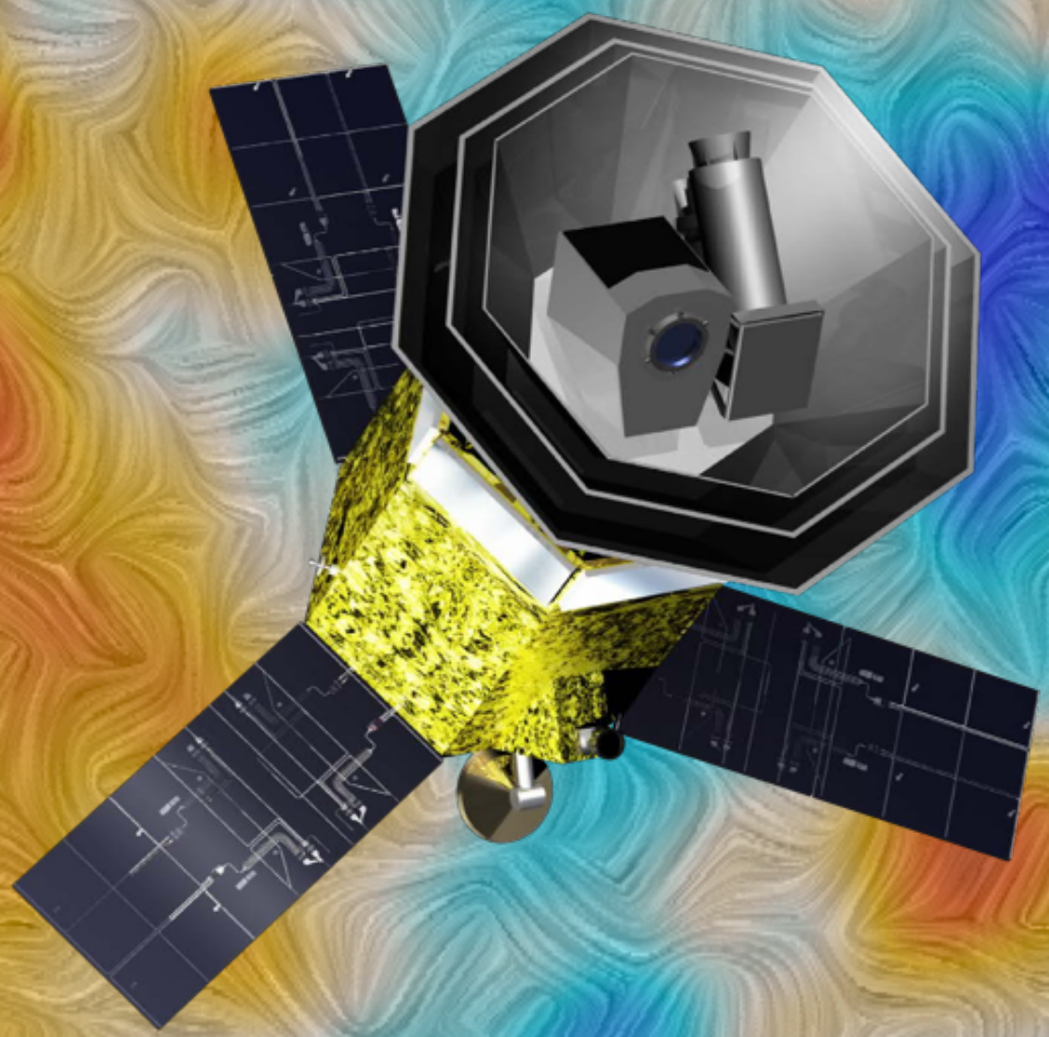
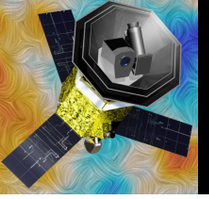


