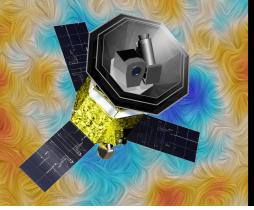


# European Consortium Activities

L. Montier  
on behalf of LiteBIRD-Europe

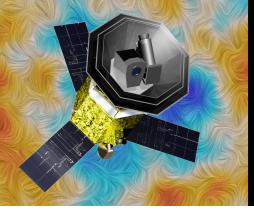


# European Collaboration

## History

- 2015      Official Invitation from ISAS JAXA Director General S.Tsuneta to the European CMB Community
- 2016      JSG contributions as external members
- 2017      Building a European collaboration
- 2018      European collaboration takes lead of the MHFT design
- 2019      Building a European contribution to LiteBIRD with ESA and National Space Agencies (in progress)





# European Collaboration

## *LiteBIRD-Europe*

~100 external members including experts on instrument and data analysis:

### 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)  
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-Institut für  
Astrophysik  
Universitäts-Sternwarte,  
Ludwig-Maximilians-  
Universität München,  
Dr. Karl Remeis-Sternwarte,  
Universität Erlangen-Nürnberg  
RWTH Aachen Universität  
Universität Bielefeld  
Universität Göttingen

### 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

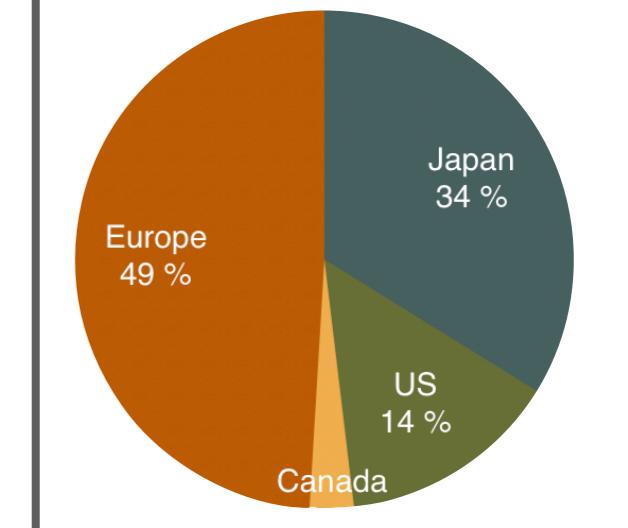
### Sweden

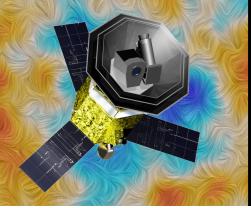
Stockholm University

### Ireland

Maynooth

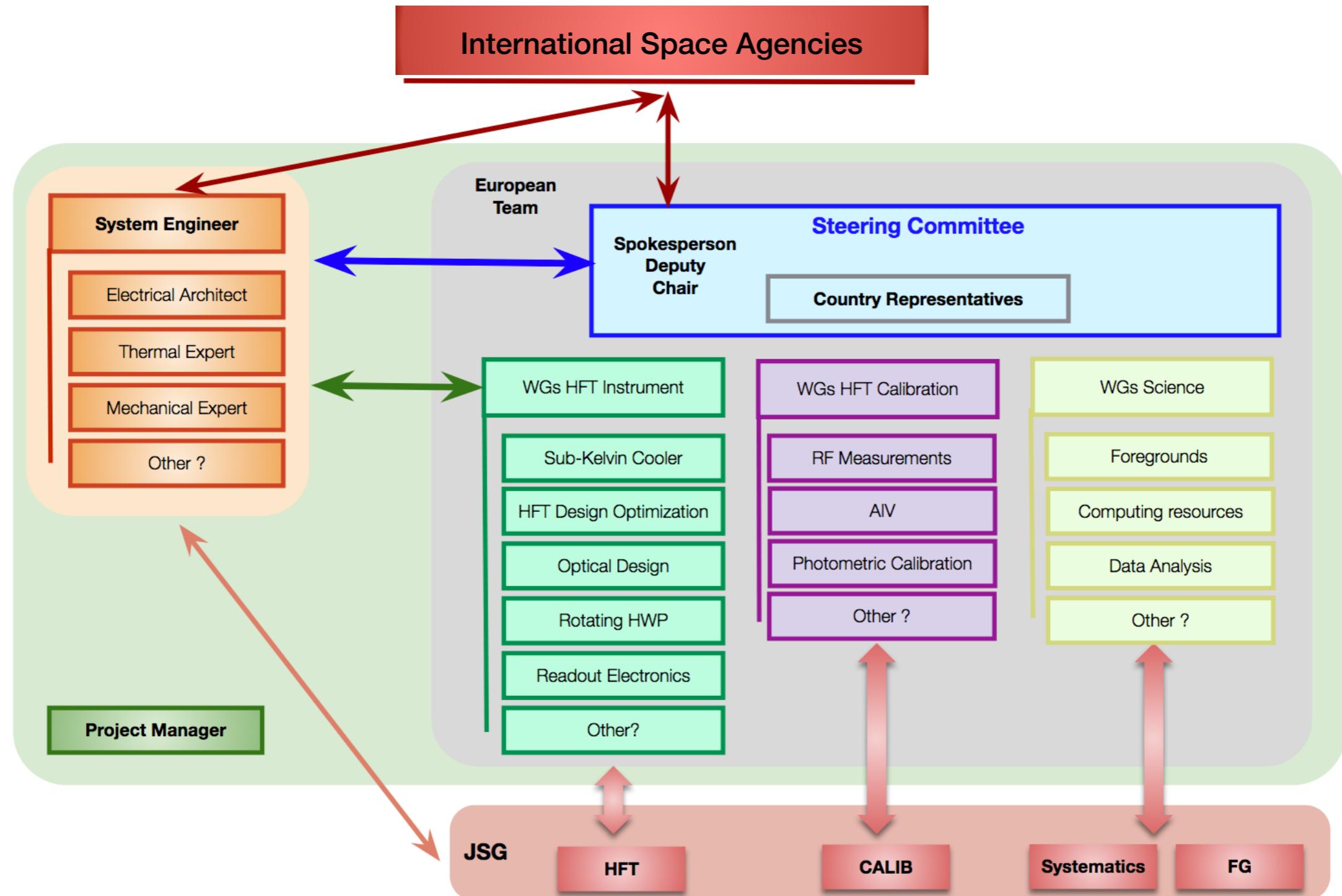
