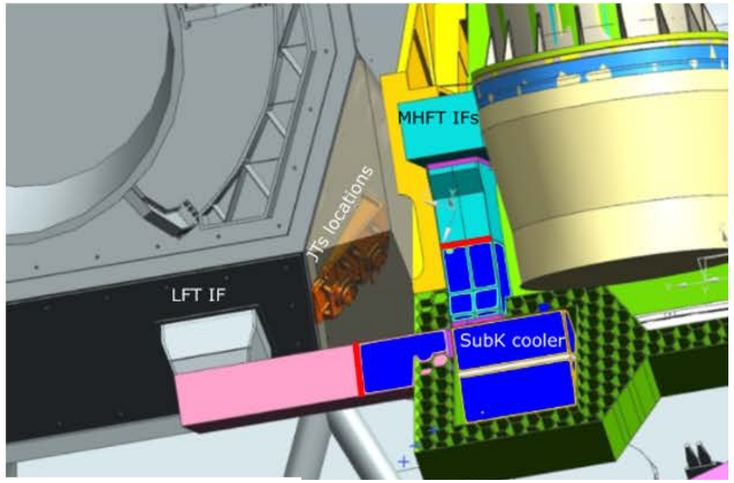


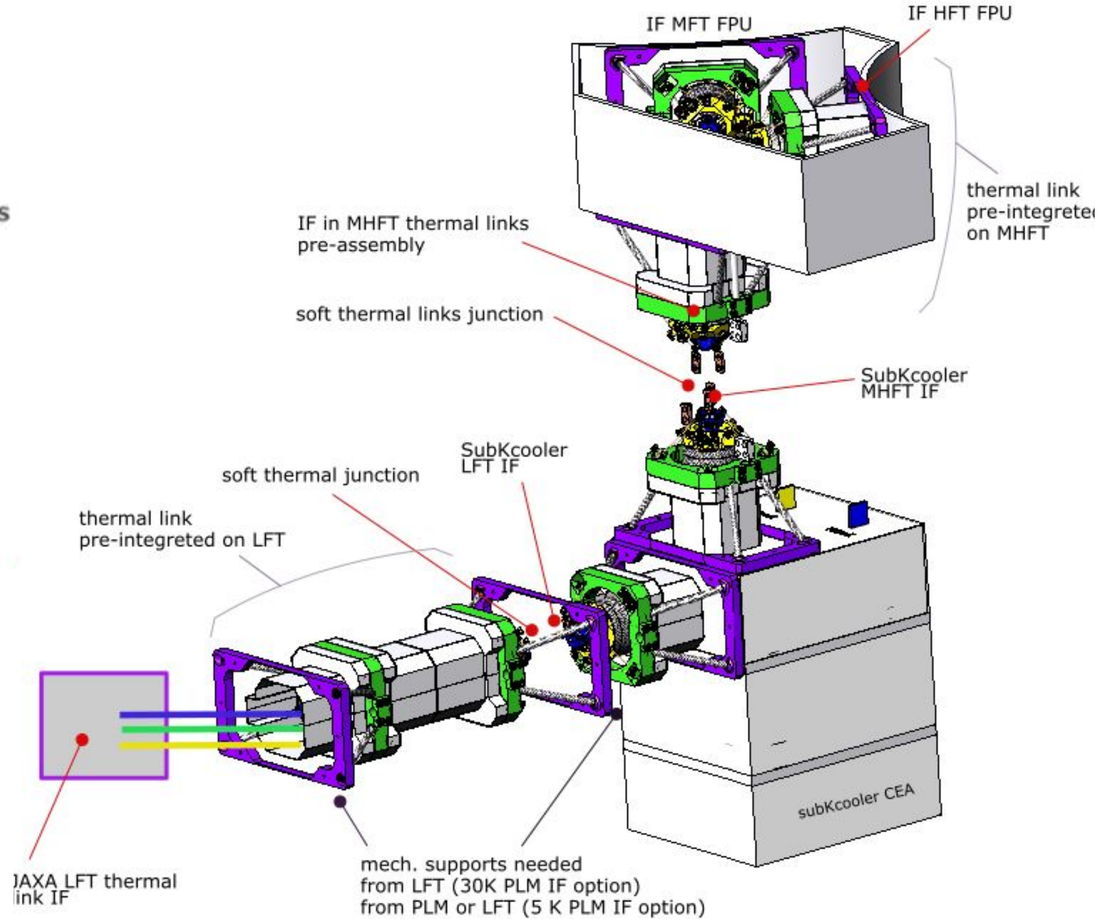
4 hours cycles
2.7 K interface

- Continuous cooling at 100 mK & 300 mK

Thermal Links Assembly





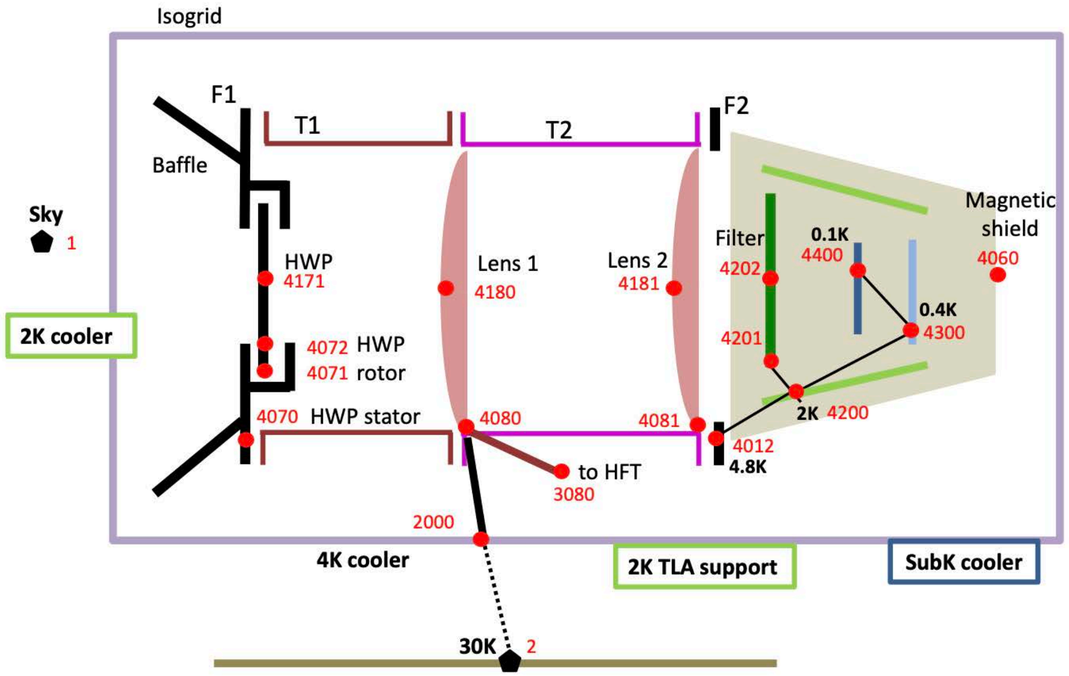