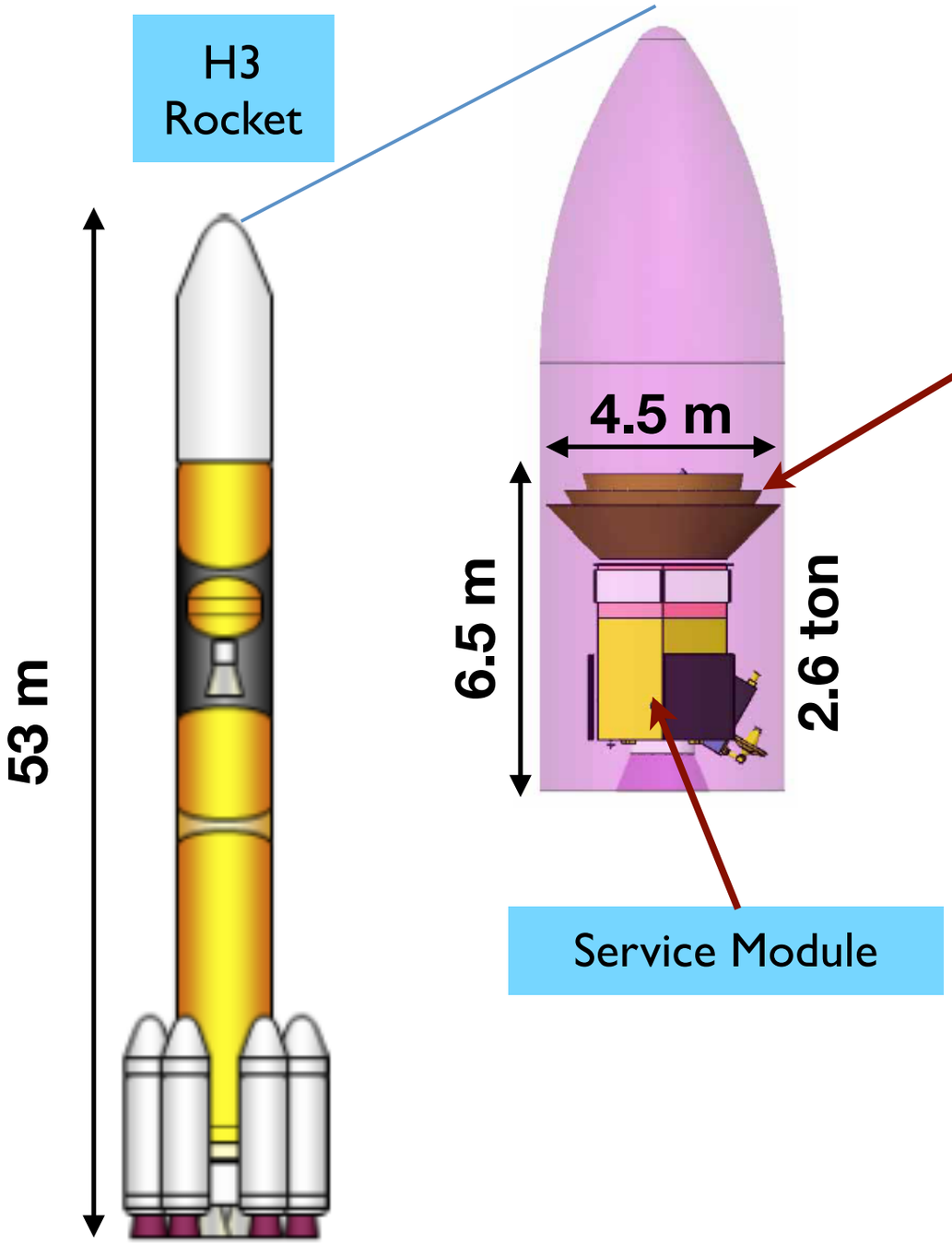
LiteBIRD MHFT Overview

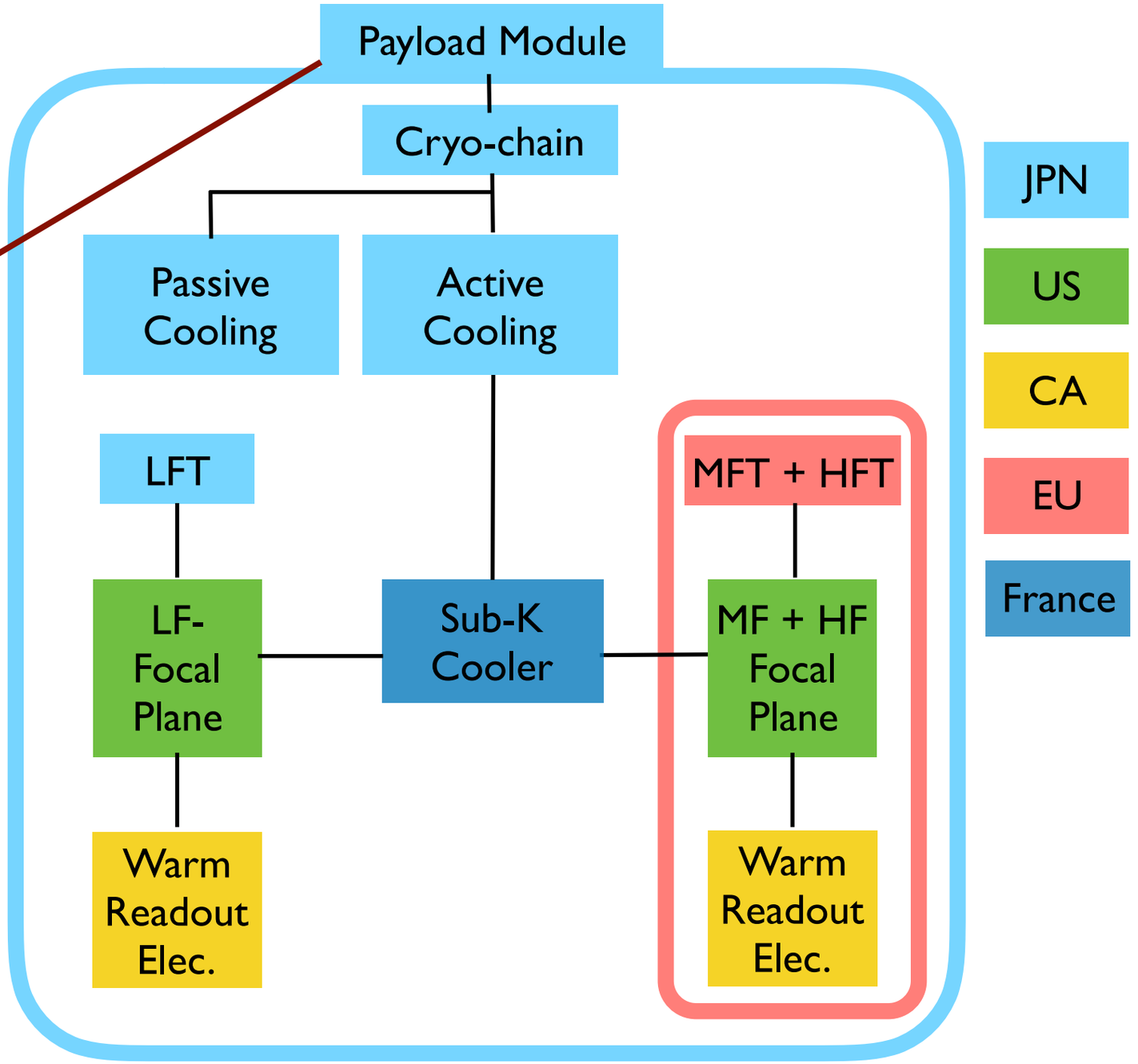
B. Mot
on behalf of LiteBIRD-FRANCE



LiteBIRD Mission

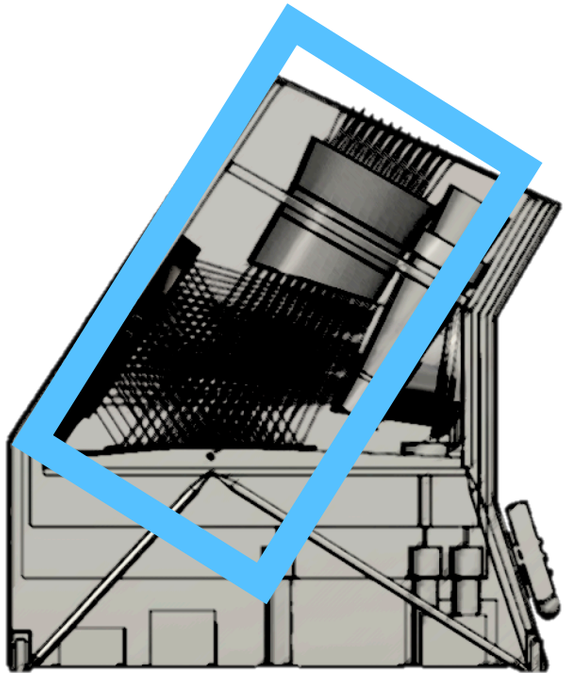
Payload



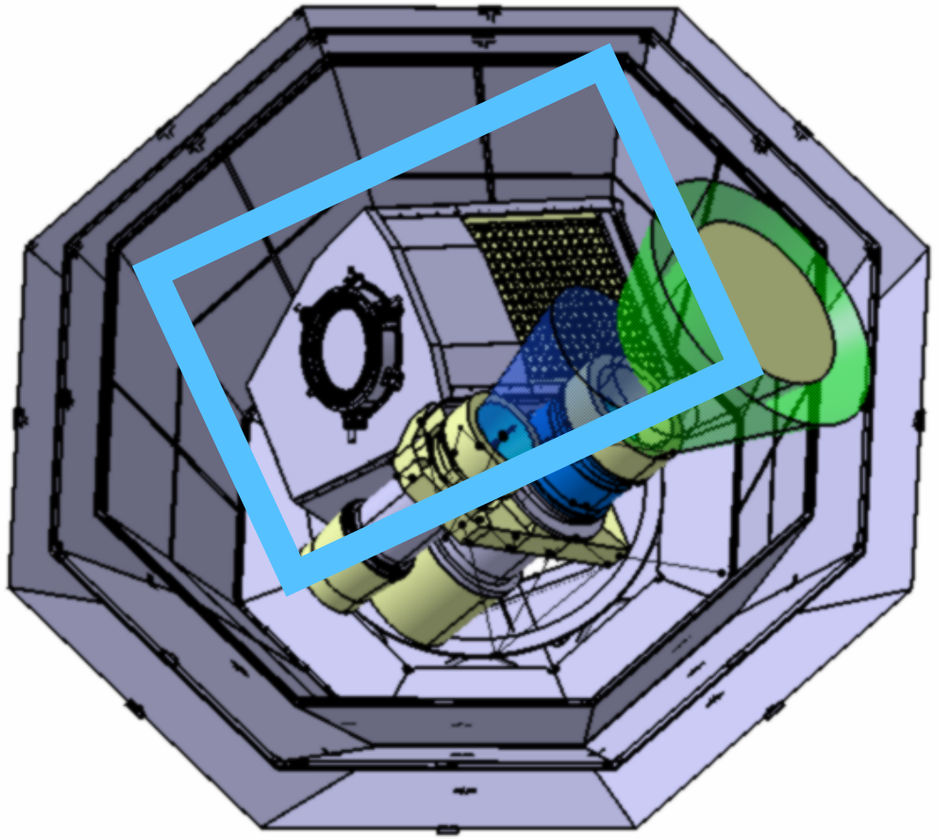


Instrumental design

LFT, HFT & MFT Baseline



2017



2019

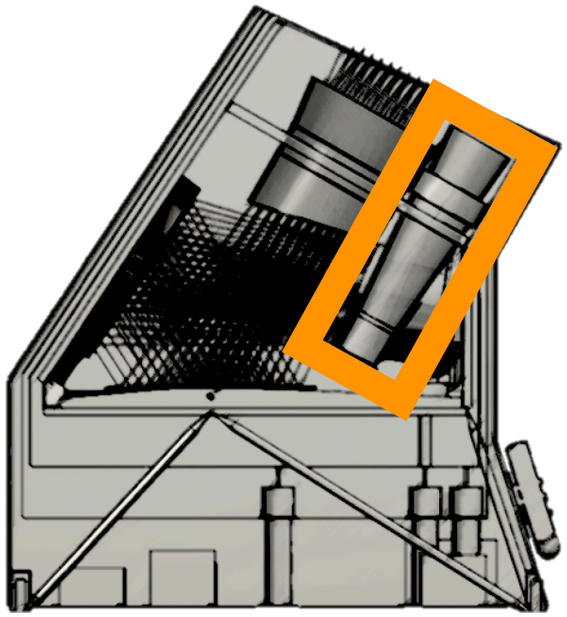
Main evolutions on LFT during last 2 years

- 34 - 270 GHz
- 12 Channels
- 2238 detectors

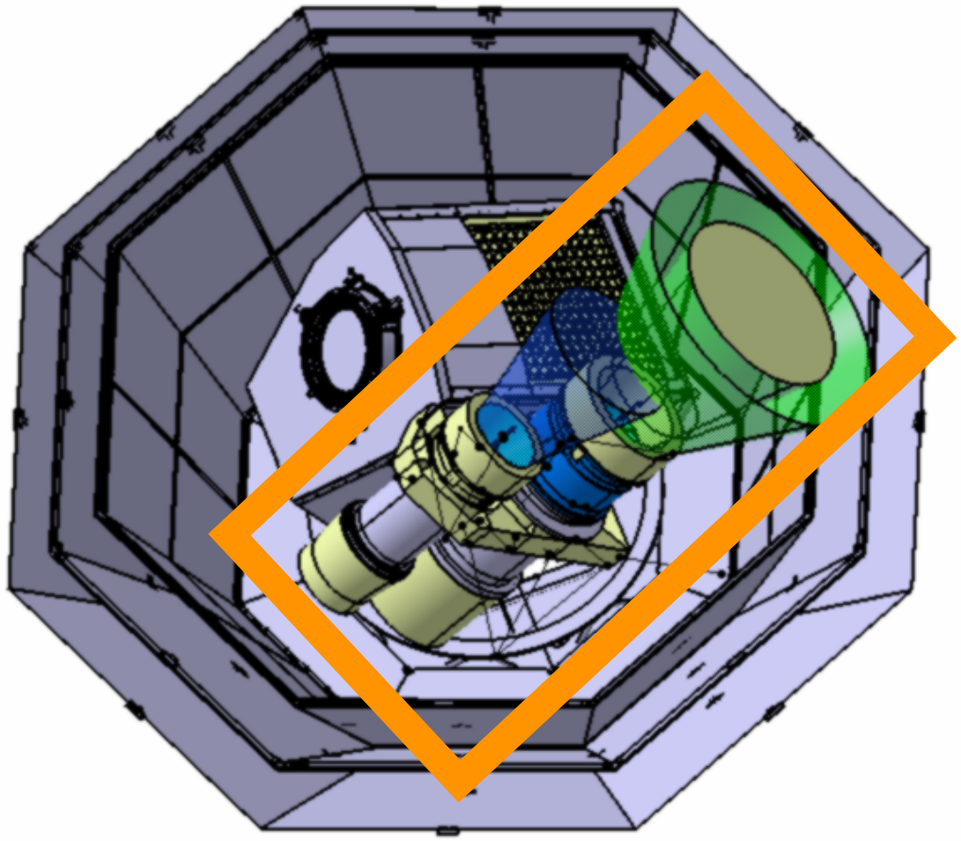
- 34 - 161 GHz
- 9 Channels
- 1248 detectors

Instrumental design

LFT, HFT & MFT Baseline



2017



2019

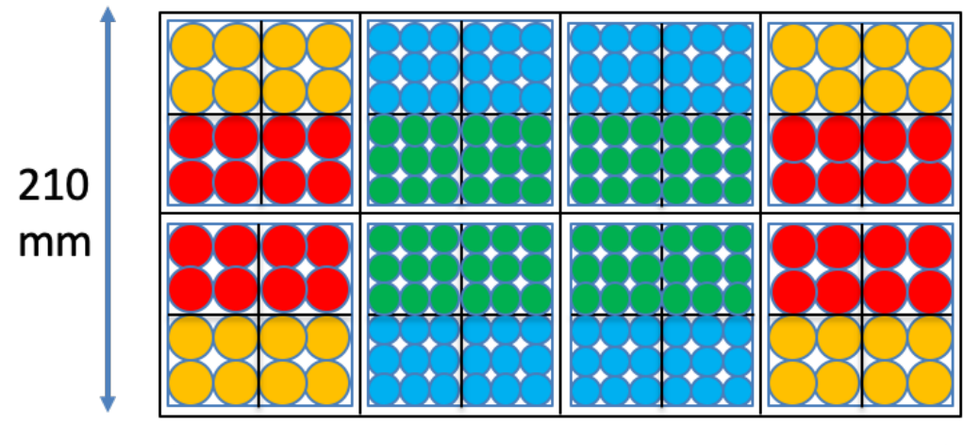
Main evolutions on HFT during last 2 years

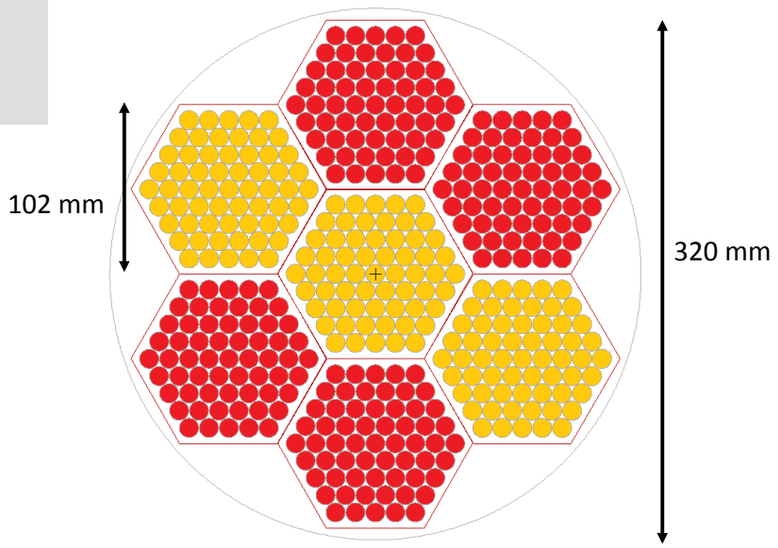
- Single telescope (HFT)
- 238 - 448 GHz
- 3 Channels
- 384 detectors
- 21 kg