### JSG members

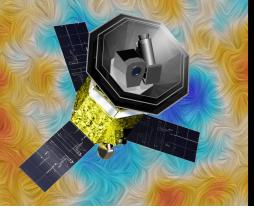




# European Collaboration

## LiteBIRD-Europe





# European Collaboration

## *European Meetings*

08/17: Cardiff

Kick-Off meeting

10/17: Paris

Overview of European Interests & Expertises

02/18: Turin

Settling of European Steering Committee

04/18: Munich

ESA CDF focused analysis

10/18: Toulouse

MHFT Baseline trade-off

11/18: Cardiff

European Task-Sharing + Phase-AI Exit review

01/19: Rome

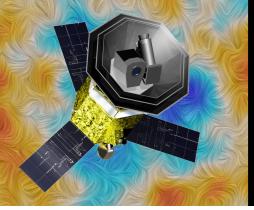
New Baseline Optimisation

04/19: Munich

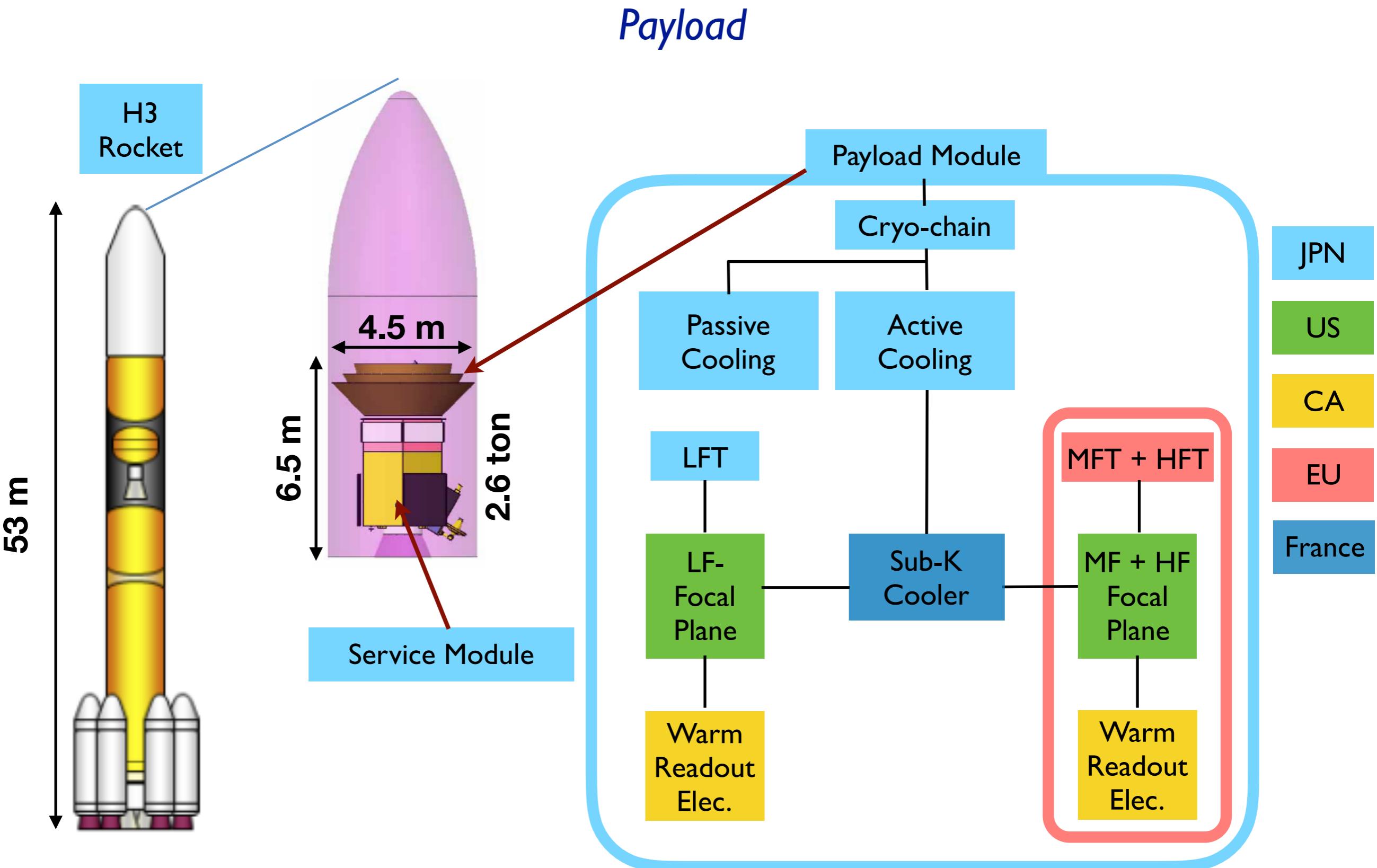
MHFT Interfaces Definition

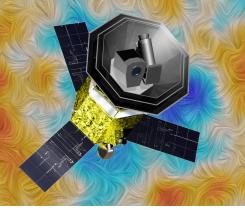
06/19: Toulouse

Instrument Model Object + Data management organisation



# Payload responsibility





# MHFT Instrument

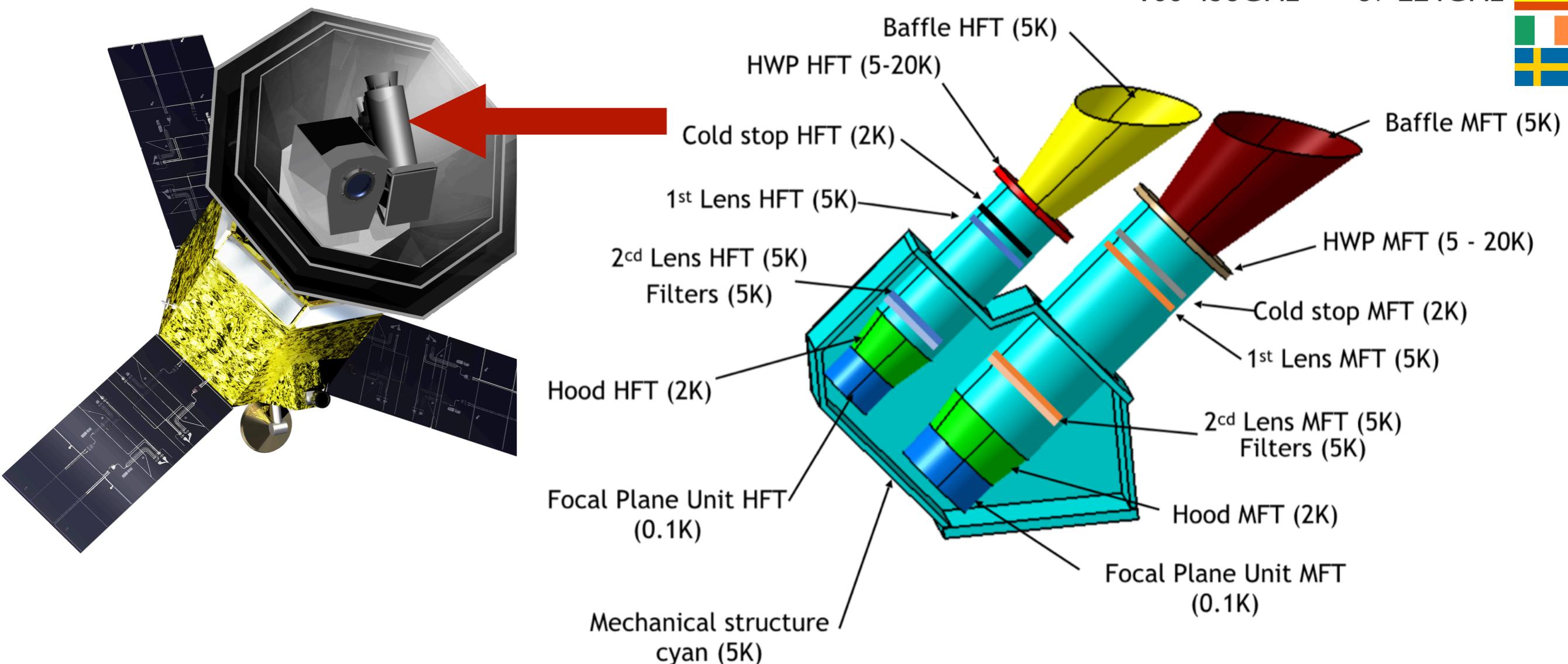
## Design Overview

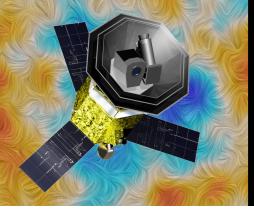
Refractive option has been adopted as a baseline



HFT + MFT

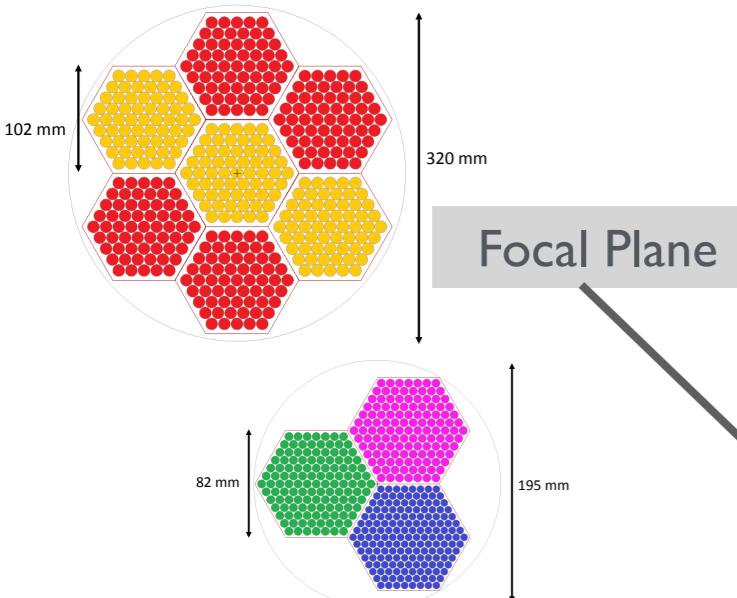
166-438GHz 89-224GHz





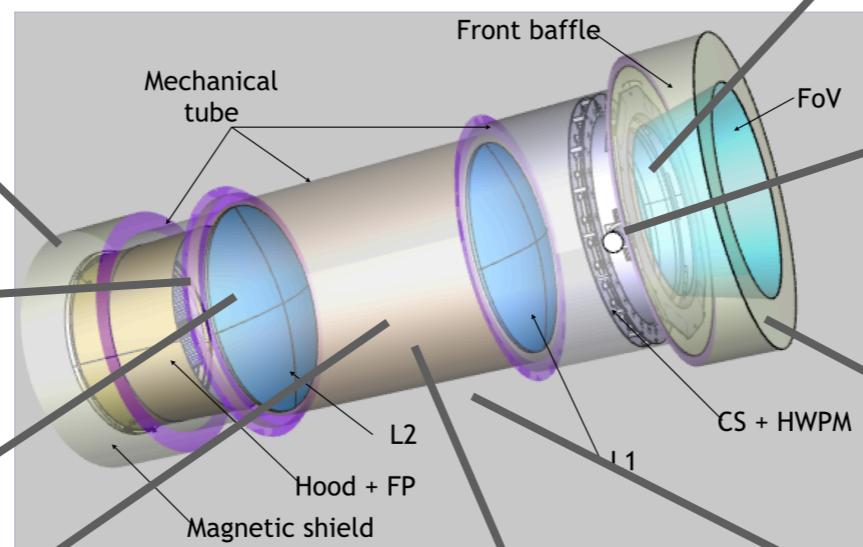
# MHFT Instrument

## Design Optimisation

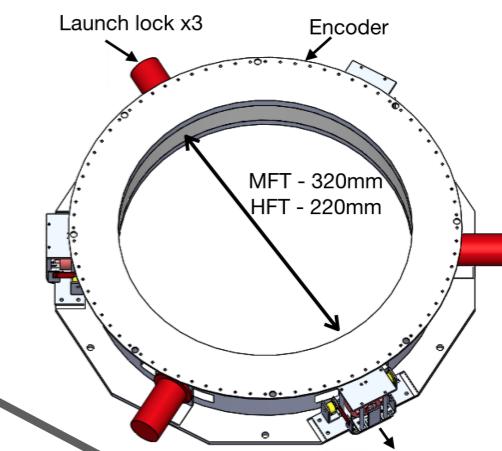


We have recently settled a MHFT - WG

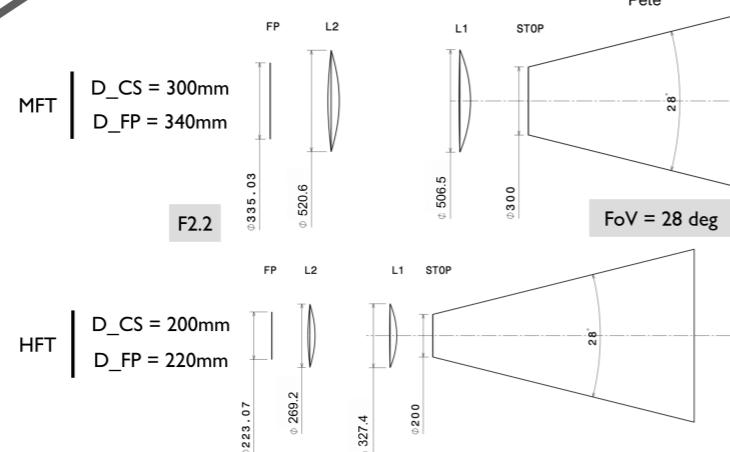
Paolo de Bernardis  
Bruno Maffei  
Giampaolo Pisano



