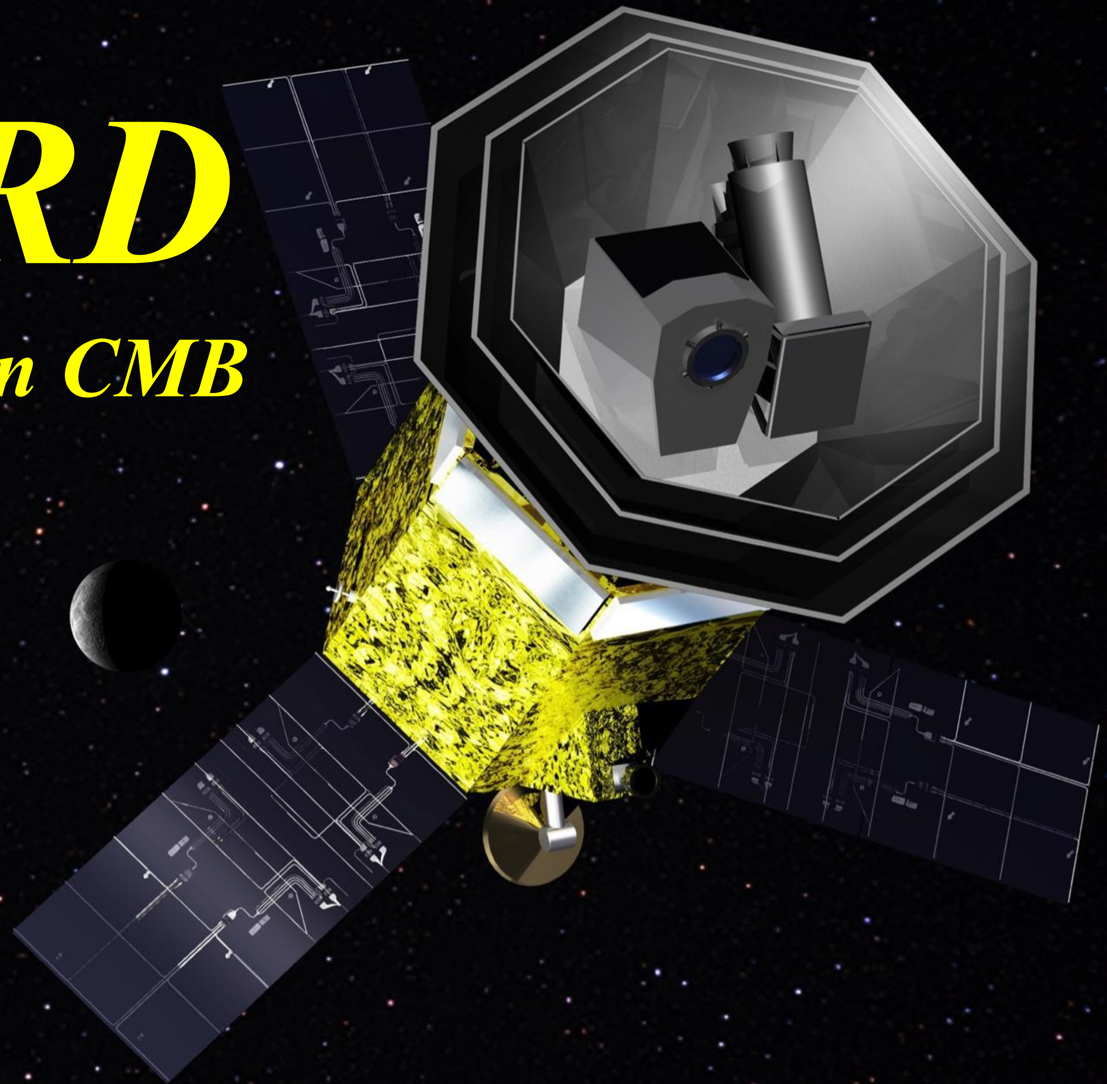
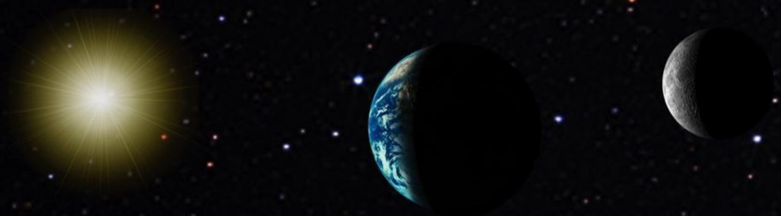
# *LiteBIRD*