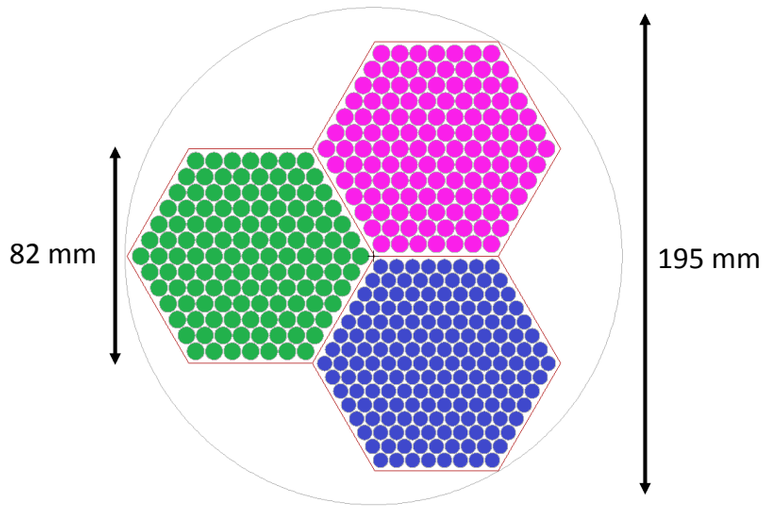
- Two telescopes (M-HFT)
- 89 - 448 GHz
- 5 + 5 channels
- 3428 detectors
- 100 kg

Focal plane configuration

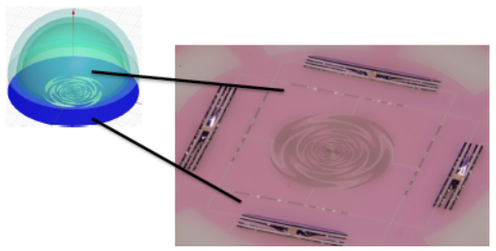
Number of detectors: 4676
Overlap between instruments



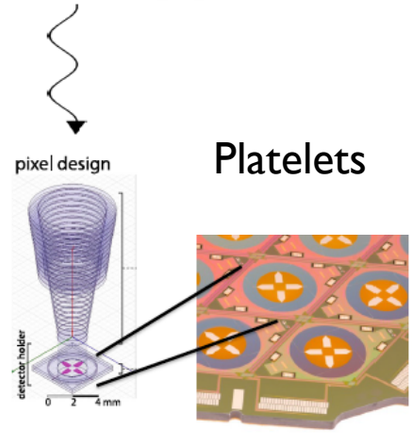




Lenslets



Platelets



89GHz **MFT** (2.5:1) 224 GHz

2074 detectors
366 Trichroic TES
488 Dichroic TES

100 119 140 166 195

LFT (4.7:1)

40 50 60 68 78 89 100 119 140

1248 detectors
2 x (64 + 144) Trichroic TES

34GHz 161 GHz

HFT (2.7:1)

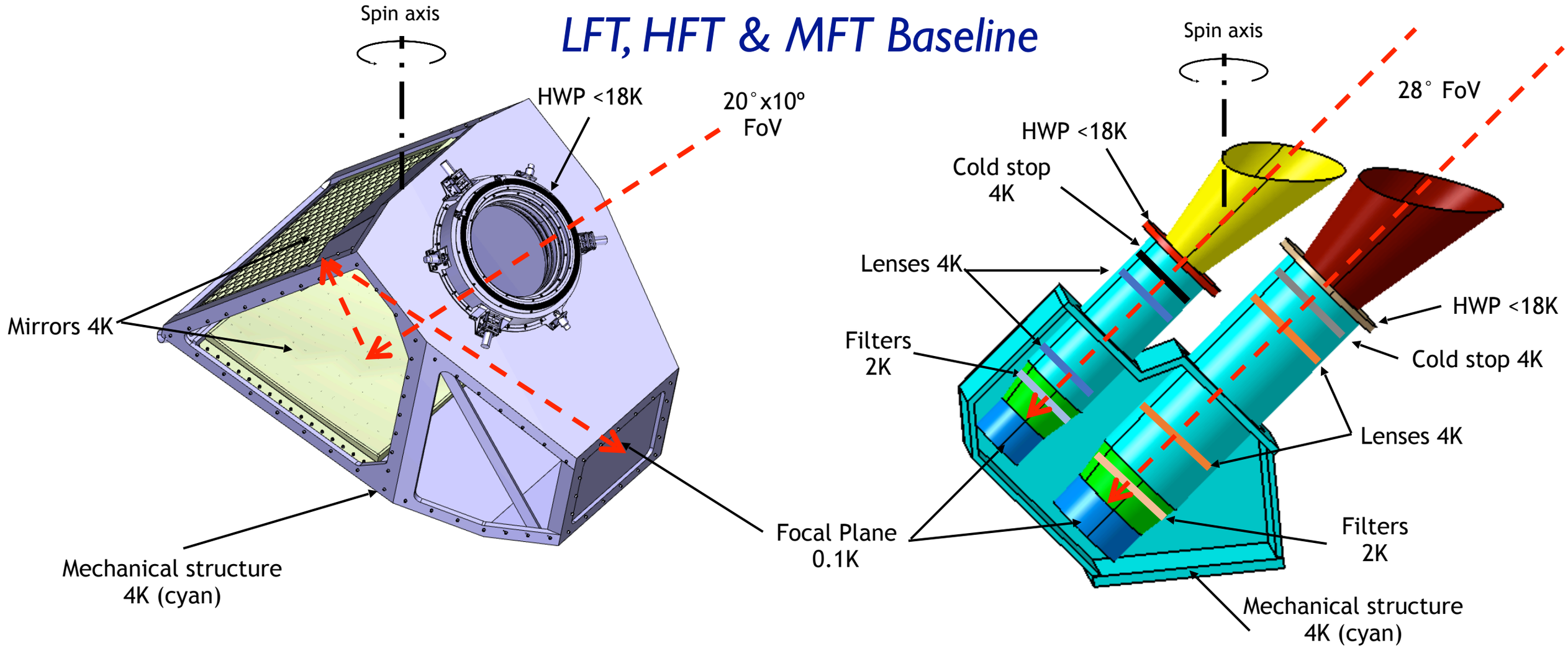
195 235 280 337 402

1354 detectors
2 x 254 Dichroic TES
338 Monochromatic TES

166 GHz 448 GHz

Instrumental design Overview

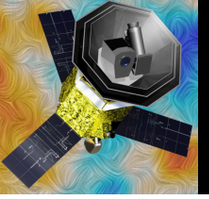
LFT, HFT & MFT Baseline



L-M-HFT concept

- LFT => Crossed Dragone
  - Aperture ø : 400 mm
- MFT => Transmissive
  - Aperture ø : 300 mm
- HFT => Transmissive
  - Aperture ø : 200 mm

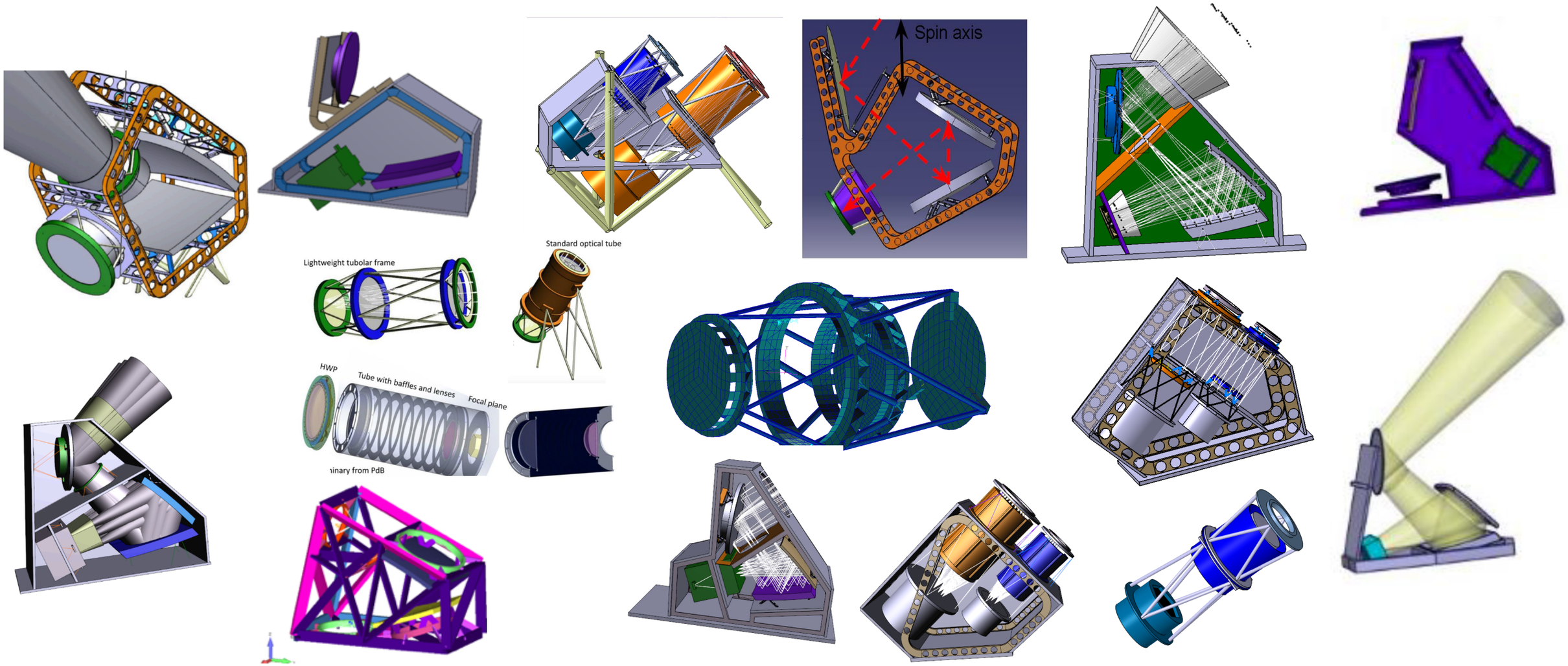
- Continuously rotating HWP
- Cryogenic temperature telescopes 4K
- Focal plane at 100mK