HWP Mechanism

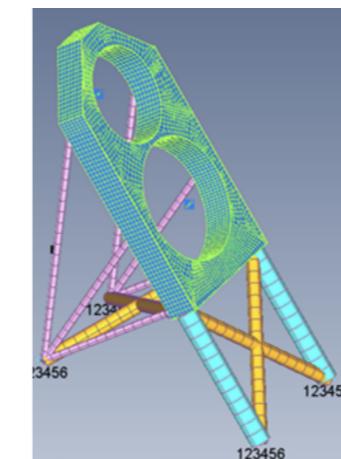


Lenses

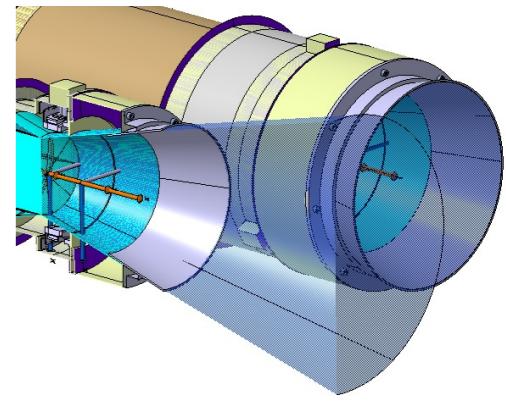
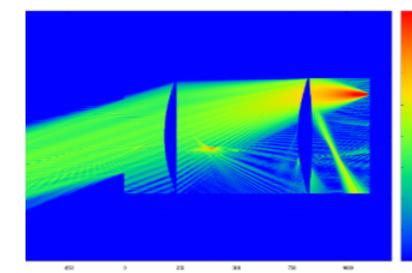