Thermal Modeling

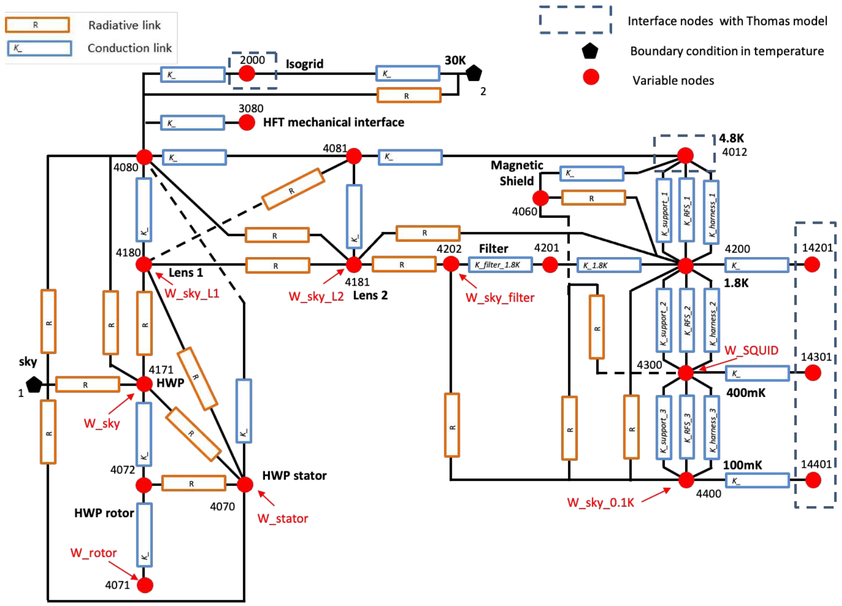
Simplified mechanical architecture of the MFT instrument

→ Geometry used for calculations

→ Location and name of thermal nodes (●)