ESA CDF for MHFT

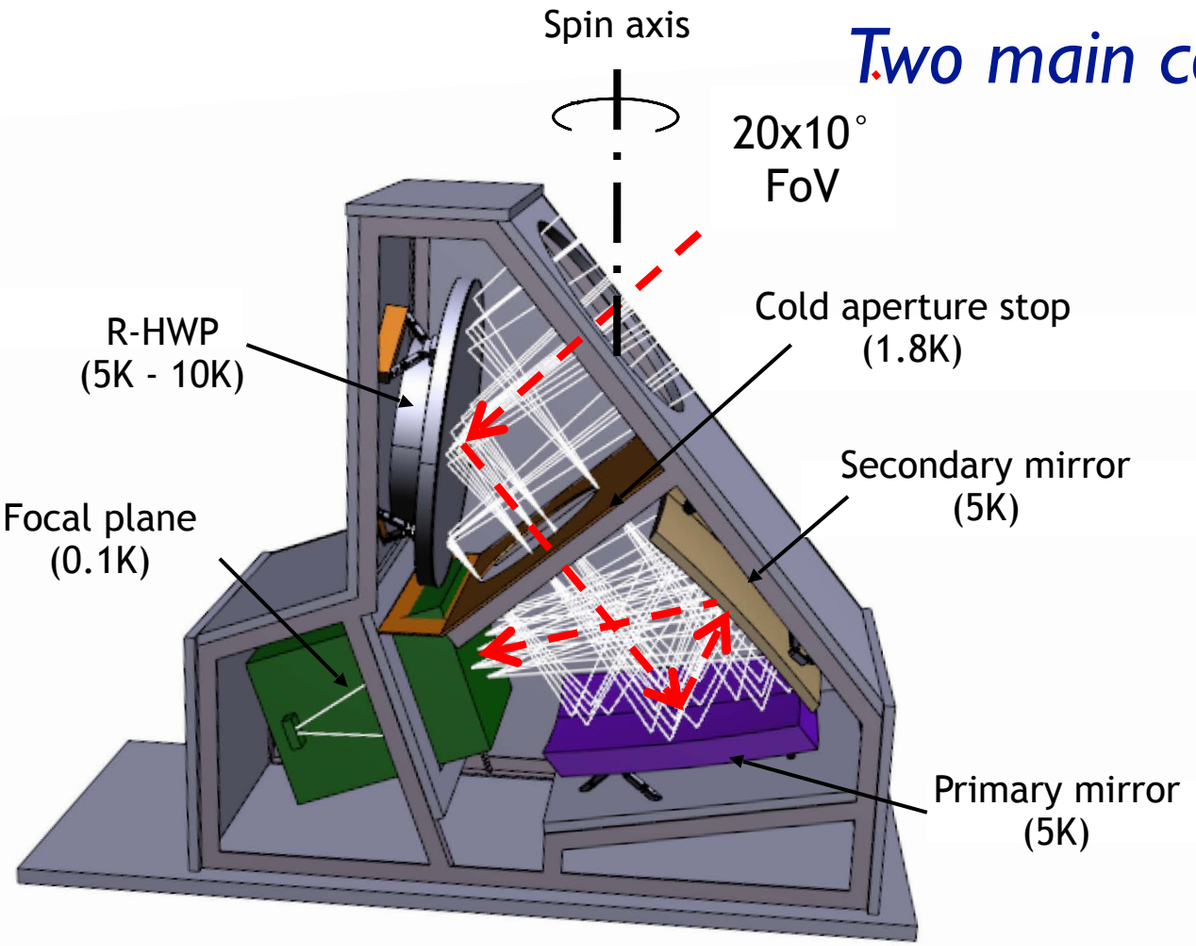
Few iterations in a few months and trade off analysis last year

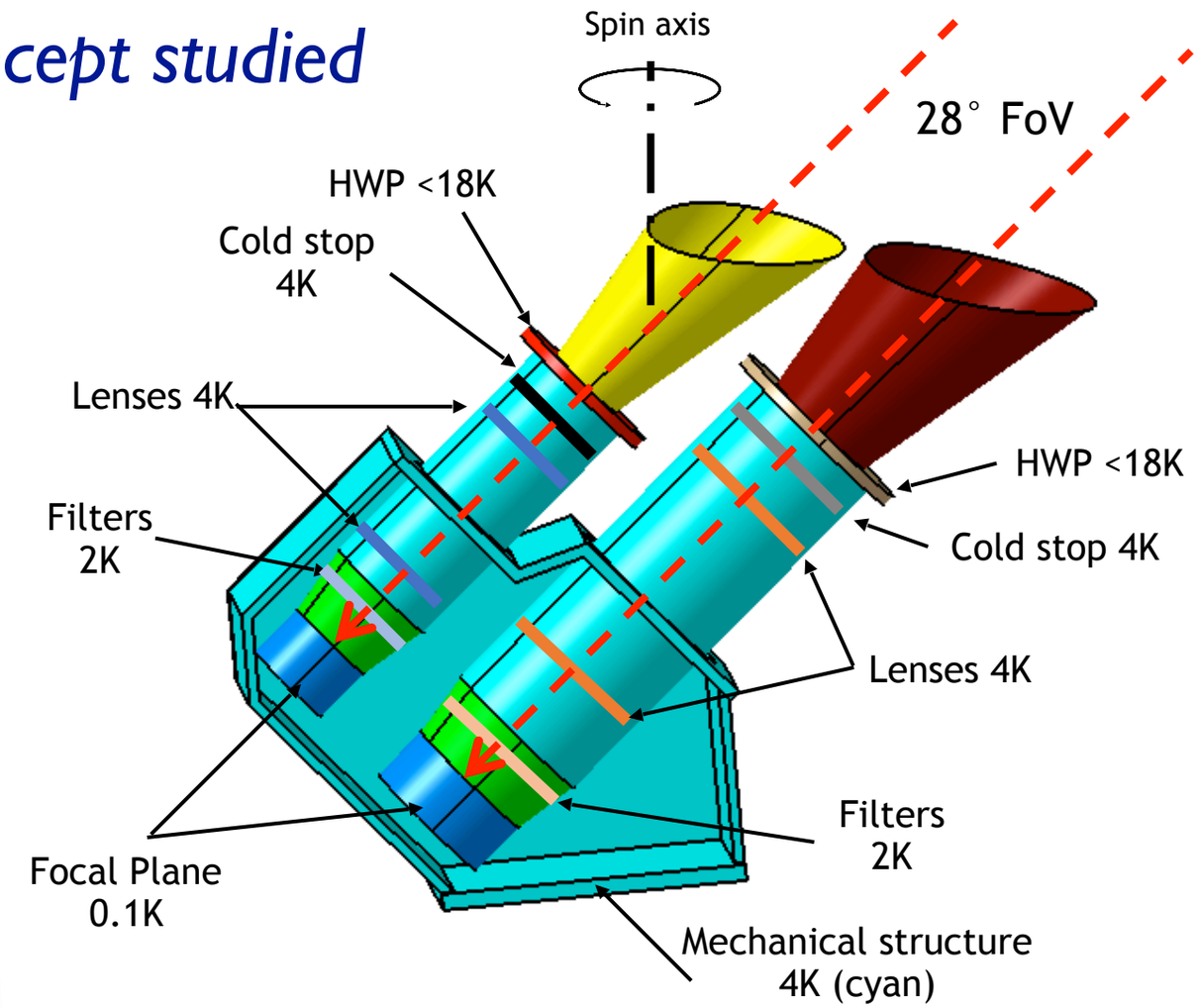
	Assumptions
1	HFT Frequency coverage: 9 bands from 89GHz to 448GHz
2	HFT resolution: from 10' to 30' maximum
3	HFT Volume: a 1700 x 1400 x 750 mm^3 5K envelope
4	HFT continuously rotating HWP
5	HFT Mass limit: 100kg (margins included)
6	Sub-K cooler: 100mK stage common to LFT and HFT



MHFT Instrumental design

Two main concept studied





Fully reflective

- Crossed Dragone telescope - F/3.5
- Frequency coverage: 89 - 448 GHz
- Continuous rotating HWP mechanism
  - Reflective Embedded Metal-mesh HWP tilted at 45°
- **Alternative design since end 2018**

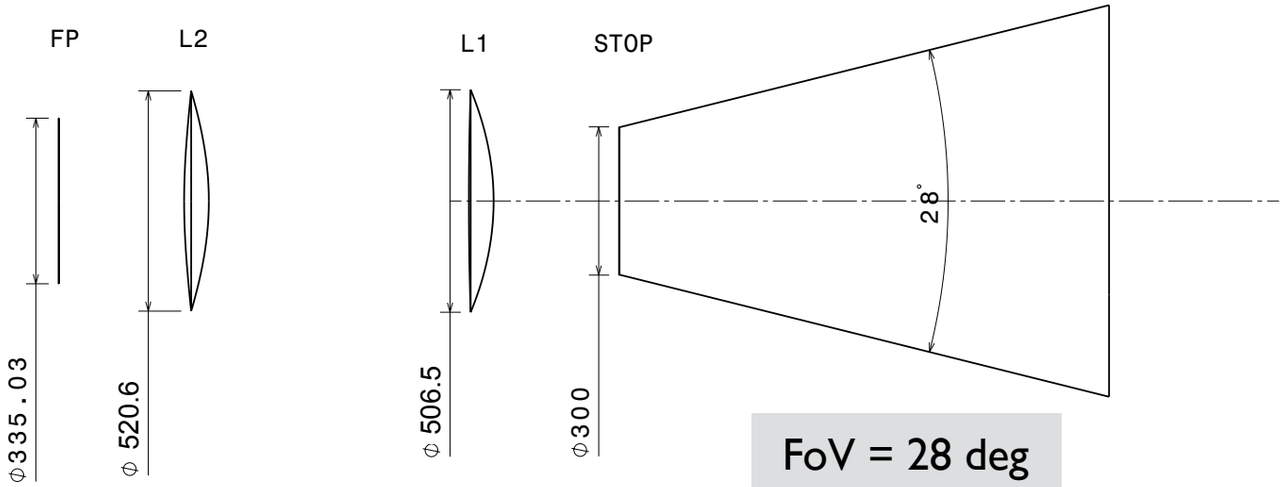
Fully transmissive

- Two telescopes - F/2.2
  - MFT: 89 - 224 GHz
  - HFT: 166 - 448 GHz
- HDPE lenses
- Continuous rotating HWP mechanism
  - Transmissive Metal-mesh HWP
- **Baseline since end 2018**