Optical Design

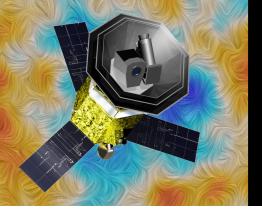
Mechanical Structure



Ghosting Analysis

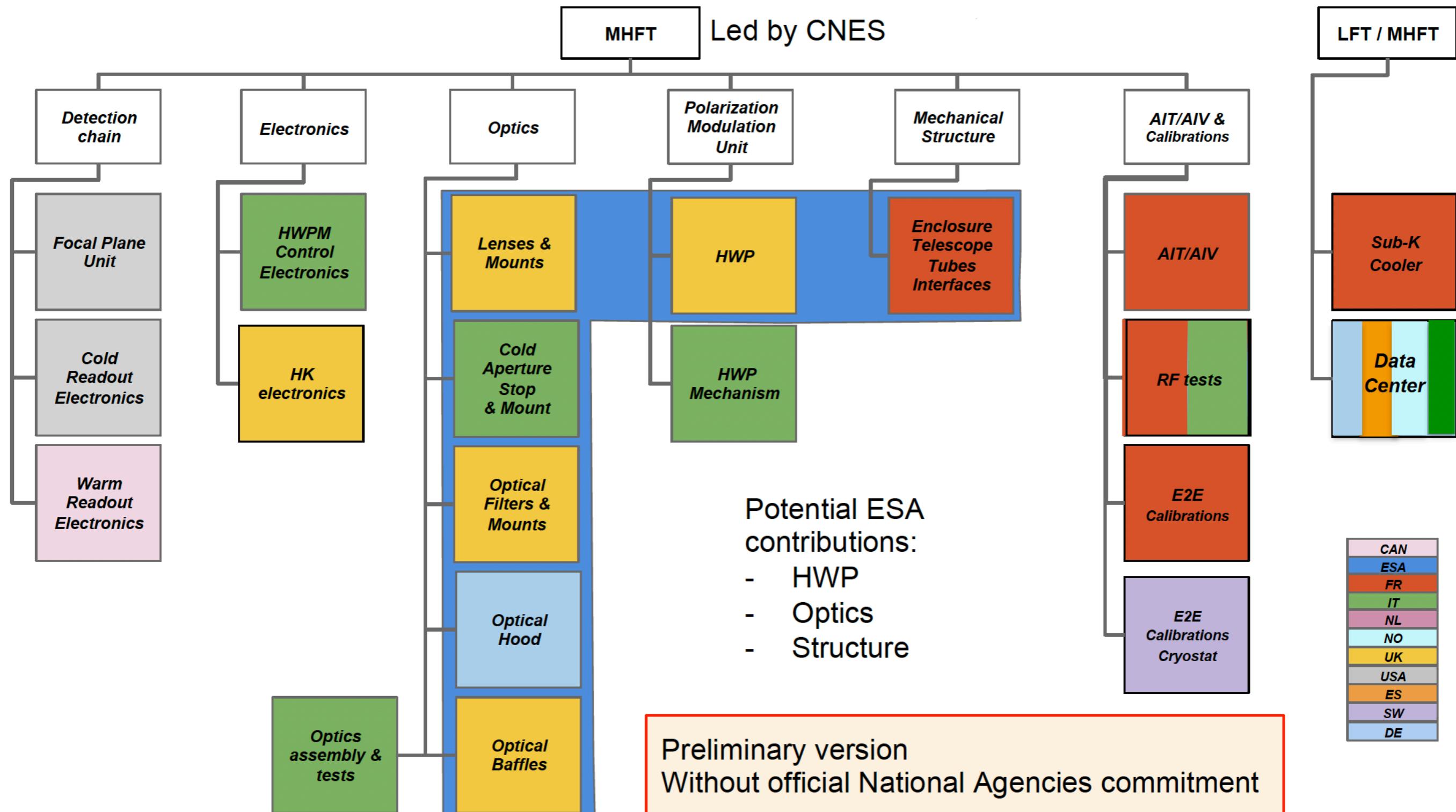


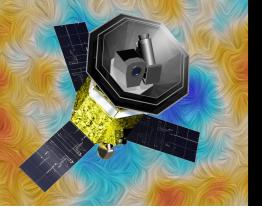
Baffle



# MHFT Instrument

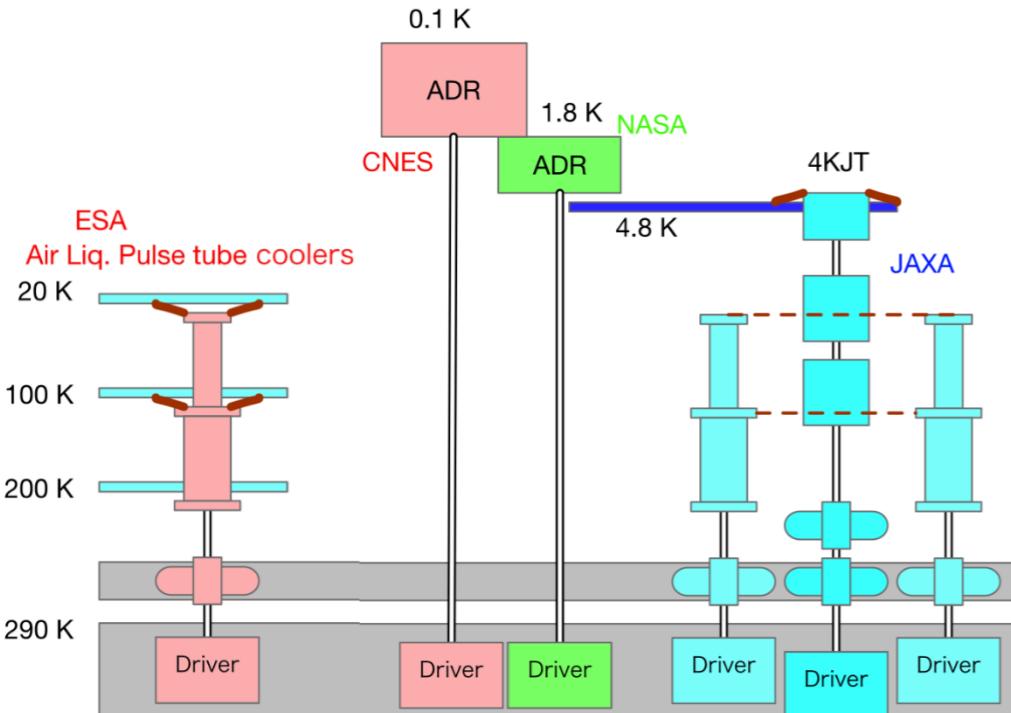
## LiteBIRD-Europe Task-Sharing



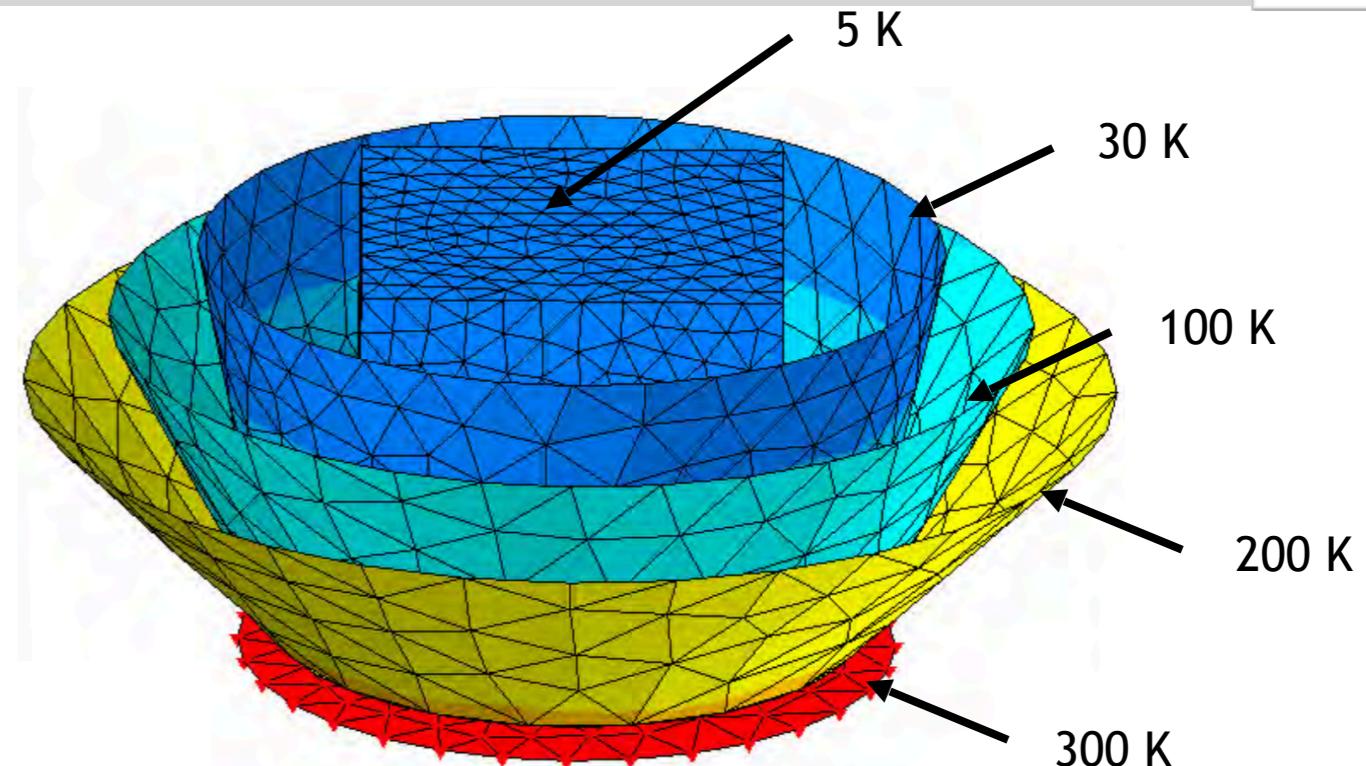


# LiteBIRD Cryo-chain

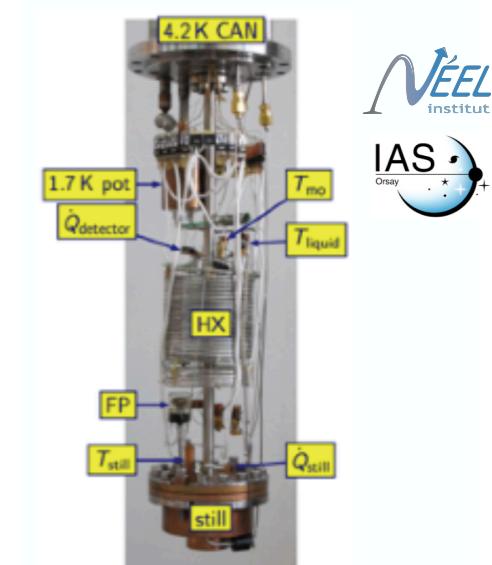
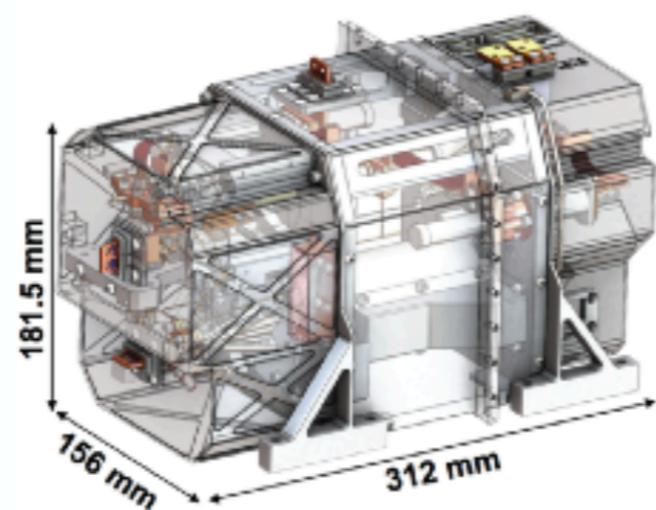
## Cryo-chain

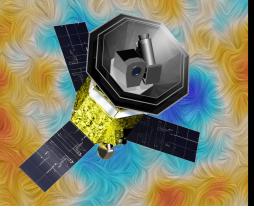


## V-Grooves / Thermal shields



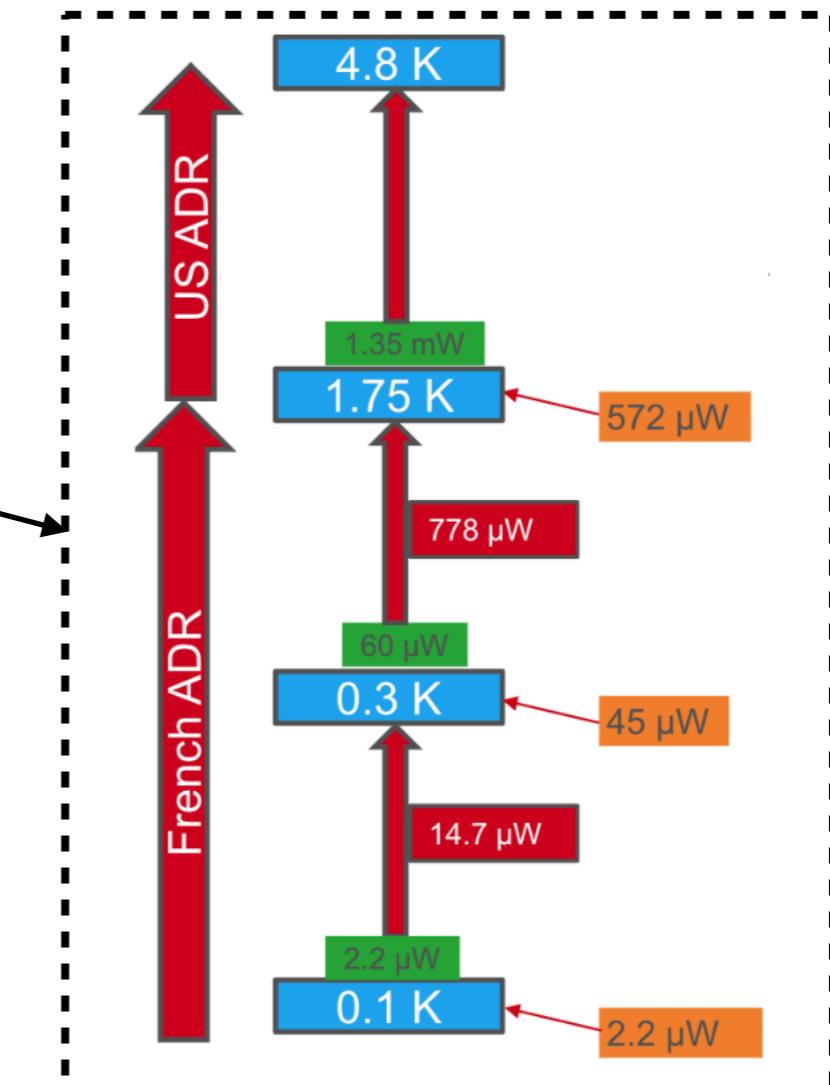
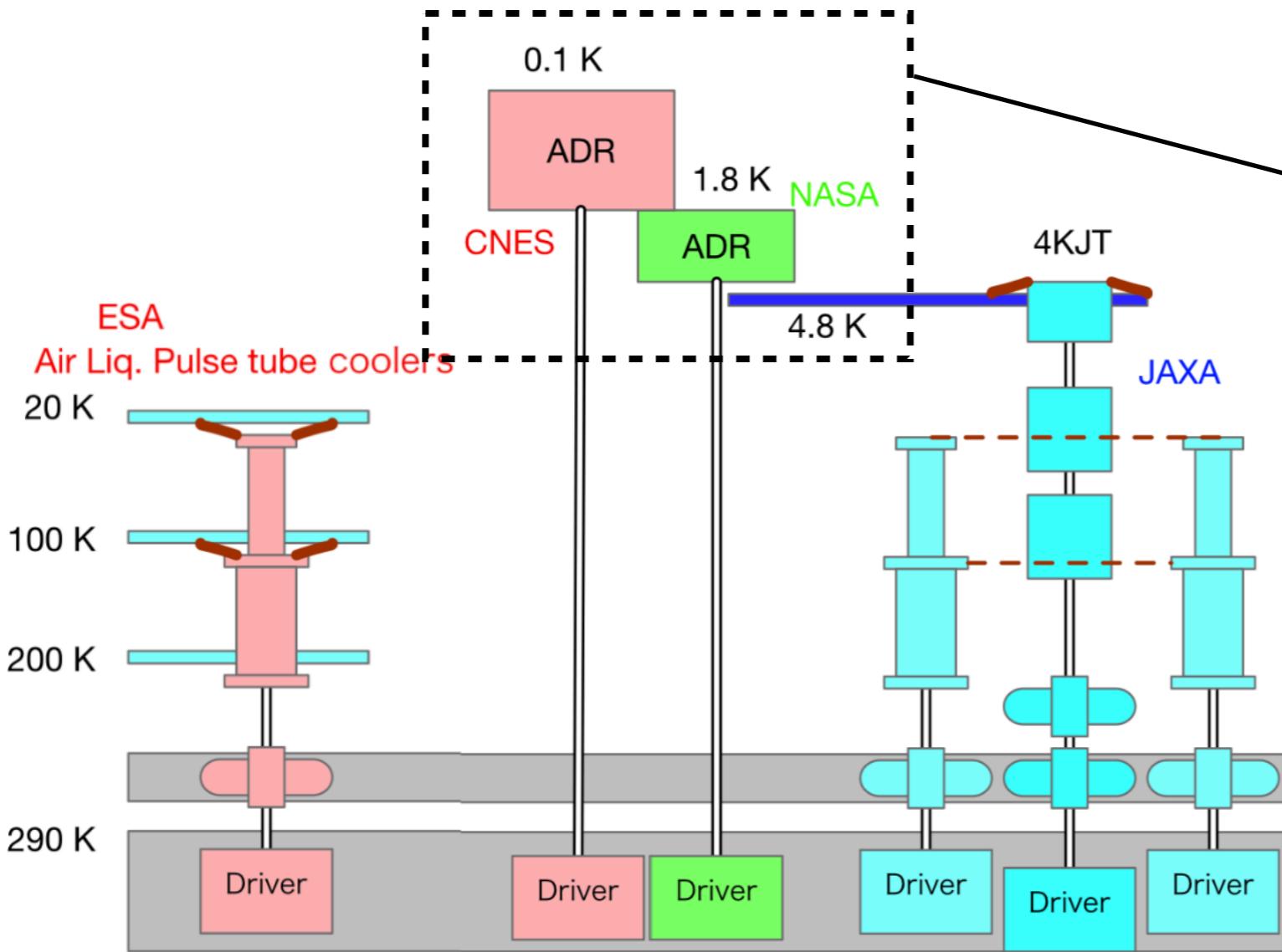
## Sub-Kelvin cooler - 100 mK