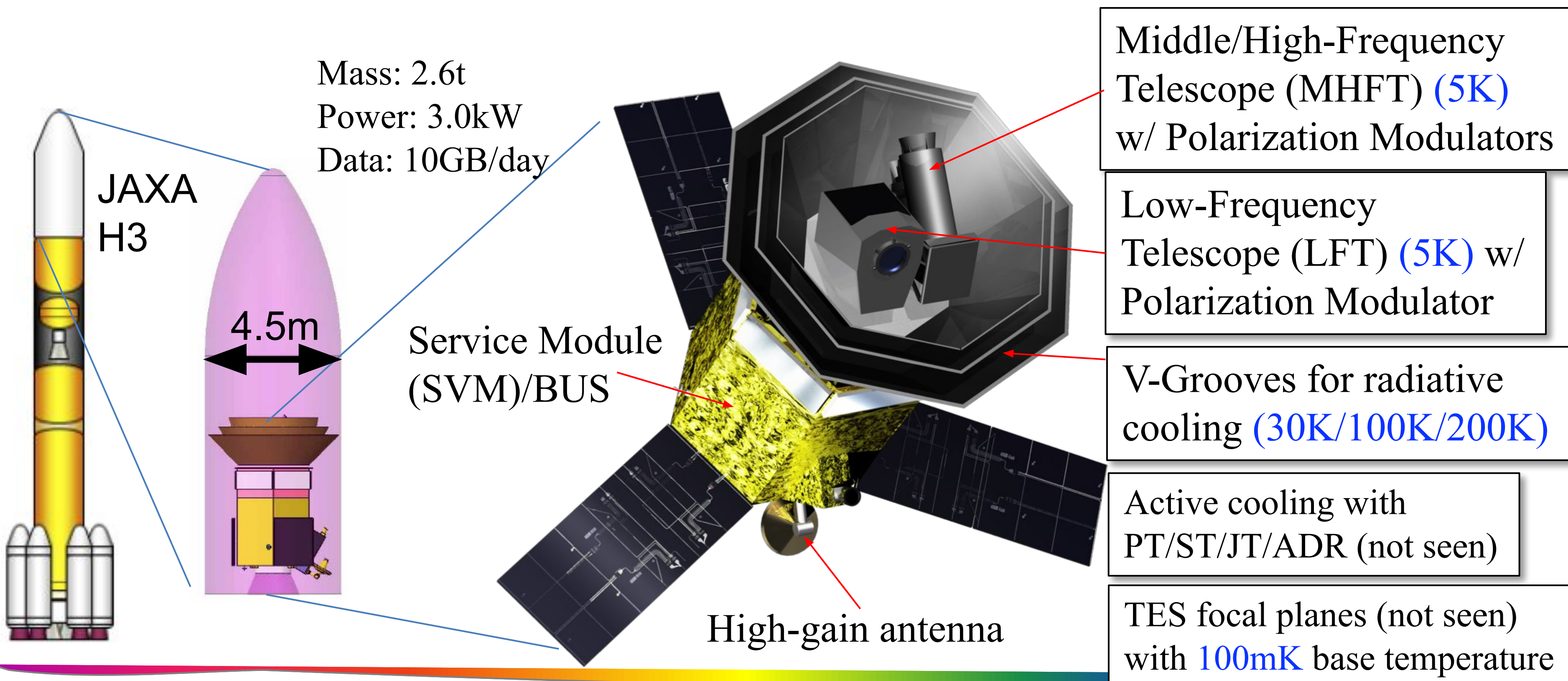
## *the next generation CMB satellite*





# LiteBIRD Overview

- JAXA's L-class mission selected in May 2019
- Expected launch in Japanese fiscal year 2027 with JAXA's H3 rocket.
- Observations for 3 years (baseline) around Sun-Earth Lagrangian point L2
- Millimeter-wave all sky surveys (34–448 GHz, 15 bands) at 70–20 arcmin.
- Mission: δr (total uncertainty) < 0.001 (for r=0) with CMB B-mode observation

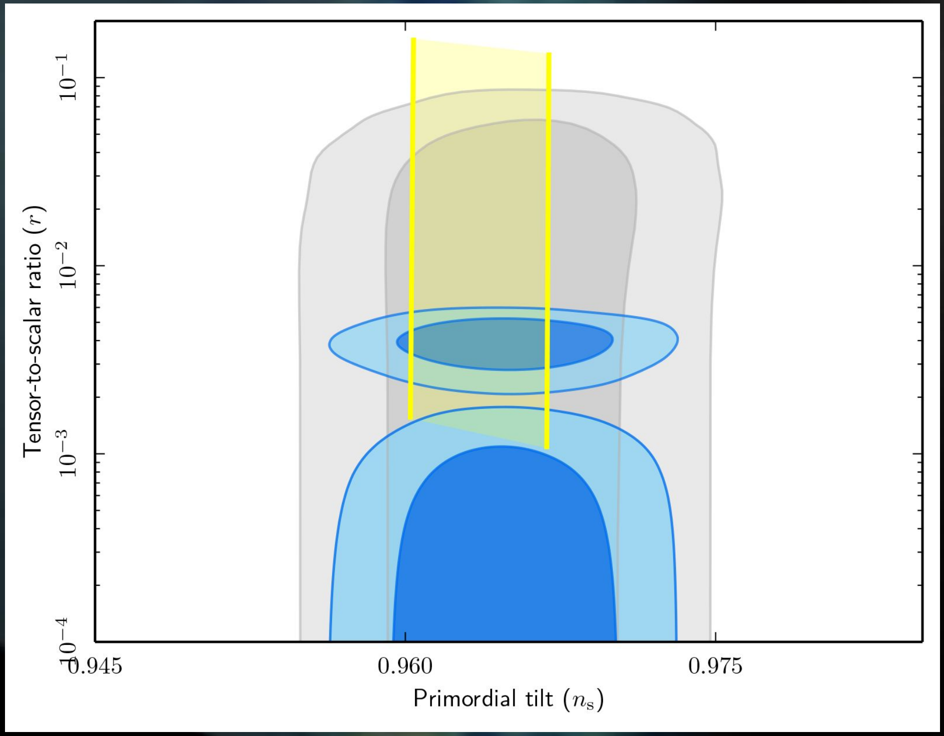


# LiteBIRD science objectives

**Full success:**
- $\delta r < 1 \times 10^{-3}$ (for r=0)
- >5σ observation for each bump (for r≥0.01)

**Feasibility:**
- Detailed foreground cleaning studies yield $\sigma(r=0) = 0.6 \times 10^{-3}$
- Thorough systematic and statistical error studies yield total uncertainty $\delta r < 1.0 \times 10^{-3}$ without delensing

**Rationale**
- Large discovery potential for $0.005 < r < 0.05$
- Simplest and well-motivated $R+R^2$ "Starobinsky" model will be tested.
- Clean sweep of single-field models with characteristic field variation scale of inflaton potential greater than $m_{pl}$ (A. Linde, JCAP 1702 (2017) no.02, 006)



# LiteBIRD science objectives

Focused mission: driven by a single science goal

which has

- huge potential impact;
- huge discovery space;

and what permits for

- robust design and optimization;
- synergistic opportunities, while bringing in unique information;

However LiteBIRD will reach many other science goals.