MHFT Optical Design

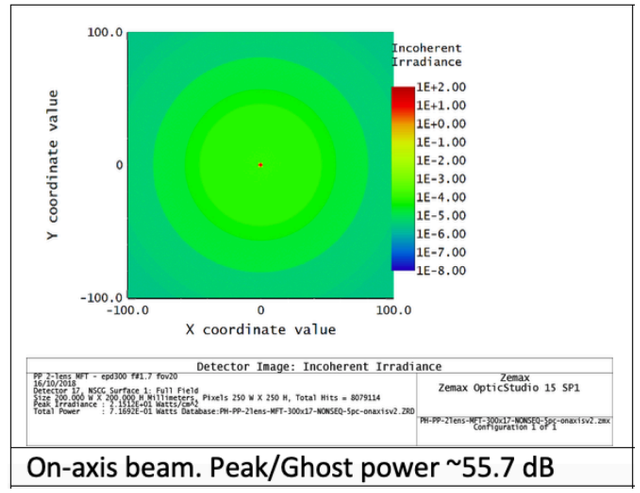
Pete

MFT | D_CS = 300mm, D_FP = 340mm



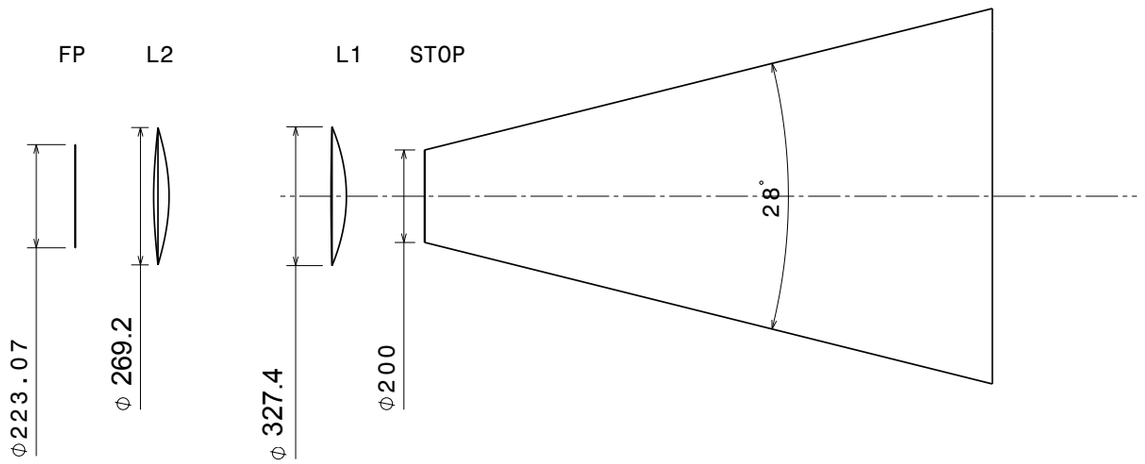
F2.2

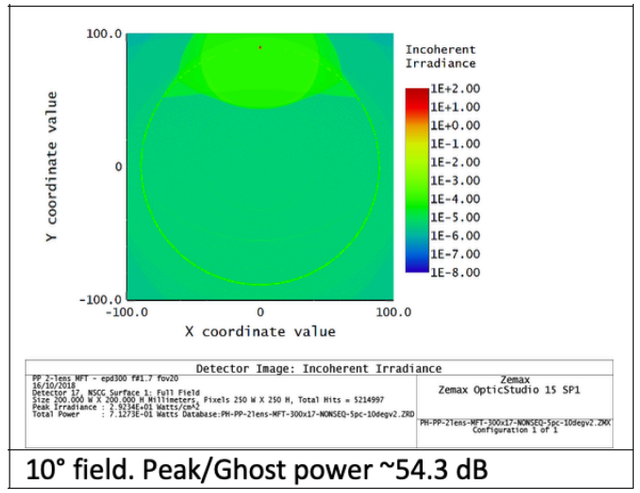
FoV = 28 deg



On-axis beam. Peak/Ghost power ~55.7 dB

HFT | D_CS = 200mm, D_FP = 220mm

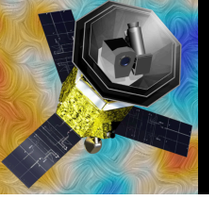




10° field. Peak/Ghost power ~54.3 dB

- Two refractive telescopes
- Optics
  - HDPE lenses
  - P-PTFE ARC

=> Diffraction limited @ 750μm across the whole FoV
=> Peak vs Ghost power ratio always < 54 DB



MHFT Optical Tolerancing table

What kind of shift implies to drop the Strehl ratio to 0.907?

Mean Strehl = 0.988 across the FoV

To keep the Strehl ratio > 0.907:
=> +/- 20 mm on lenses position
=> +/- 5º on tilt angle
=> +/- 11 mm on FP position

=> No strong constraint on the Optical alignment

	Bounds	270 GHz mean Strehl reduction	270 GHz mean Strehl
Stop: shift along axis	-18.36 / + 18.23 mm	0.018/0.018	0.970
L1 (primary): Surf 1 ROC	-1.1/1.5%	0.018/0.018	0.970
L1 (primary): shift along axis	± 20 mm	0.004/0.004	0.984
L1 (primary): XY translation	± 5 mm	0.001/0.001	0.987
L1 (primary): rotation	-4.37/4.16 deg	0.018/0.018	0.970
L1 (primary) index (nom. n=1.52)	-0.008/0.008 (~0.5%)	0.018/0.018	0.970
L2 (secondary): ROC (surf1)	± 1.5%	0.001	0.987
L2 (secondary): ROC (surf2)	± 1.5%	< 0.001	0.988
L2 (secondary): shift along axis	± 20 mm	0.005/0.005	0.983
L2 (secondary): XY translation	± 5 mm	0.001	0.987
L2 (secondary): rotation	± 5 deg	0.006/0.004	0.983
L2 (secondary) index (nom. n=1.52)	-0.177/0.120 (~10%)	0.018/0.018	0.970
Focal plane: shift along axis	-11.3 / + 11.1 mm	0.018/0.018	0.970

	Bounds	270 GHz mean Strehl reduction	270 GHz mean Strehl
Stop: shift along axis	-18.36 / + 18.23 mm	0.018/0.018	0.970
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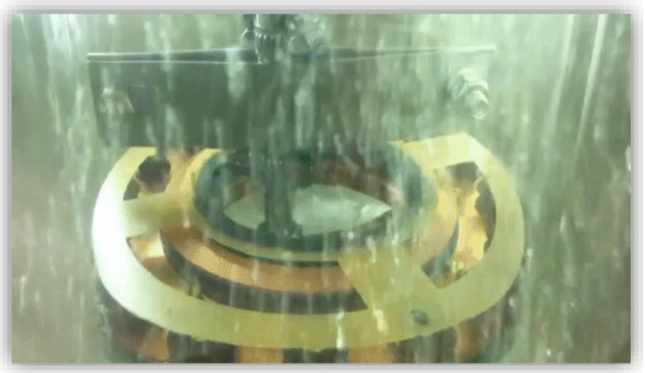
Focal plane: shift along axis	-11.3 / + 11.1 mm	0.018/0.018	0.970

HWP Rotating Mechanism

Magnetic sustentation for continuously rotating HWP

France

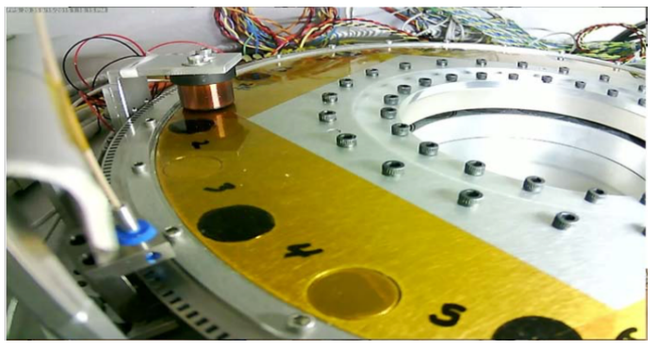
Development already started for BSIDE



HWPM Prototype tested:
- 70mm diameter
- T = 4K in 4He vapours
- freq = 2Hz
- tilt angle up to 30°

Italy

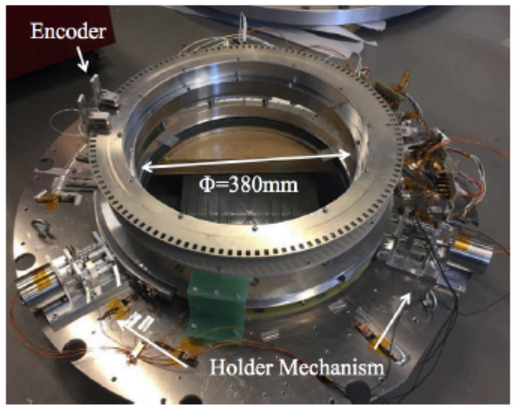
Development started for LSPE



Gripper Prototype tested:
- 100mm diameter
- T = 4K
- freq = <3Hz
- tilt angle up to 5°

Japan

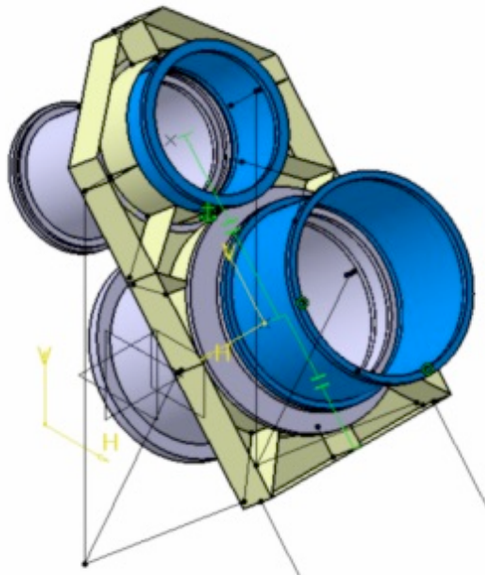
Development started for LiteBIRD/LFT

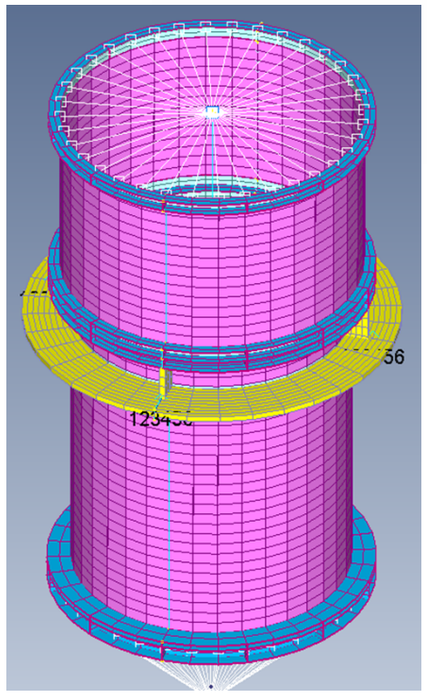


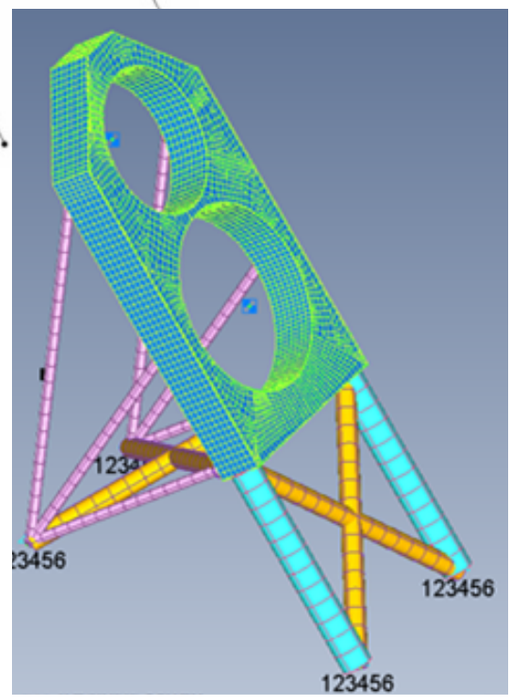
HWPM Prototype tested:
- 380mm diameter
- T = 4K
- freq = few Hz
- Gripper implemented