# LiteBIRD Cryo-chain

Strong involvement to work on a new cryo-chain baseline  
to adapt for the 2K-JT removal

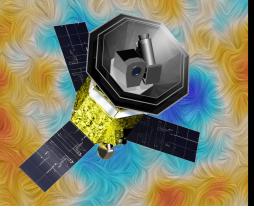


## 4.8 K - 1.75 K Stages

- 'Continuous' 1.8 K stage with 2 ADRs
- 2 mW at 1.8 K could be achieved
- Mass = 9 kg

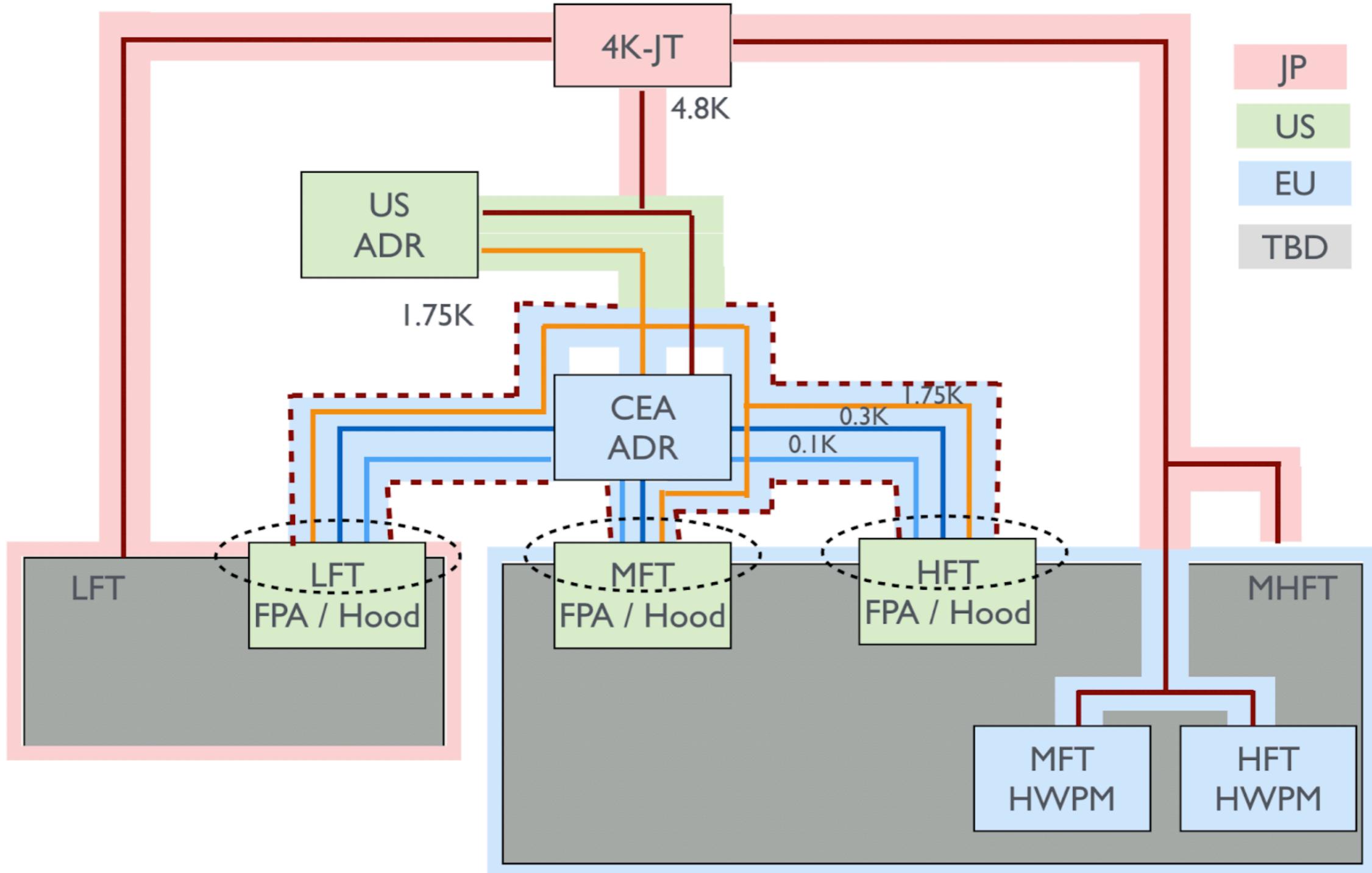
## 1.75 K - 0.1 K Stages

- 'Continuous' 0.3 K & 0.1 K stages
- 2.2 μW at 0.1 K could be achieved
- Mass = 10.2 kg

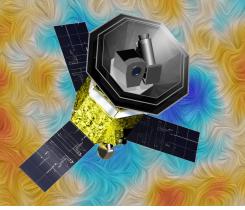


# LiteBIRD Cryo-chain

## Sub-5K architecture



Deep Contribution to the architecture of the thermal links below 5K



# JSG Activities

## *Payload JSG*

Yutaro Sekimoto  
Baptiste Mot

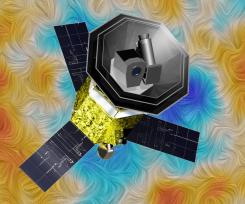
**France:** Didier Auguste, Anthony Banday, Julien Bonis, Jean-Marc Duval, Sophie Henrot-Versillé, Hiroaki Imada, Bruno Maffei, Romain Mathon, Ludovic Montier, Baptiste Mot, Thomas Prouvé, Damien Rambaud, Gilles Roudil, Gerard Vermeulen

**Italy:** Carlo Baccigalupi, Fabio Columbro, Paolo de Bernardis, Marco de Petris, Cristian Franceschet, Luca Lamagna, Silvia Masi, Francesco Piacentini, Giovanni Signorelli