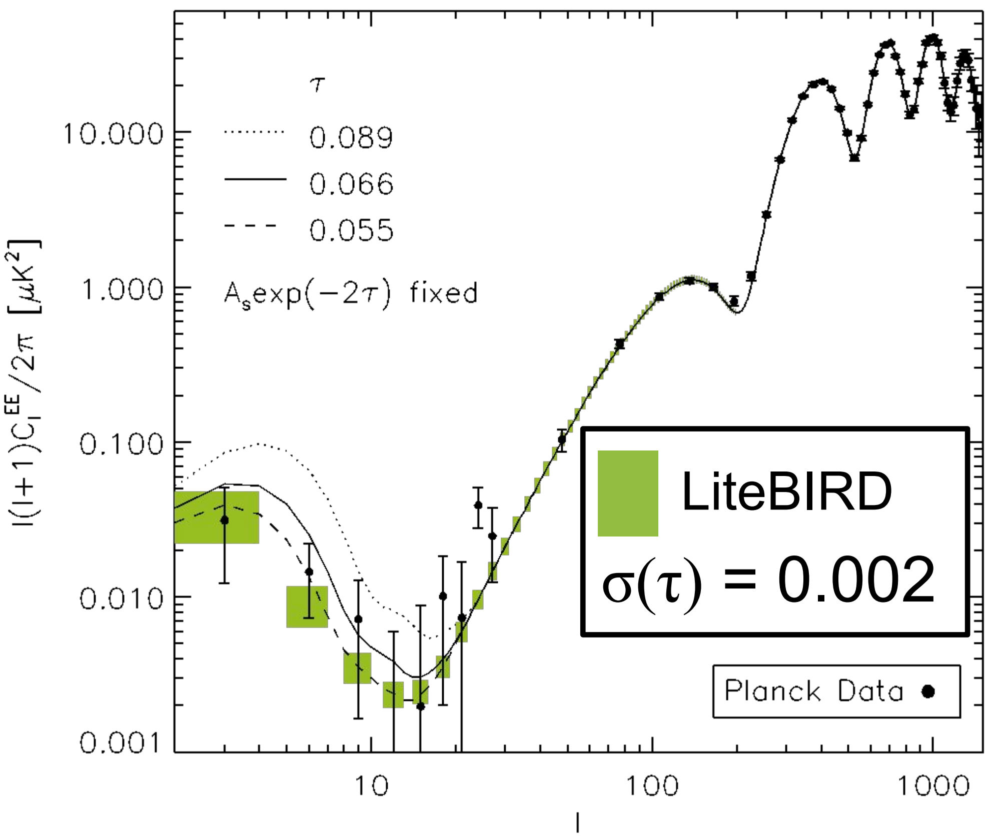
# LiteBIRD Science Outcomes

1. Full success — System requirements from full success only
2. Extra success; further improving sensitivity with external data
3. Characterization of B-mode and search for sources fields (e.g., scale-invariance, non-Gaussianity, parity violation)
4. Power spectrum features in polarization
5. Large-scale E mode
   - its implications for reionization history and the neutrino mass
6. Cosmic birefringence
7. SZ effect (thermal and relativistic correction)
8. Elucidating anomalies
9. Galactic science

3. – 9. in principle guaranteed if full success is achieved.