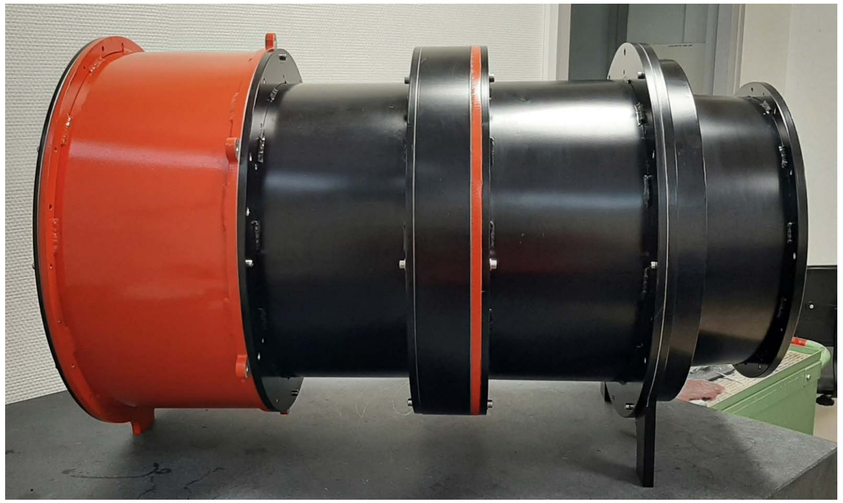


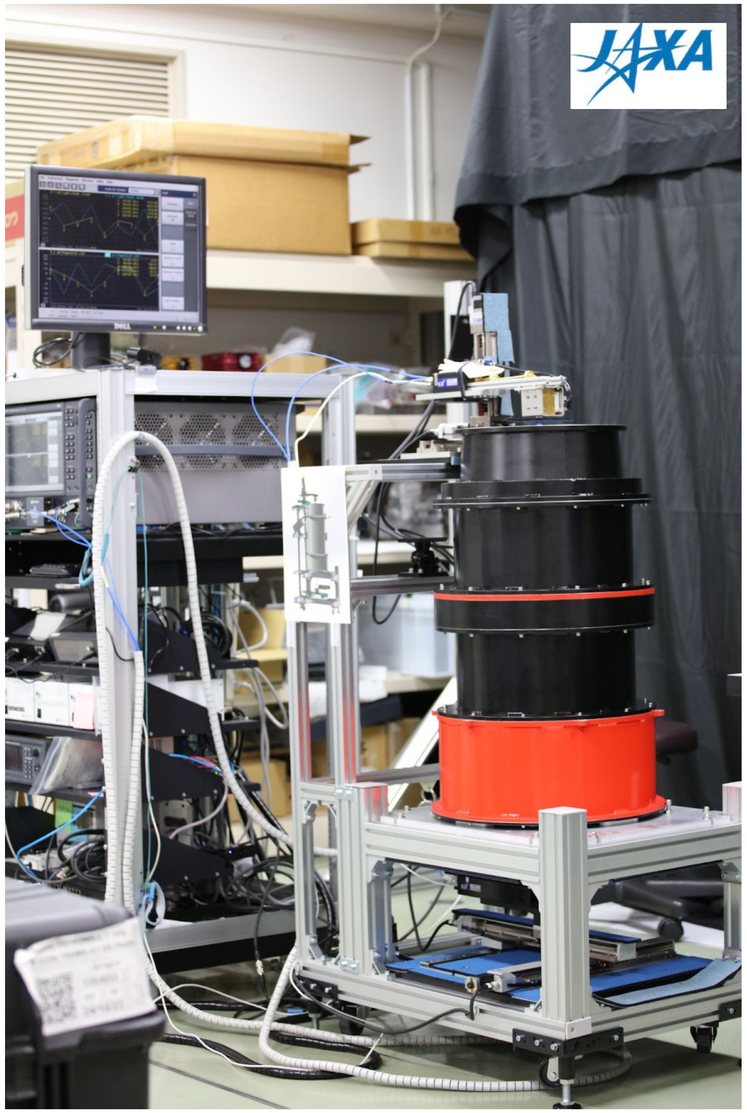
HFT architecture is similar to that the MFT



- Thermal model made on ThermXL
- Sub-systems-thermal models included
- Cold stages stability estimation
  - => Cryochain oscillations
  - => Sky heat load

MHFT Optical Prototype





- HFT like telescope
  - => Same optical design
  - => HDPP Lenses
  - => Absorbers (CR110)
  - => Aperture Stop
  - => Detectors hood
- NF & holographic characterization done

Conclusion

- Strong French technical / hardware contribution to LiteBIRD.
- Consolidation and justification of the design to be finalized.
- Consolidation of the organization and task sharing on-going.


LiteBIRD