**UK:** Peter Hargrave, Giampaolo Pisano, Giorgio Savini, Carole Tucker, Berend Winter

**Sweden:** Jon Gudmundsson

**Germany:** Frank Grupp

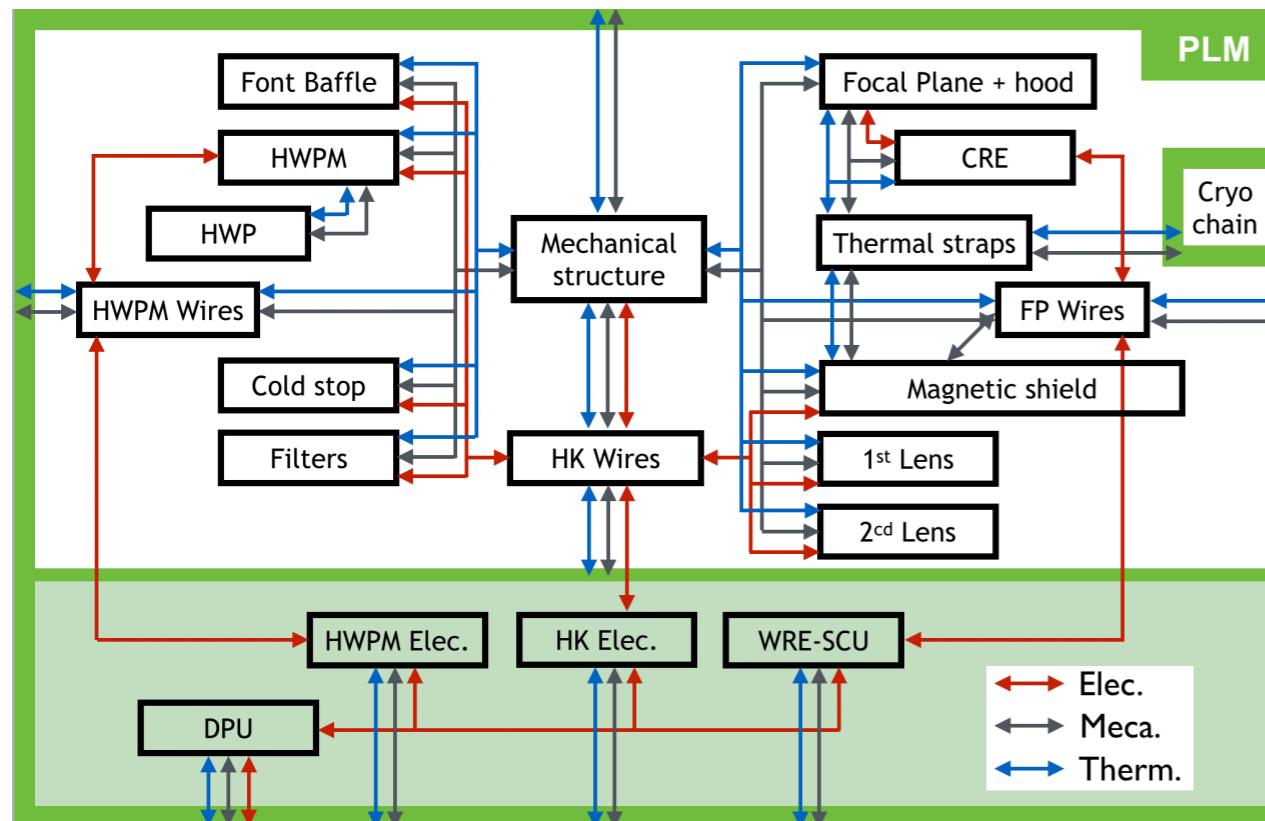


# JSG Activities

## Payload JSG

Yutaro Sekimoto  
Baptiste Mot

MHFT Interfaces definition:

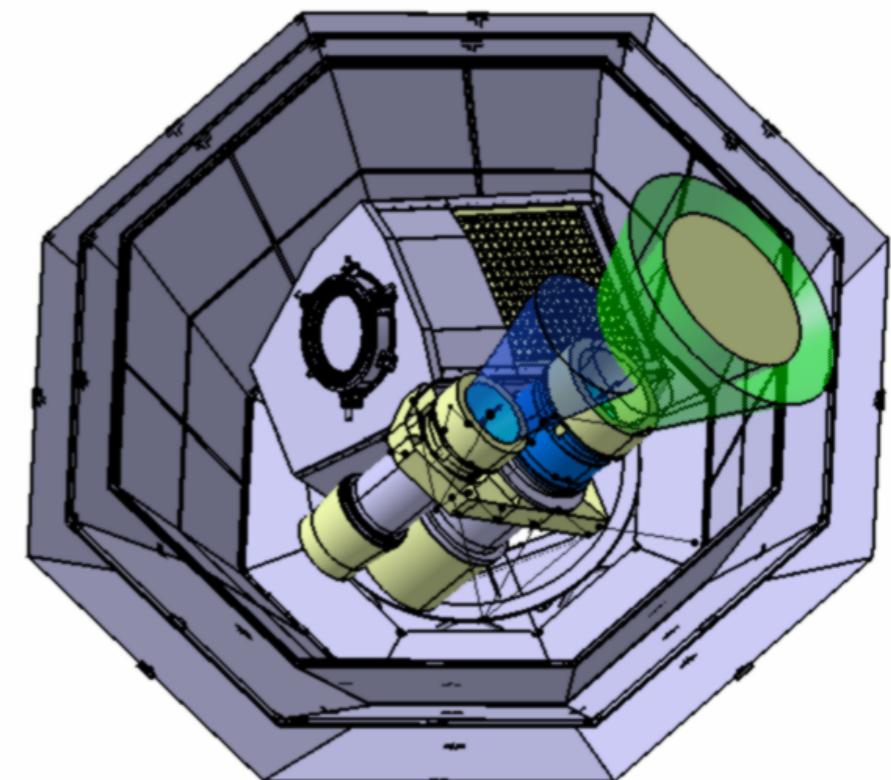


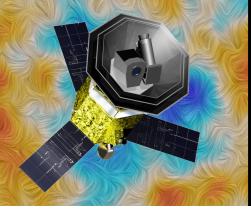
05/19: Montreal  
Electrical interfaces

06/19: Berkeley  
Focal Planes Interfaces

Payload optimisation:

- Cryo-chain optimisation
- Mechanical structure
- Electrical architecture



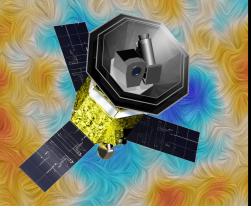


# JSG Activities

## *Systematics JSG*

Hirokazu Ishino  
Guillaume patachon  
Julian Borrill

- Beam systematics (Davide Poletti, Davide Maino, Cristian Franceshet, Jon Gudmundsson, Hiroaki Imada, Josquin Errard)
- Instrumental polarization (Guillaume Patanchon, Hiroaki Imada)
- Gain (Maurizio Tomasi)
- Polarization angle (Patricio Vielva, Enrique Martinez-Gonzalez)
- Band pass (Guillaume Patanchon, Tommaso Ghigna, Hoang Duc Thuong, Ranajoy Banerji, Martin Bucher)
- Time correlated noise (Diego Molinari, Paolo Natoli, Massimiliano Lattanzi)
- CDR documentation (all the members)

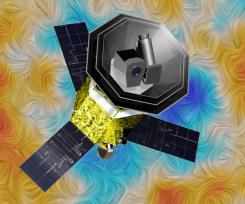


# JSG Activities

## *Foreground JSG*

Eiichiro Komatsu  
Nobu Katayama  
Carlo Baccigalupi  
Raphael Flauger

- Creation of state-of-the-art sky models, using all the information we have available today (and beyond)
- Development/implementation/application of the methodology to remove the foregrounds and estimate the cosmological parameters (such as  $r$ )
- Interaction with the systematics JSG to study the coupling between FG and systematics, such as beams, bandpasses, calibrations, etc.

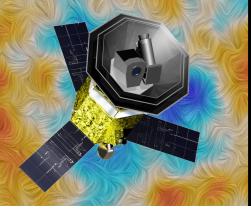


# JSG Activities

## *Foreground JSG*

Eiichiro Komatsu  
Nobu Katayama  
Carlo Baccigalupi  
Raphael Flauger

- **France:** J. Aumont, A. Banday, F. Boulanger, J. Errard, K. Ganga, J. Grain, S. Henrot-Versille, A. Mangilli, L. Montier, R. Stompor, M. Tristram, F. Vansyngel
- **Italy:** C. Baccigalupi, F. Finelli, A. Gruppuso, N. Krachmarnicoff, M. Lattanzi, M. Migliaccio, D. Molinari, P. Natoli, L. Pagano, D. Paoletti, D. Poletti
- **UK:** D. Alonso, E. Calabrese, C. Dickinson, M. Remazeilles, B. Thorne
- **Germany:** E. Komatsu
- **Spain:** B. Barreiro, R. Genova-Santos, D. Herranz, E. Martinez-Gonzalez, J.A. Rubino-Martin, P. Vielva
- **Norway:** R. Banerji, H.K. Eriksen, U. Fuskeland, I. Wehus

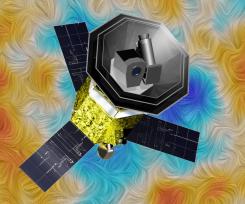


# JSG Activities

## *Foreground JSG*

Eiichiro Komatsu  
Nobu Katayama  
Carlo Baccigalupi  
Raphael Flauger

- The European consortium has been making fundamental contributions to the progress of all aspects of the FG JSG
  - Creation of state-of-the-art sky models
  - Development and comparison of different FG removal/ component separation methods
  - Study of the impacts of FG on systematics, such as beams, bandpass and calibration, and place the requirements on them
- These efforts are summarized in Chapter 3 of the Concept Design Report (CDR) submitted to JAXA for downselection