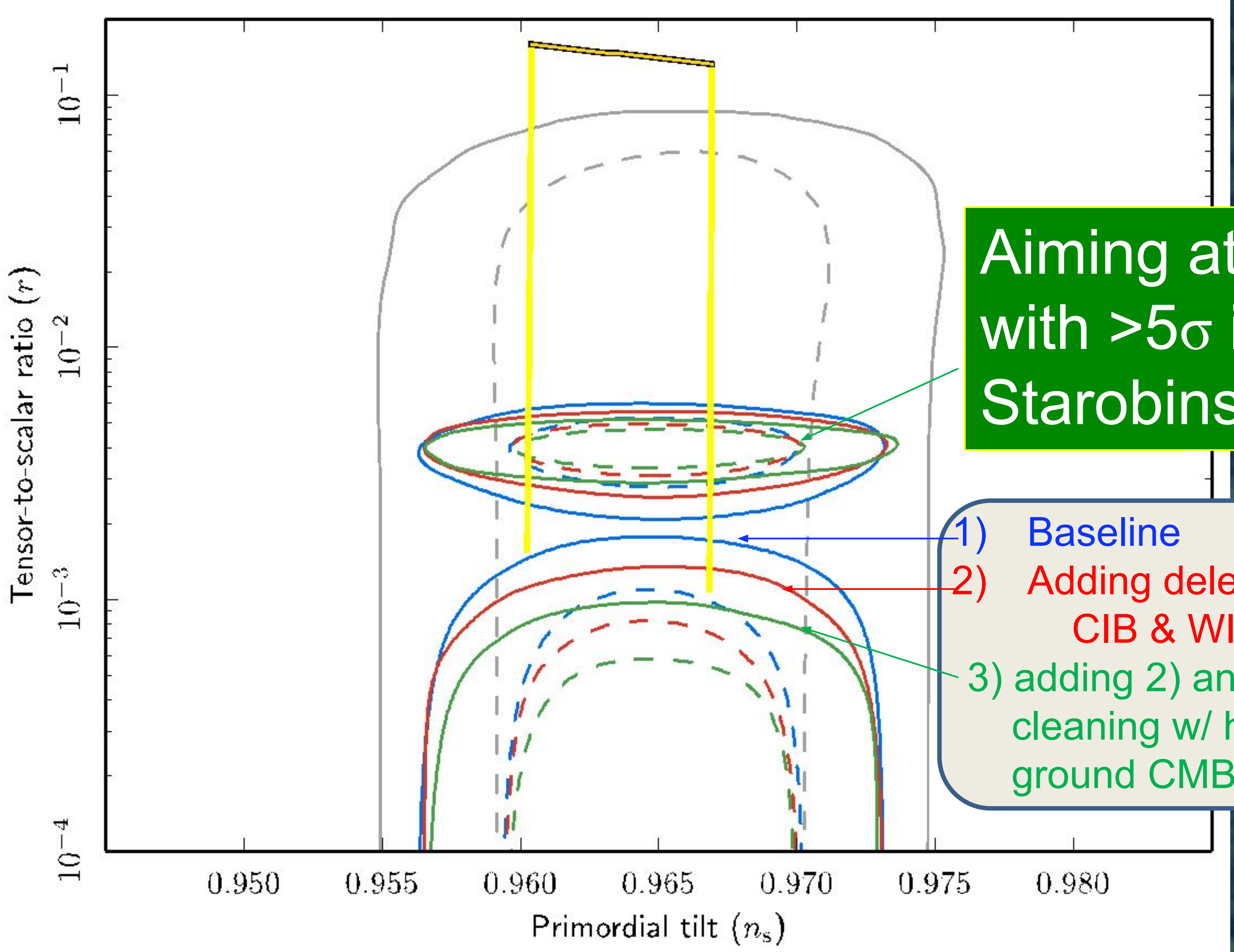
# An example: large-scale E-mode

A cosmic variance limited measurement of EE on large angular scales will be an important, and guaranteed, legacy for LiteBIRD!




- shed light on the reionization history

# An example: extra success




Aiming at detection with >5σ in case of Starobinsky model

1) Baseline
2) Adding delensing w/ Planck CIB & WISE
3) adding 2) and extra foreground cleaning w/ high-resolution ground CMB data

# Space !

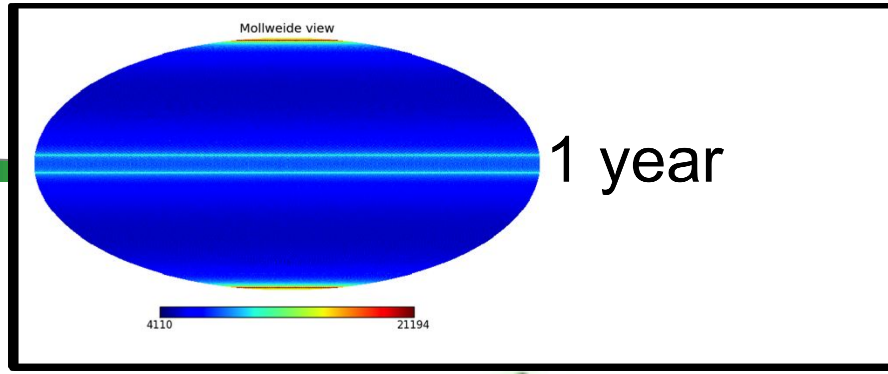
- Superb environment !
  - No statistical/systematic uncertainty due to atmosphere (cf. polarization due to icy clouds in POLARBEAR obs., S. Takakura et al. 2018)
  - No limitation on the choice of observing bands (except CO lines); important for foreground separation
  - No ground pickup

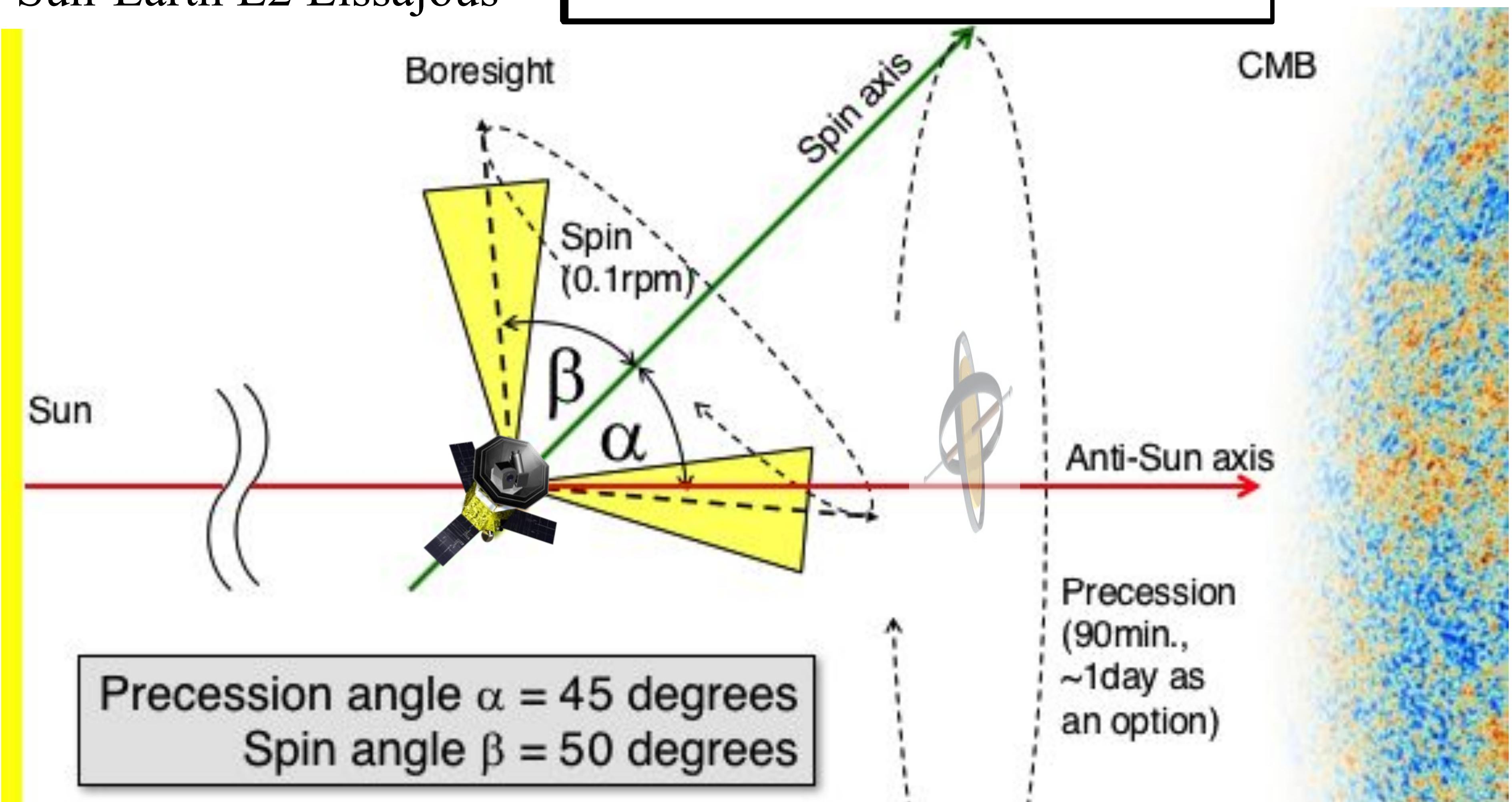
**Rule of thumb: 1,000 detectors in space ~ 100,000 detectors on ground**