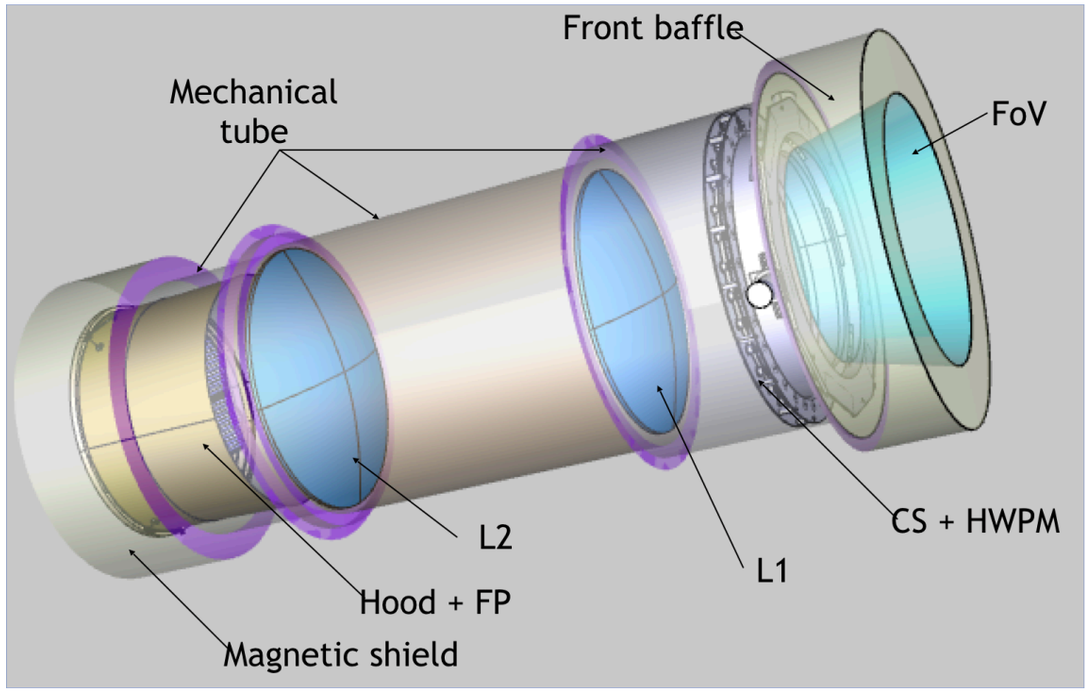
- Continuous modulation of the sky polarization signal
  => Reduces the 1/f noise
  => Mitigates the “differential systematics”
- Minimisation of the HWP temperature variation during observations
- Reduce the risk on this single point failure system

MHFT Mechanical structure





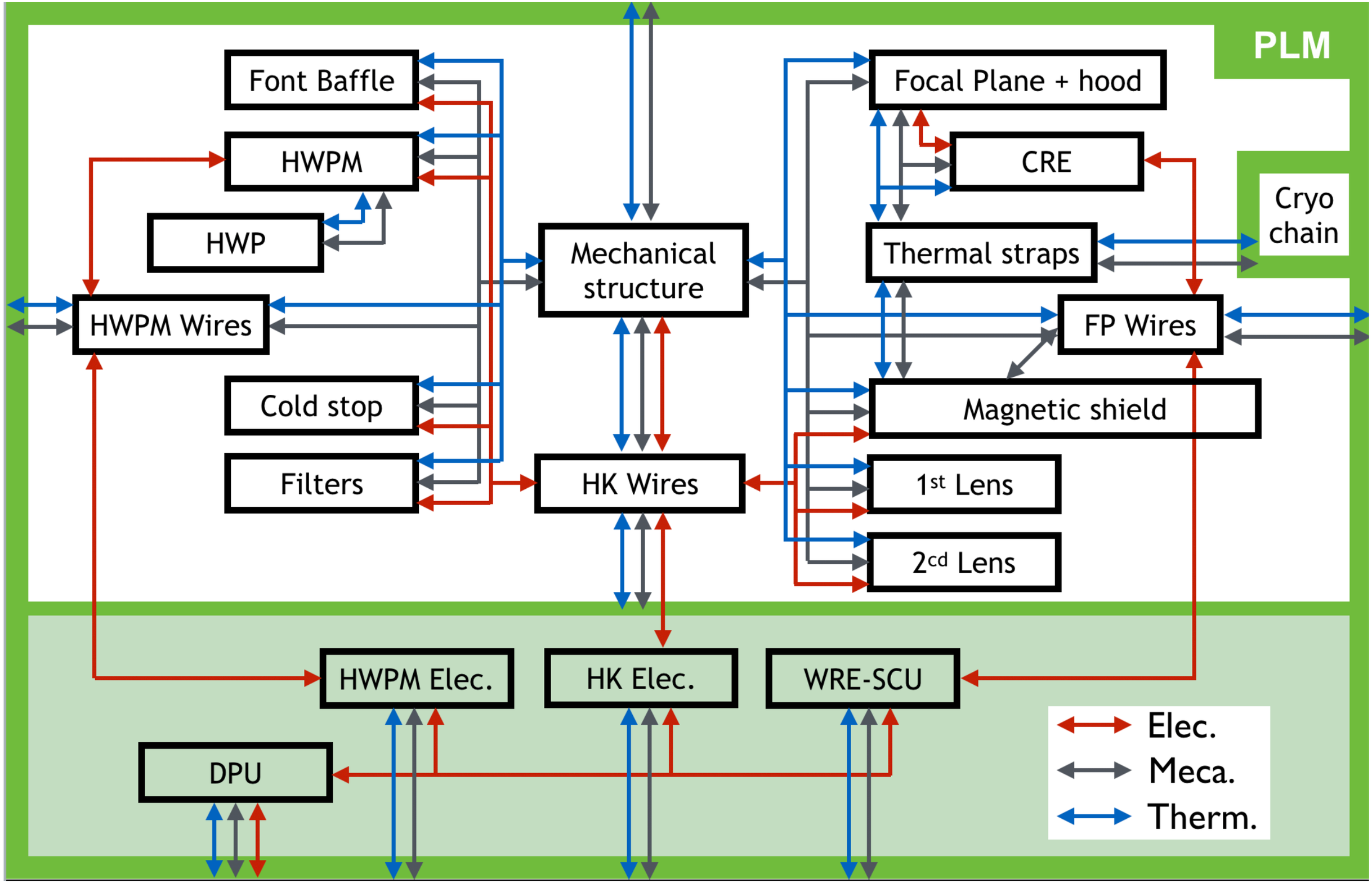




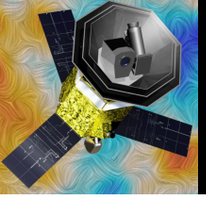
- No strong constraint on the Optical alignment
- The total mass and eigen frequency are the drivers on the mechanical structure design

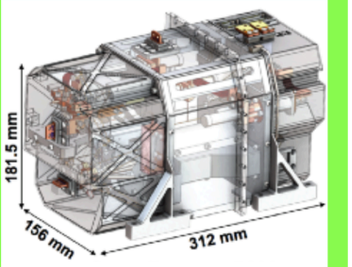
	MFT	HFT
Total mass	100 kg	
Eigen freq	Lateral: 51Hz Longitudinal: 113Hz	
Total enveloppe	1700 x 1400 x 750 mm	
Tubes length	1539 mm (1027 mm w/o front baffle)	1186 mm (1369 mm w/o front baffle)
Tubes diameter	560 mm	480 mm