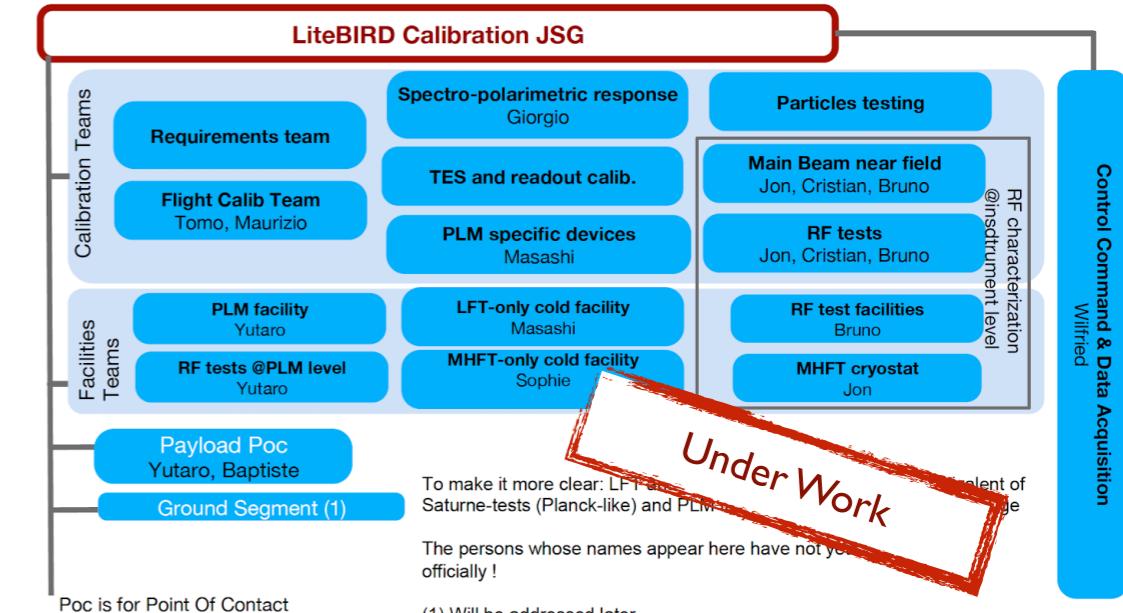
# JSG Activities

## Calibrations JSG

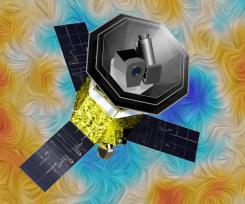
Tomotake Matsumura  
Sophie Henrot-Versillé  
Hajime Sugai

### WBS Calibration JSG European Responsibilities

- \* Flight calibration team: Maurizio
- \* Spectro-Polarimetric response: Giorgio
- \* RF tests (incl. facilities): Jon, Cristian, Bruno
- \* Control-command & Data Acquisition: Wilfried
- \* Cold facility: Sophie
- \* Payload PoC: Baptiste
- & European PoC: Marco & Giorgio



+ a lot more people involved in various discussions during JSG+splinter meetings:  
Peter Ade, Carlo Baccigalupi, Tony Banday, Paolo de Bernardis, Marco Bersanelli,  
Marco De Petris, Josquin Errard, Cristian Franceschet, Eric Hivon, Jon Gudmundsson,  
Peter Hargrave, Hiroaki Imada, Eiichiro Komatsu, Bruno Maffei, Davide Maino, Enrique Martinez-Gonzalez, Juan Macias Perez, Silvia Masi, Ludovic Montier, Baptiste Mot, Francois Pajot ,  
Guillaume Patanchon, Francesco Piacentini, Davide Poletti, Giampaolo Pisano, Sabrina Realini,  
Maura Sandri, Giorgio Savini, Maurizio Tomasi, Matthieu Tristram, Patricio Vielva  
+ CNES CATR RF team

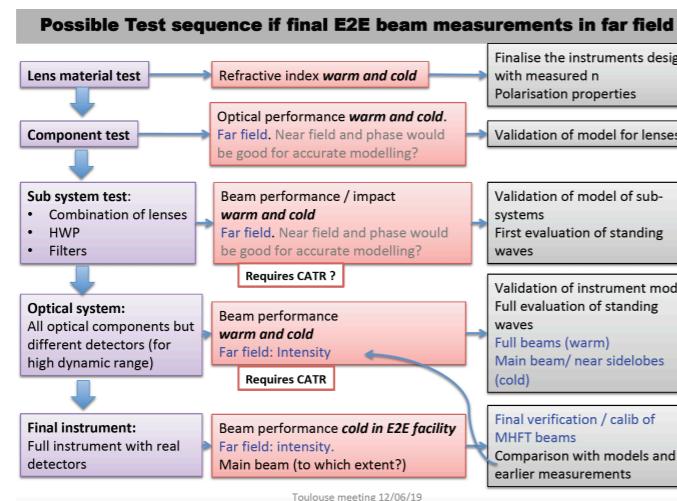


# JSG Activities

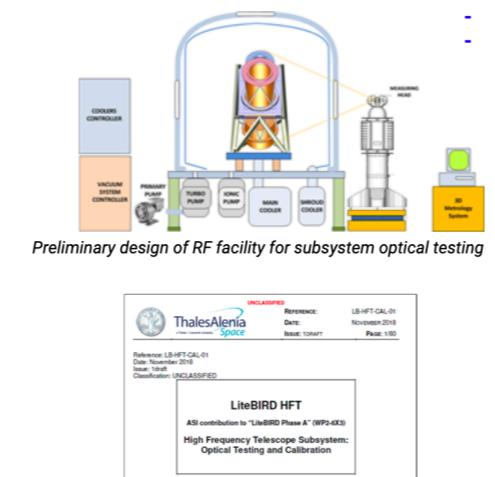
## Calibrations JSG

Tomotake Matsumura  
Sophie Henrot-Versillé  
Hajime Sugai

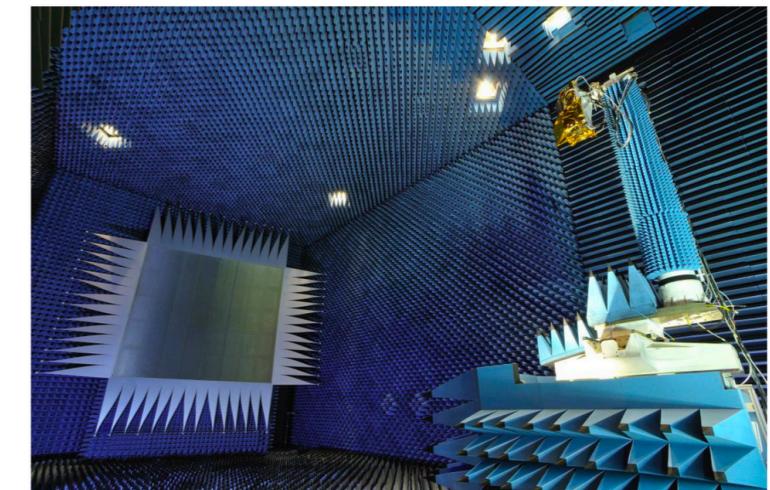
### RF tests definition



Overall calibration plan

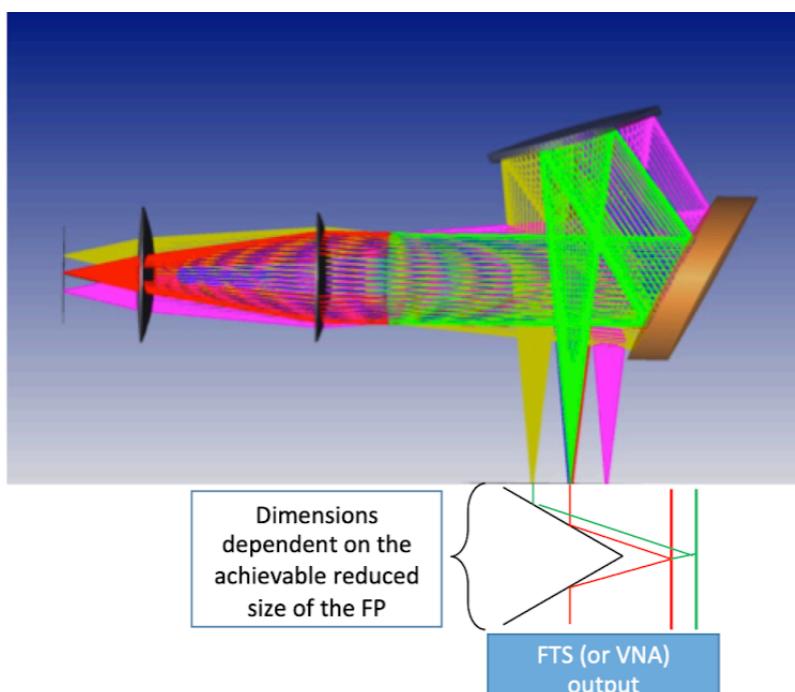


Thales-Italy RF facility



CNES-CATR

### Cold « flight-like » calibration devices & facility study & definition

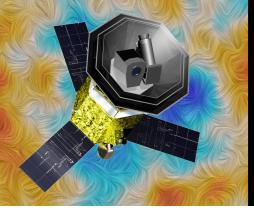


The Erios cryostat (6x4m) at LAM/Marseille



NB: needs to be upgrade to go to lower temperature (77K so far)

### Preparation for in-flight calibration/verification plans



# Connection with ESA

## ESA Payload-CDF Study 2018

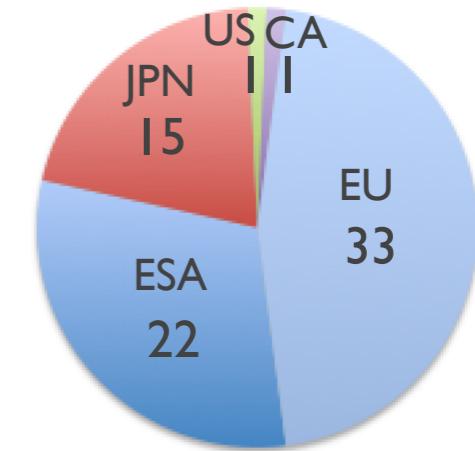
Aimed to be a first step towards an ESA Mission of Opportunity

ESA Mission of Opportunity (<50M€)