- Only way to access lowest multipoles w/ δr ~ O(0.001)
  - Both B-mode bumps need to be observed for the firm confirmation of Cosmic Inflation  We need measurements from space.
- Complementarity with ground-based CMB projects
  - Foreground information from space will help foreground cleaning for ground CMB data
  - High multipole information from ground will help "delense" space CMB data

# Operation

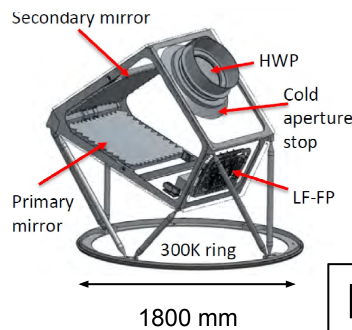
Orbit:
Sun-Earth L2 Lissajous



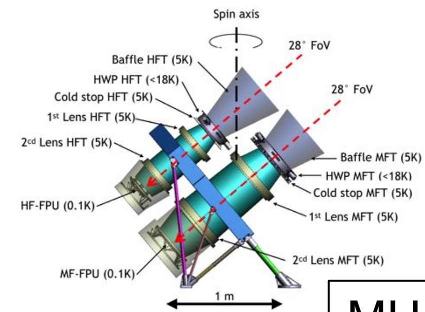



# LiteBIRD Mission Instrument

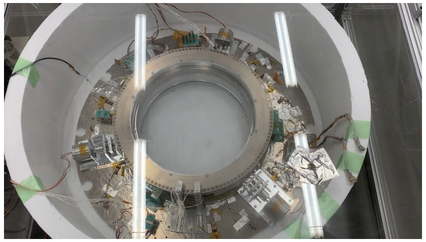
1. Two sets of telescopes w/ multichroic arrays of TES
2. Polarization modulator w/ rotating half-wave plate (HWP)
3. Cryogenic system for 0.1K base temperature