MHFT Interfaces

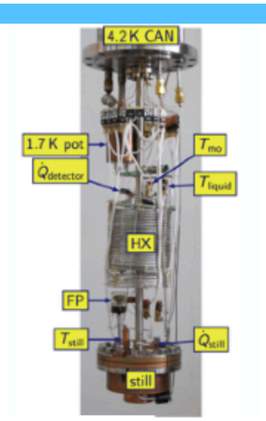


Cryo-chain

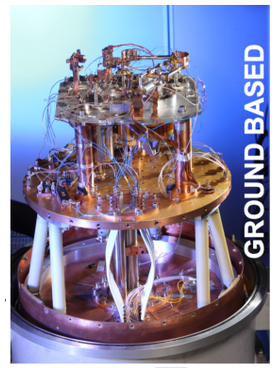




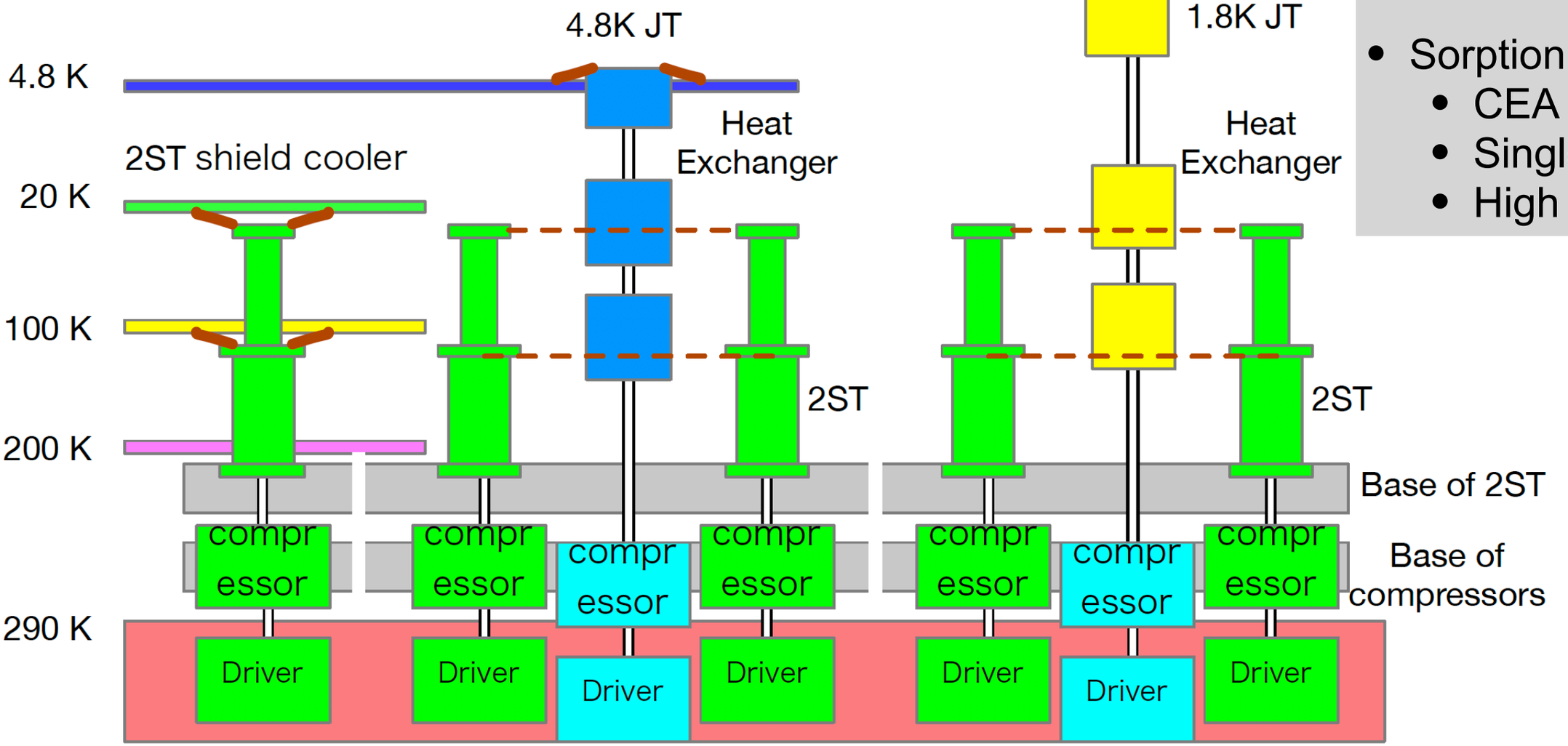
ADR-sorption Hybrid cooler



CCDR



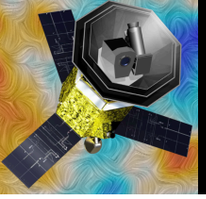
CADR

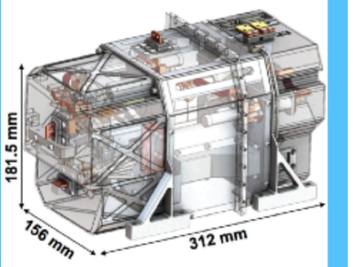


2017

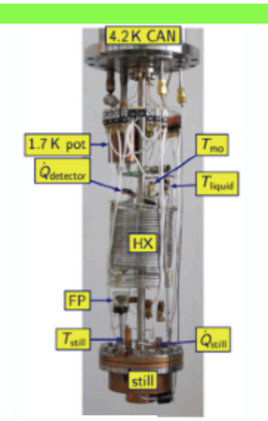
- 2ST shield cooler
  - JAXA
- 2K JT
  - JAXA
  - High cooling power
- Sorption Hybrid Cooler
  - CEA
  - Single shoot
  - High TRL

Cryo-chain

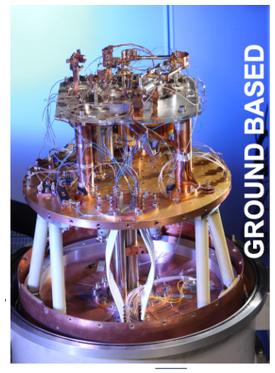




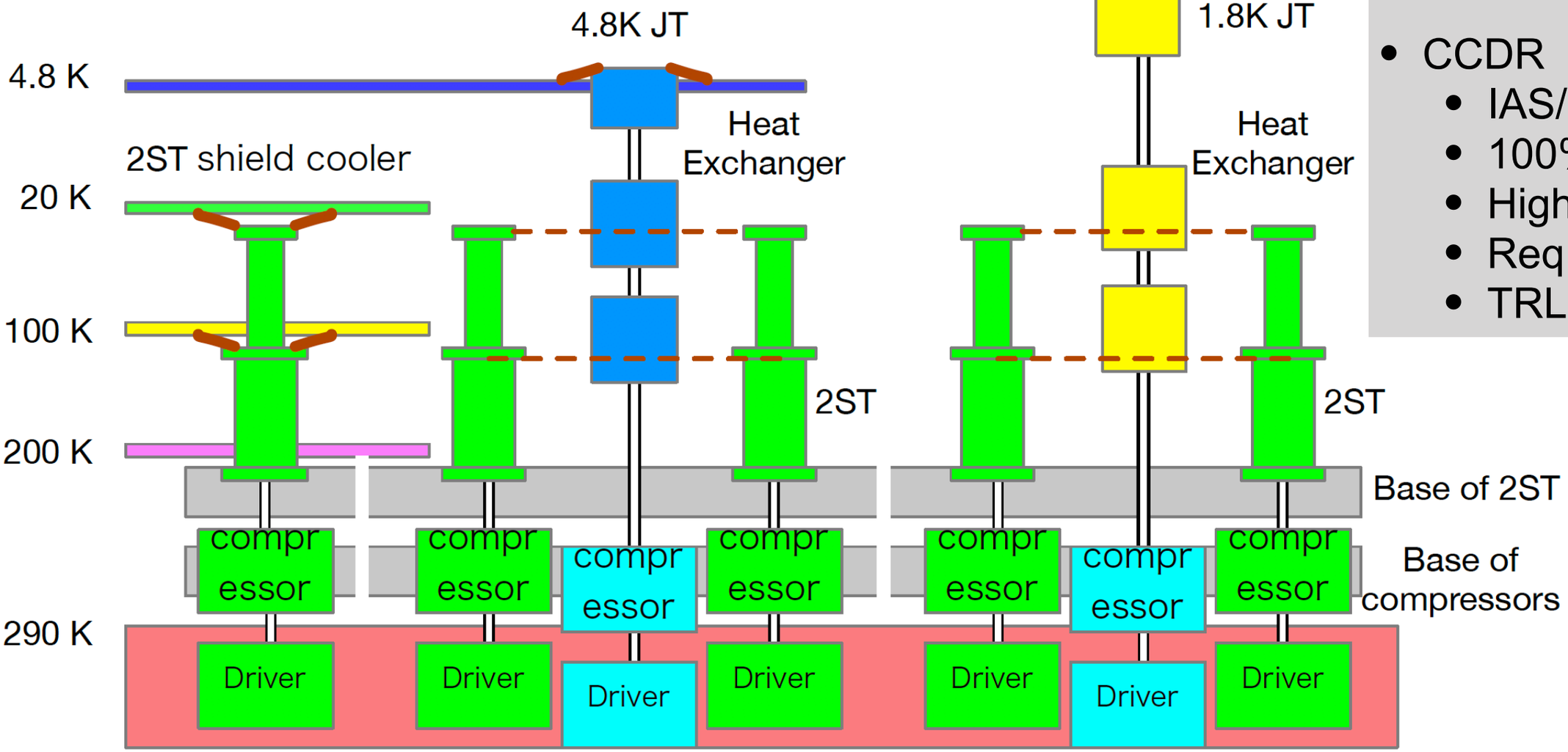
ADR-sorption
Hybrid cooler



CCDR



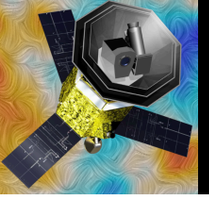
CADR

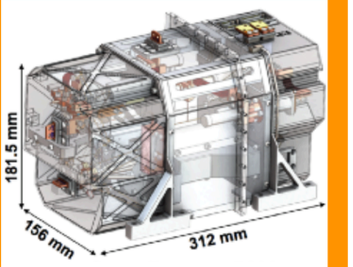


2018

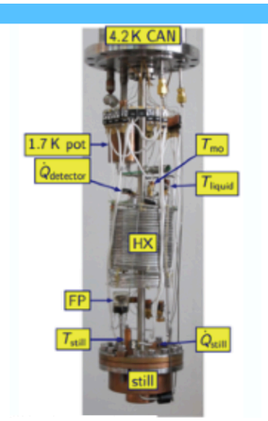
- 2 ST shield cooler
  - JAXA
- 2K JT
  - JAXA
  - High cooling power
- CCDR
  - IAS/NEEL
  - 100% duty cycle
  - High cooling power
  - Req. base <1.75K
  - TRL 3-4