Contribution to well defined and high TRL sub-systems

8 one-day sessions from 15/03/18 to 21/06/18

### CDF Team

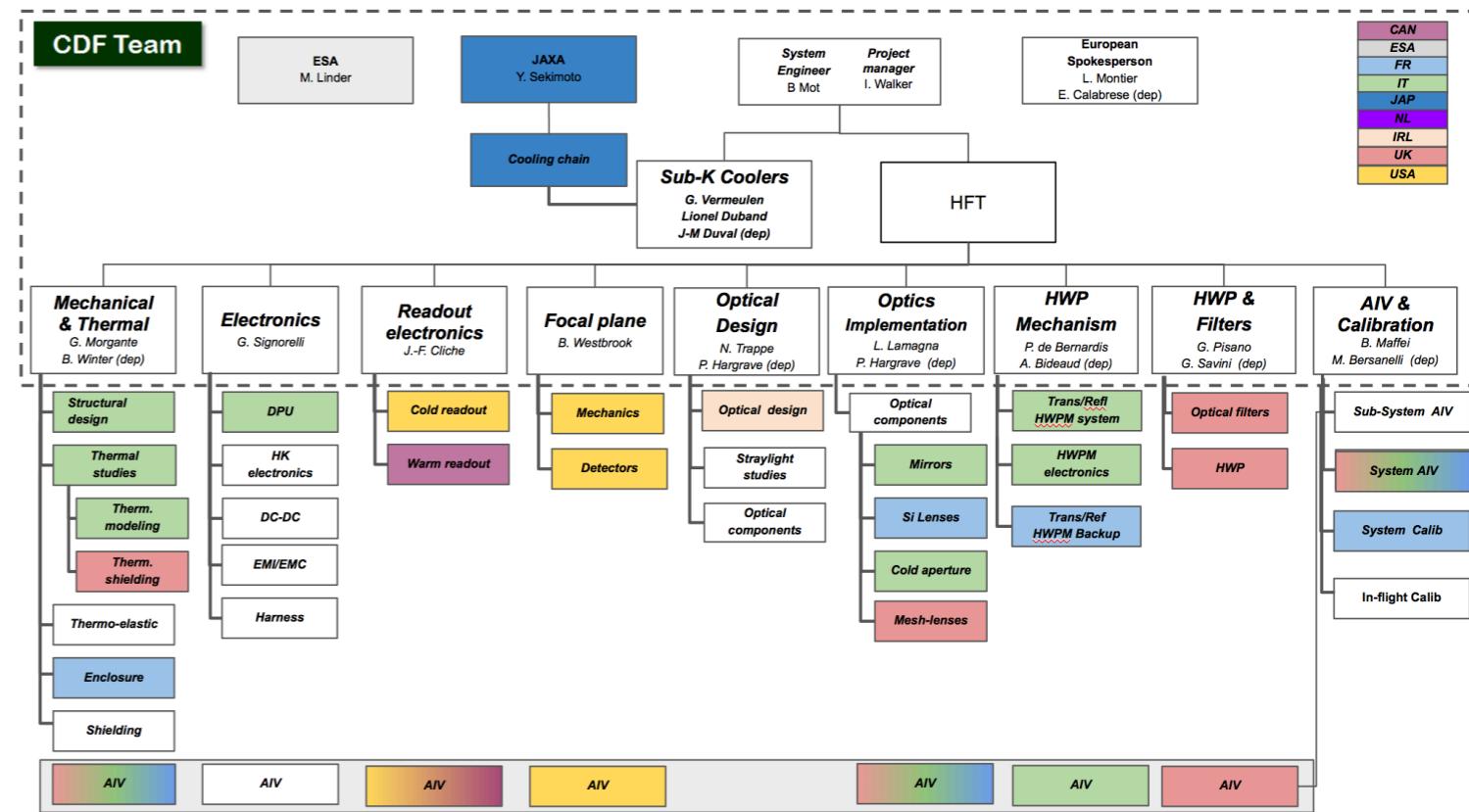


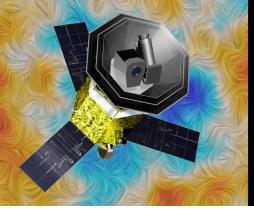
### Goals:

- Study the feasibility of HFT
- Optimisation of the cryo-chain
- Study ESA Mission of Opportunity
- Study ESA contribution

### Main Outcomes:

- Refinement of HFT requirements
- HFT Design Trade-off: 2 options
- Sub-K trade-off
- Procurement Philosophy
- Cost estimates





# Connection with ESA

## *Status at ESA*

SPC

ESA's Science Programme Committee meeting on the 15/11/18

Under MoO

“The study showed that provision of the complete instrument is not feasible under the Mission of Opportunity scheme, for a number of reasons”

Full HFT: NO

“The Executive believes that components of the telescope (e.g., optics, structure, half-wave plate) could be provided under an MoO scheme.”

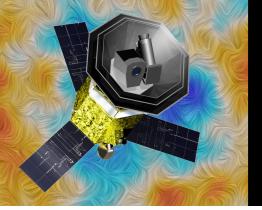
Sub-Systems: OK

“Whether a more comprehensive package could be assembled depends also on the readiness of interested Member States to contribute additional elements. The Executive would like to call a meeting of “Potential Participants” in the near future to discuss this.”

10/12/18

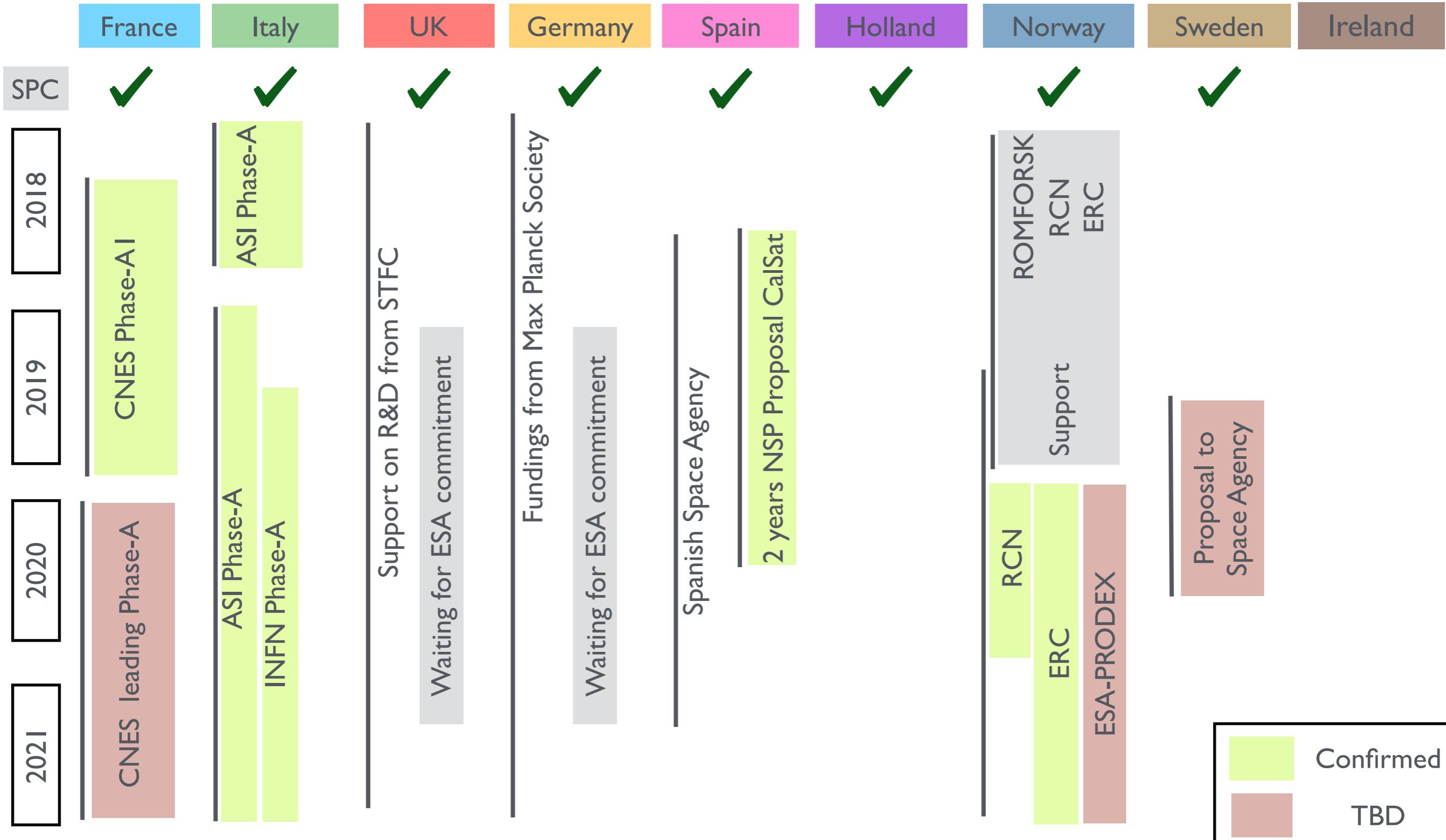
Invitation by ESA to LiteBIRD-Europe Collaboration for a CDF follow-up Meeting

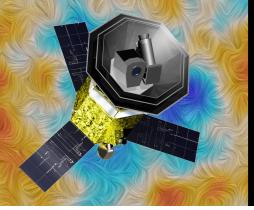
10/19



# European Contributions

## European Partners





# Conclusion

Strong heritage in Europe from Planck and ground experiments

- | Instrumentation
- | Forecasts / Simulations
- | Data Analysis

An active European collaboration

- | 9 countries
- | 100 external members

Deep involvement of the European Collaboration since 2 years

- | Instrument Design Optimisation
- | JSG activities
- | Data analysis
- | Support to JAXA Phase-AI exit review and down-selection process
- | Support to US MO

Waiting for CNES decision for commitment into a MHFT Leading Phase-A by end of 2019

Further steps to build ESA MoO, including all other European partners