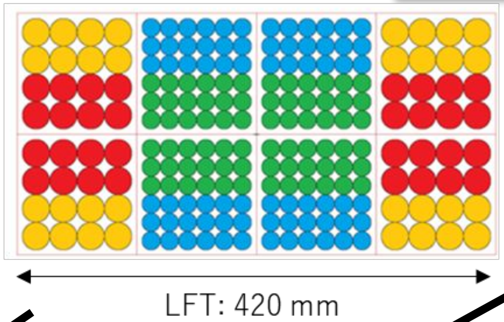


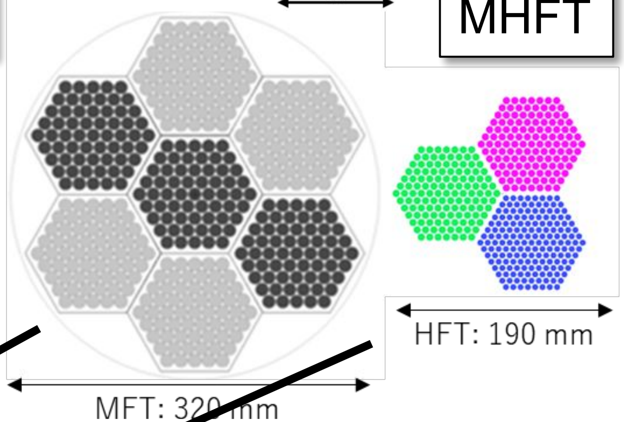

LFT

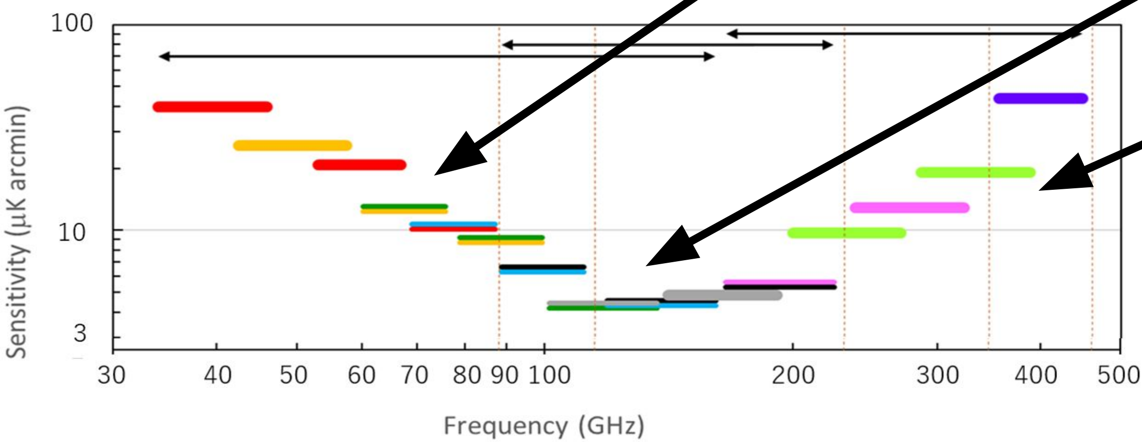


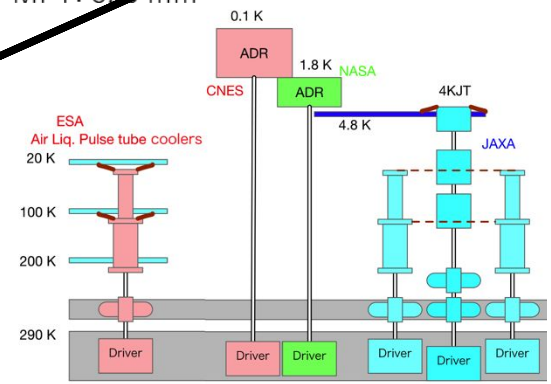

MHFT





# Design validation and optimization

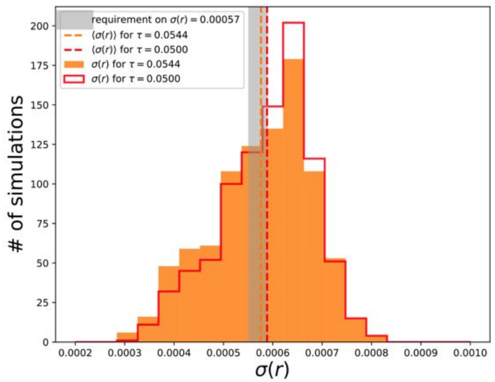
## Foreground cleaning

**Methodology:**

- Simple, but non-trivial and realistic sky model based on parametric, spatially-varying frequency scaling laws (effectively requiring 6144 parameters in the cleaning process);
- Multiple techniques: xForecast + “multipatch” (*) corroborated with COMMANDER-2.

**Snapshot of the results (2019 design):**

- $\sigma(r=0) = 0.0006$
- Negligibly small bias




On-going work of the Foreground Joint Study Group and the Performance Evaluation Task Force

## Systematic effects modeling and mitigation

**Methodology:**

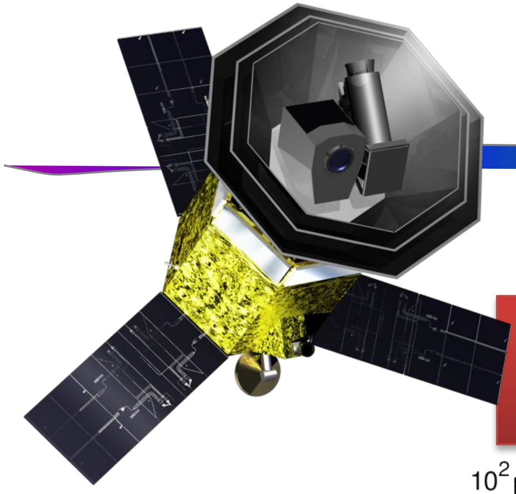
(“Systematic approach to systematics”)

- Collated a list of anticipated systematic effects: total of ~70 effects divided into 14 categories;
- Each modeled first separately and checked if it fits within the allocated error budget (typically 1/10$^{th}$ of the total systematic error budget);
- If exceeds, mitigation and calibration techniques proposed and /or specifications updated.
- Progressively more complex models and performance metrics used.

On-going work of the Systematics and Calibration Joint Study Groups.