Cryo-chain

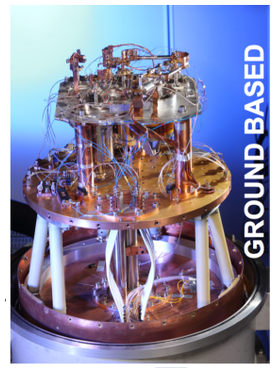




ADR-sorption
Hybrid cooler



CCDR



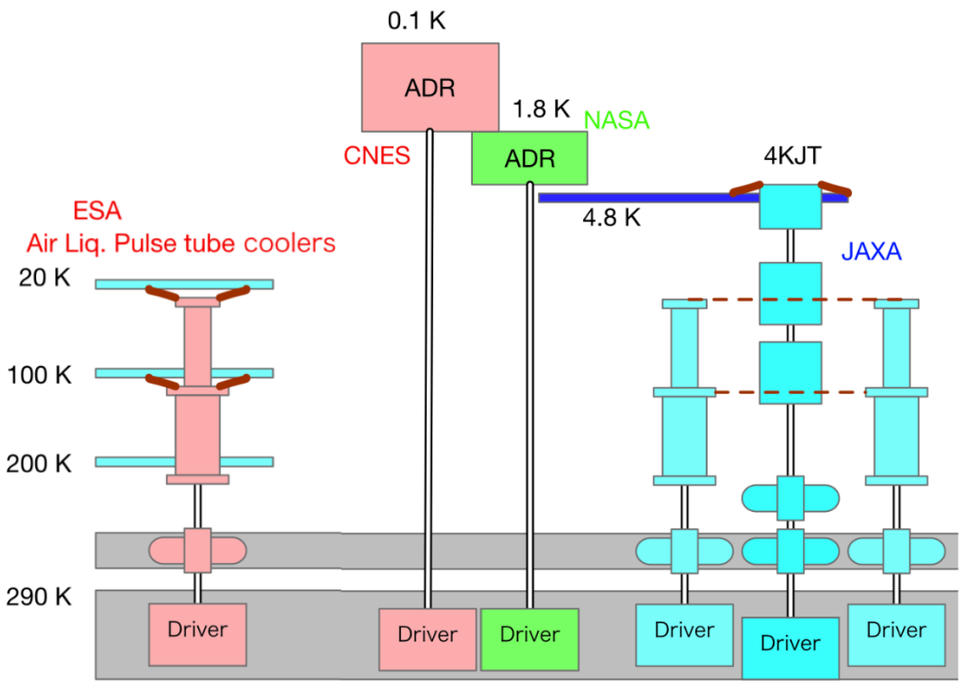
CADR

2019

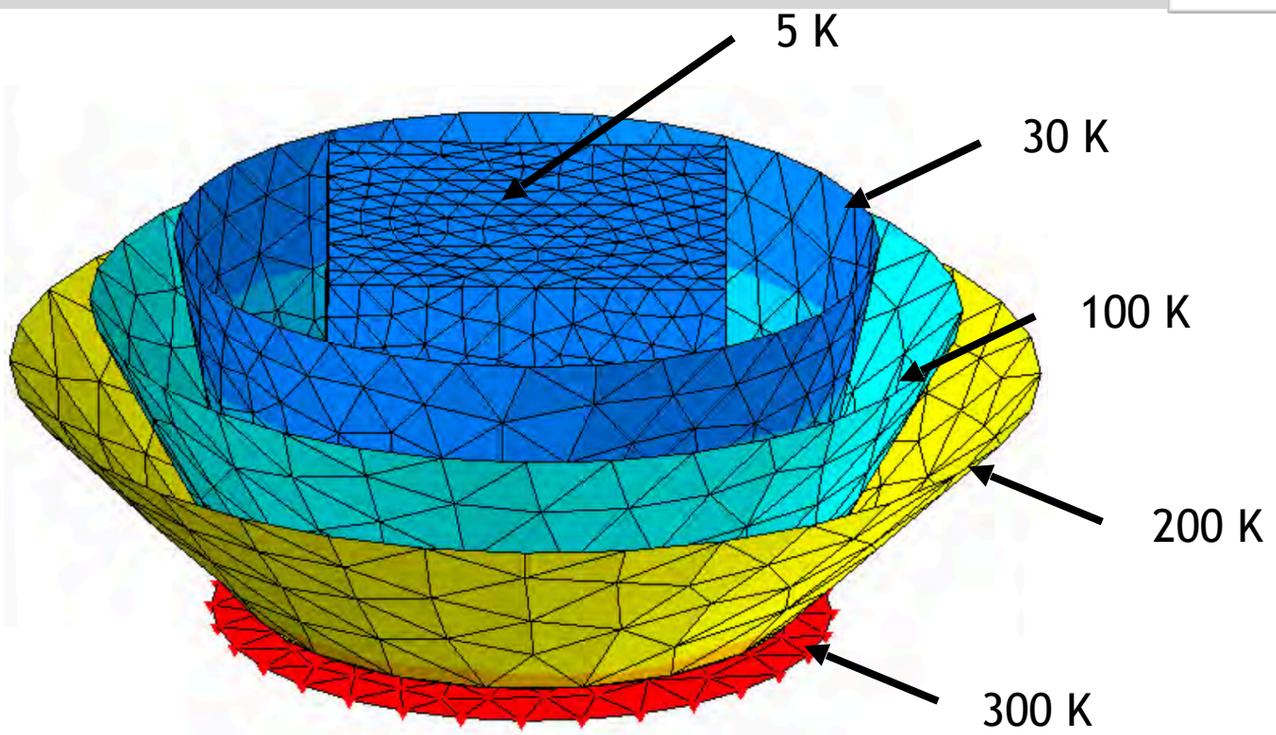
- 20K PT shield cooler
  - ESA
- 2KJT => Removed
  - JAXA Cost saving
- 2K CADR
  - NASA
  - 3 stages ADR
  - Limited cooling power
  - High TRL
- 0.1 CADR
  - CEA
  - 4 stages ADR
  - 100% duty cycle
  - TRL 5 to 9

Cryo-chain Overview

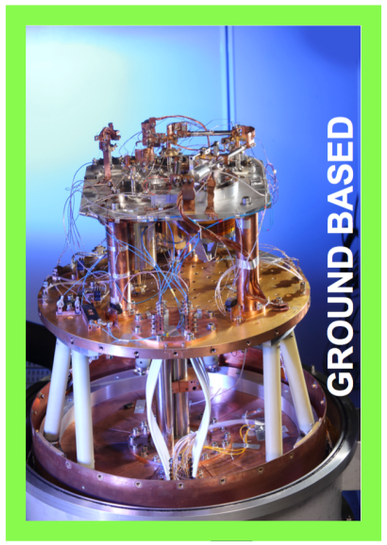
Cryo-chain



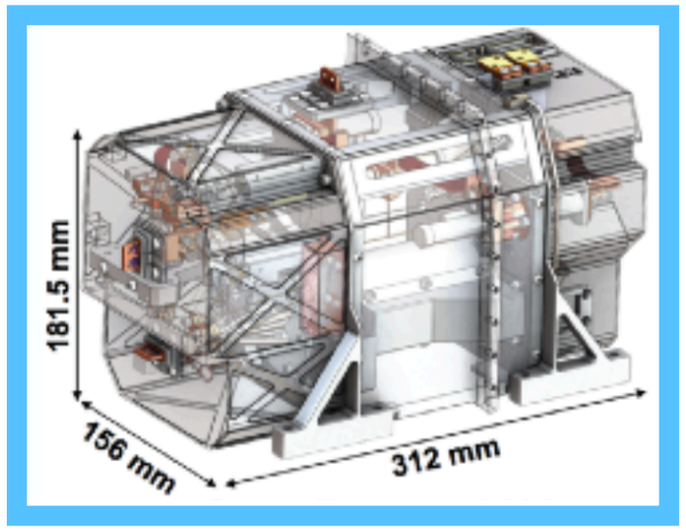
V-Grooves / Thermal shields



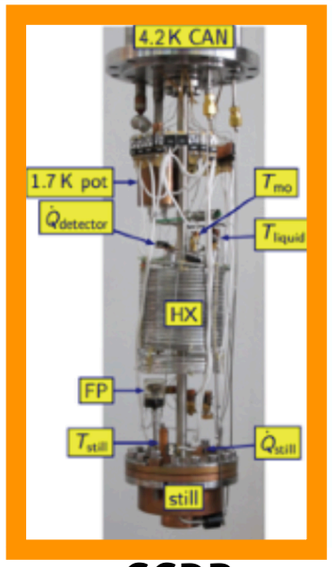
Sub-Kelvin cooler - 100 mK



CADR



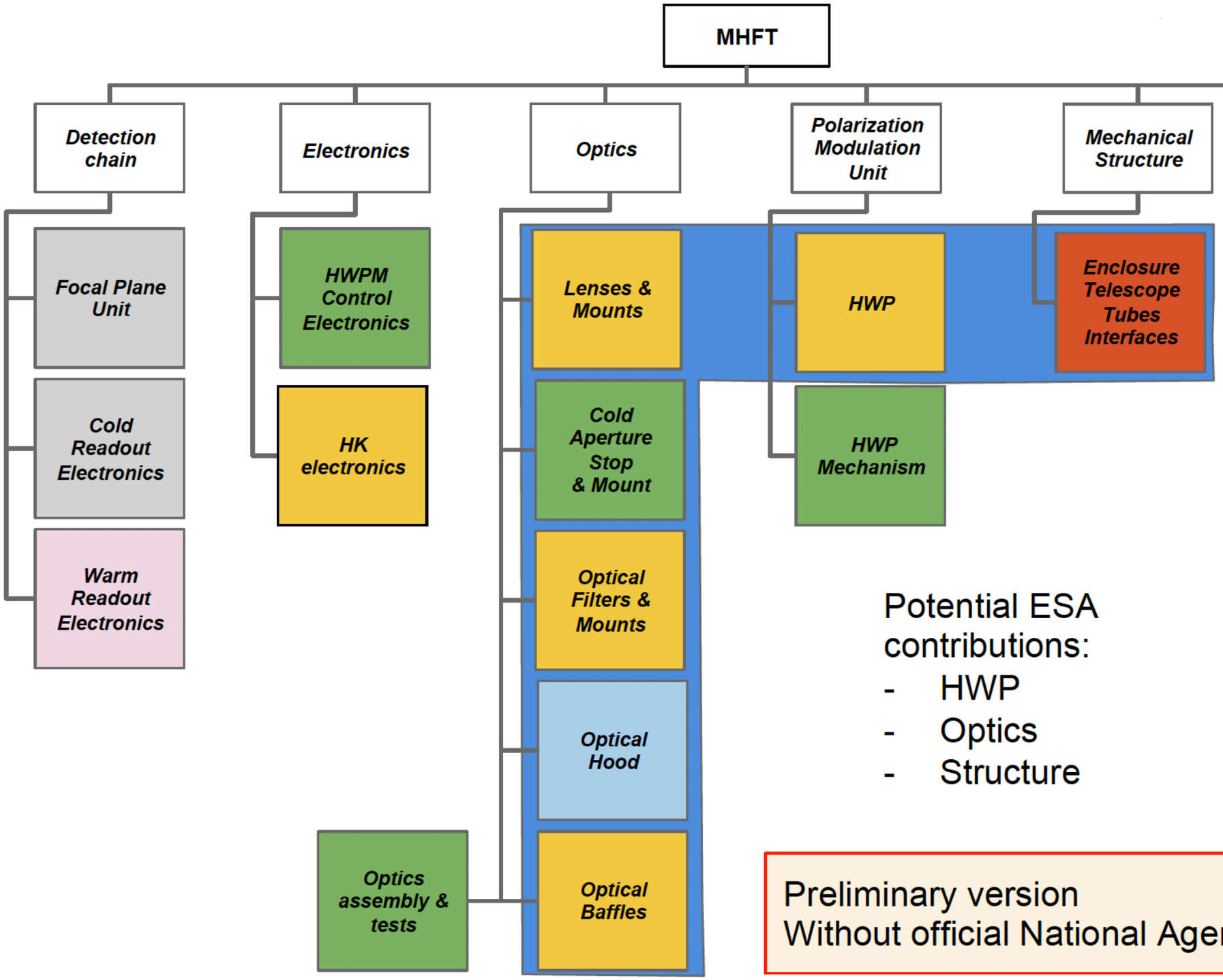
ADR-sorption Hybrid cooler



CCDR

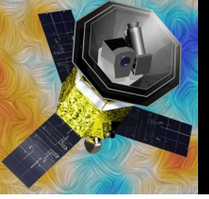
MHFT Task Sharing

LiteBIRD-Europe Task-Sharing



Potential ESA contributions:
- HWP
- Optics
- Structure

Preliminary version
Without official National Agencies commitment



LiteBIRD Mission

LiteBIRD Main properties

	Low Frequency Telescope (LFT)	Mid and High Frequency Telescope (MFT & HFT)
Frequency	34 ~ 161 GHz	89 ~ 448 GHz
field of view	> 20 deg ×10 deg	28 deg
aperture diameter	400 mm	200 mm & 300 mm
angular resolution	20 ~ 70 arcmin	10 ~ 40 arcmin
rotational HWP	88 rpm	~90 - 180 rpm
number of detectors	~1250	~3400
Uncertainty of r	$\delta r < 1 \times 10^{(-3)}$	
Observation period	3 years	
Scan	L2 Lissajous, precession angle 45 deg, spin angle 50 deg (0.05 rpm)	
Sensitivity	< 3 μK·arcmin	
pointing knowledge	< 3 arcmin	
focal plane array	bath temperature 100 mK	
	NET^{P}array = 1.7 μK√s@ 100 mK	
	f_{knee} < 20 mHz	
data transfer	7 GByte/day	
mass	2.6 ton	
electrical power	3.0 kW