* Errard and Stompor, Phys.Rev. D99 (2019) no.4, 043529

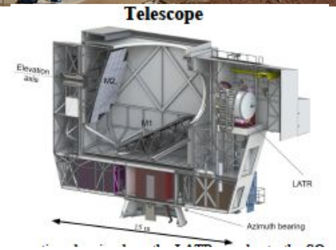
# CMB around ~2030



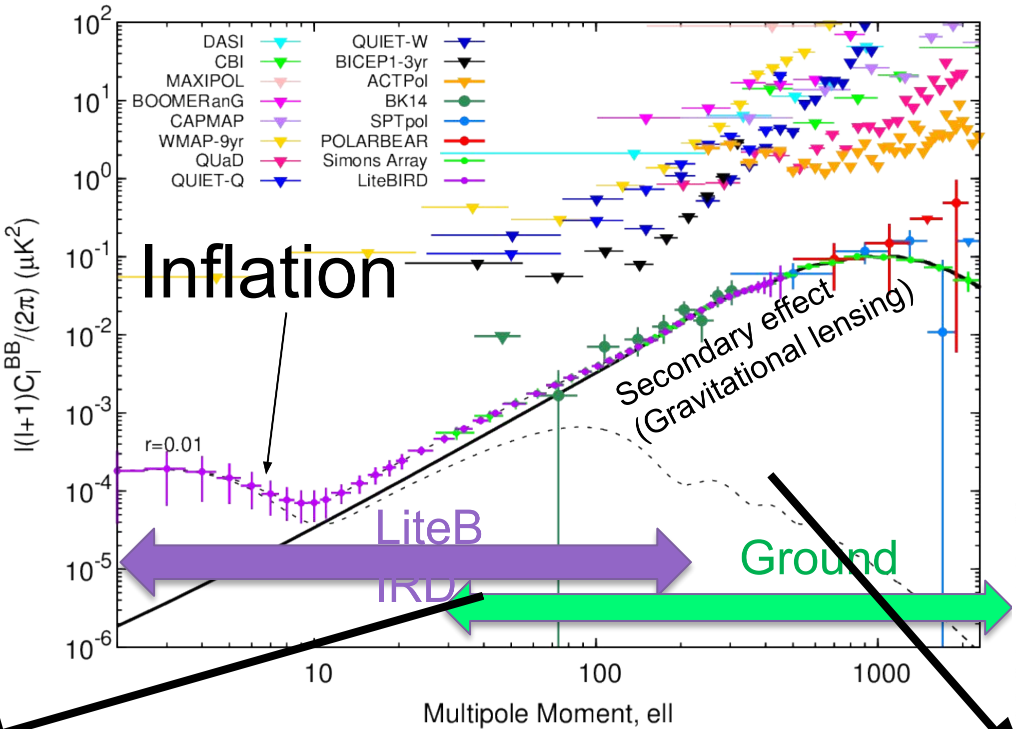
X


## Powerful Synergies

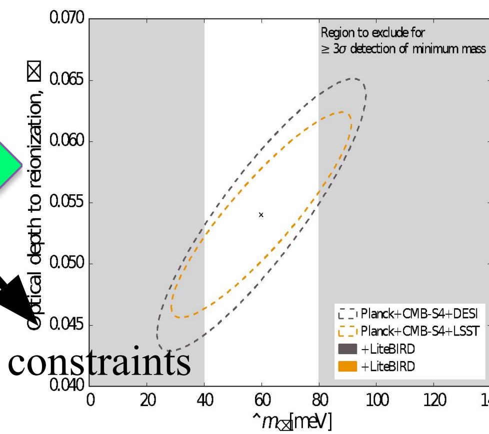
SIMONS OBSERVATORY




<u>LiteBIRD</u>
JAXA-led focused mission
σ(r)<0.001
$2 \leq l \leq 200$
focused but still with many byproducts



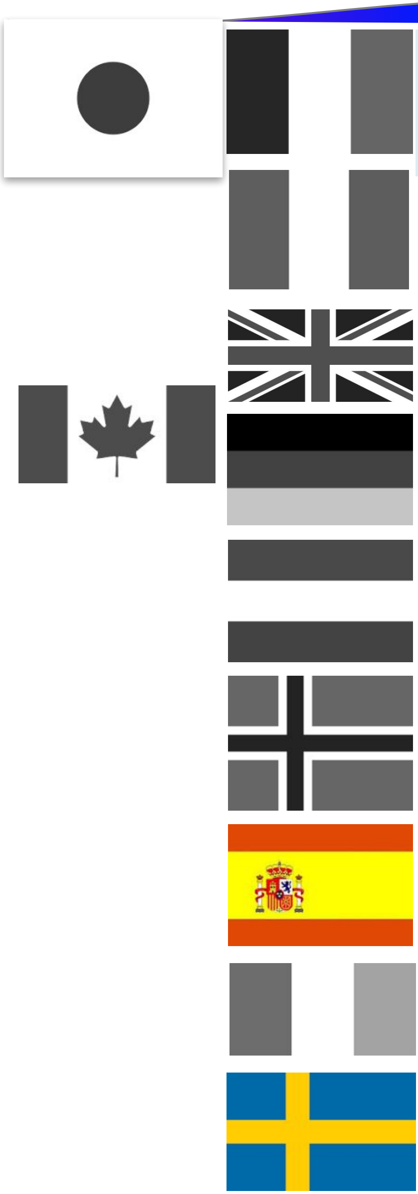

<u>Ground</u>
US-led telescopes on ground
$30 \leq l \leq \sim 8000$
e.g. Simons Observatory and CMB-S4




Cross-check !

Improved constraints

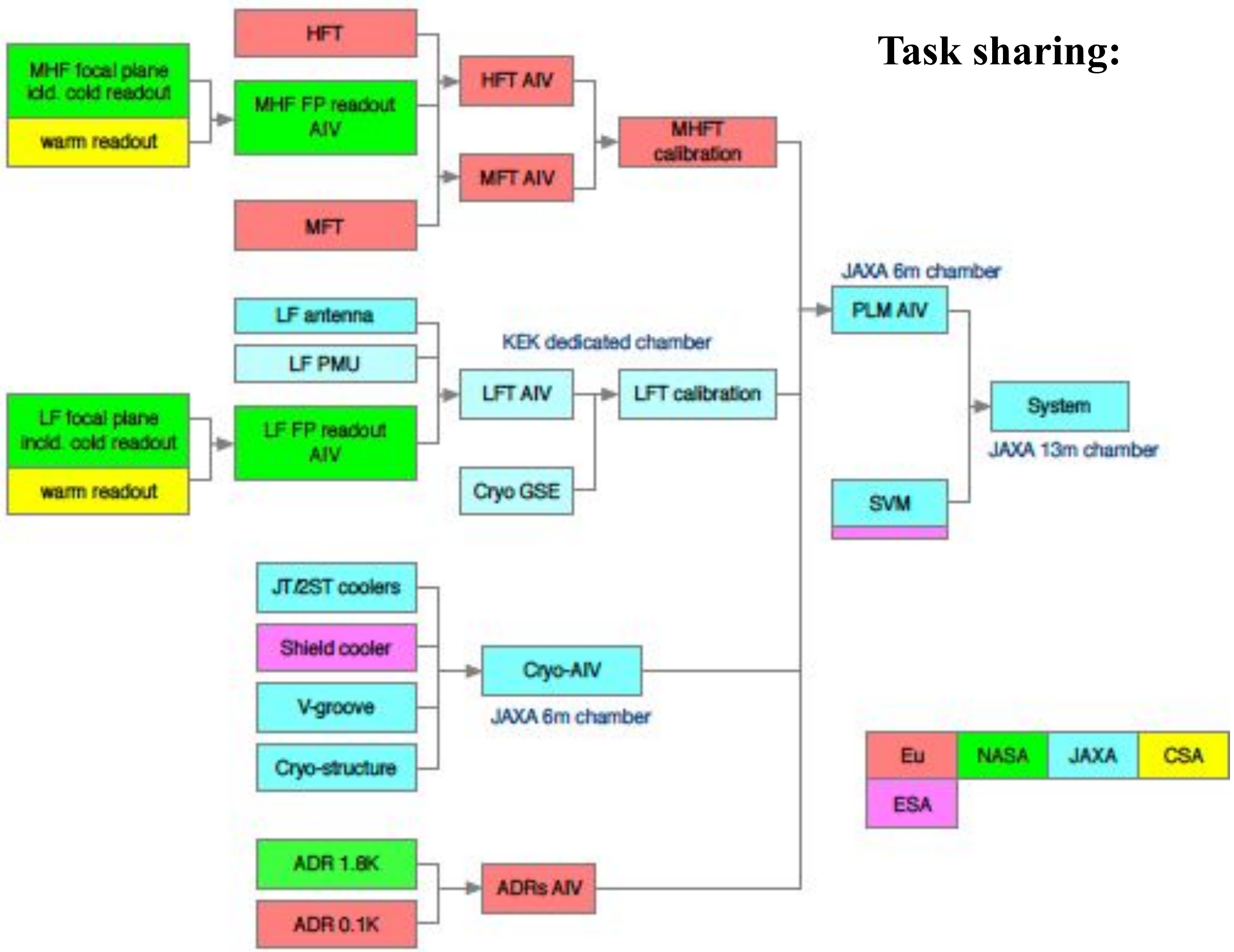
# LiteBIRD – an international project



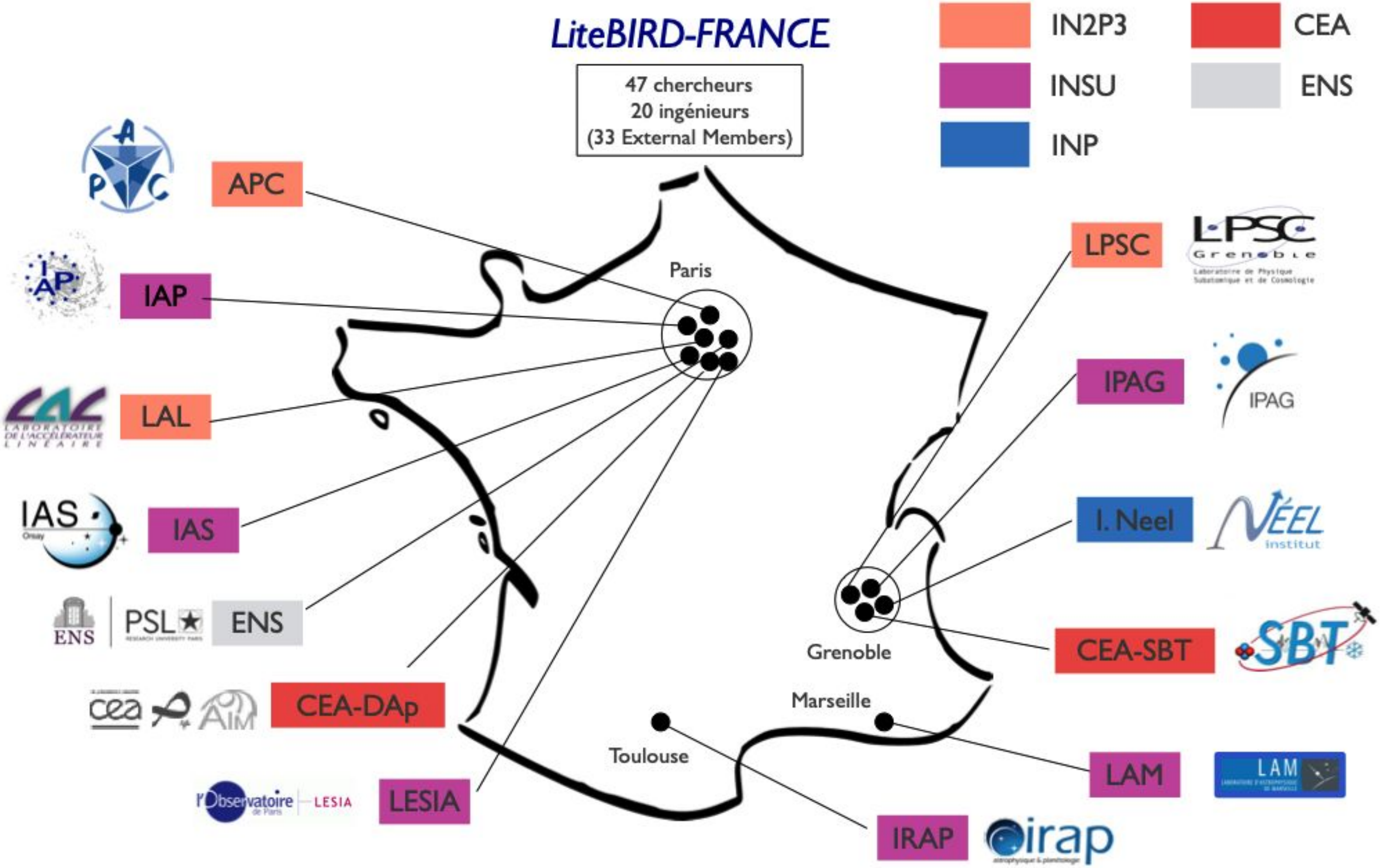
More than 200 researchers from Japan, North America & Europe

Team experiences: CMB exp., X-ray satellites, other large proj. (HEP, ALMA etc.)

**Task sharing:**



# LiteBIRD in France




Since early 2017

CNES support since the fall 2018 (pre-phase A), phase A since Jan 2020.

CNES PM: Thierry Maciaszek.

# LiteBIRD at APC

7 permanent researchers (5 actively involved in on-going LiteBIRD work);
1 post-doc (ANR)
1 PhD student;

Leading role in setting up French and European LiteBIRD collaboration.

Coordinating/leadership roles in the Foreground and Systematic Joint Studies Group;

On-going discussion of instrumental contributions (included in the task sharing plan presented to CNES at the end of the pre-phase A);

Involvement in the project governance on French, European, and global levels.