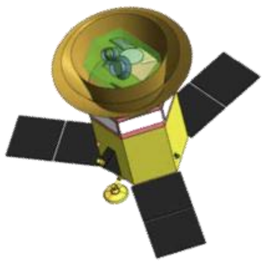
U.S. Participation in the LiteBIRD Cosmic Microwave Background Polarization Survey



U.S. Team

The U.S. team members have decades of experience in ground and balloon based Cosmic Microwave Background experiments (POLARBEAR, Atacama Cosmology Telescope, BICEP/Keck, EBEX balloon, etc..) and international satellite missions (Planck, Hitomi)

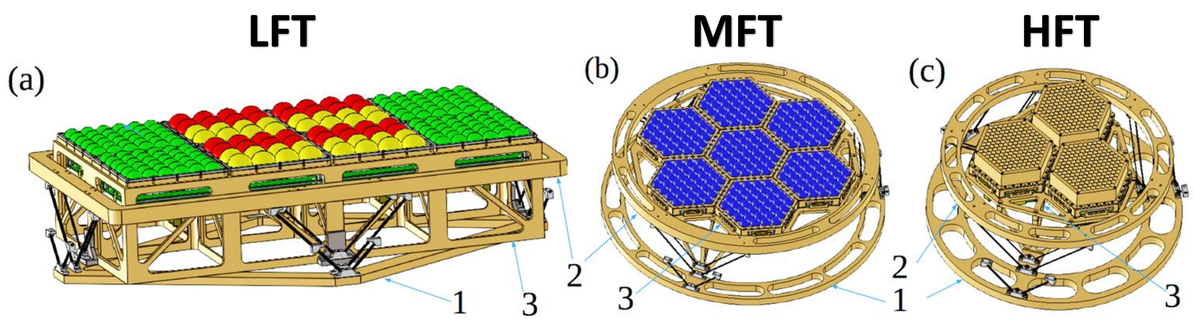
The U.S. team will contribute all focal planes with detector modules, cryogenic readout electronics, adiabatic demagnetization refrigerators, data management, and data analysis

The U.S. team allocated tasks among institutions according to their expertise as following:

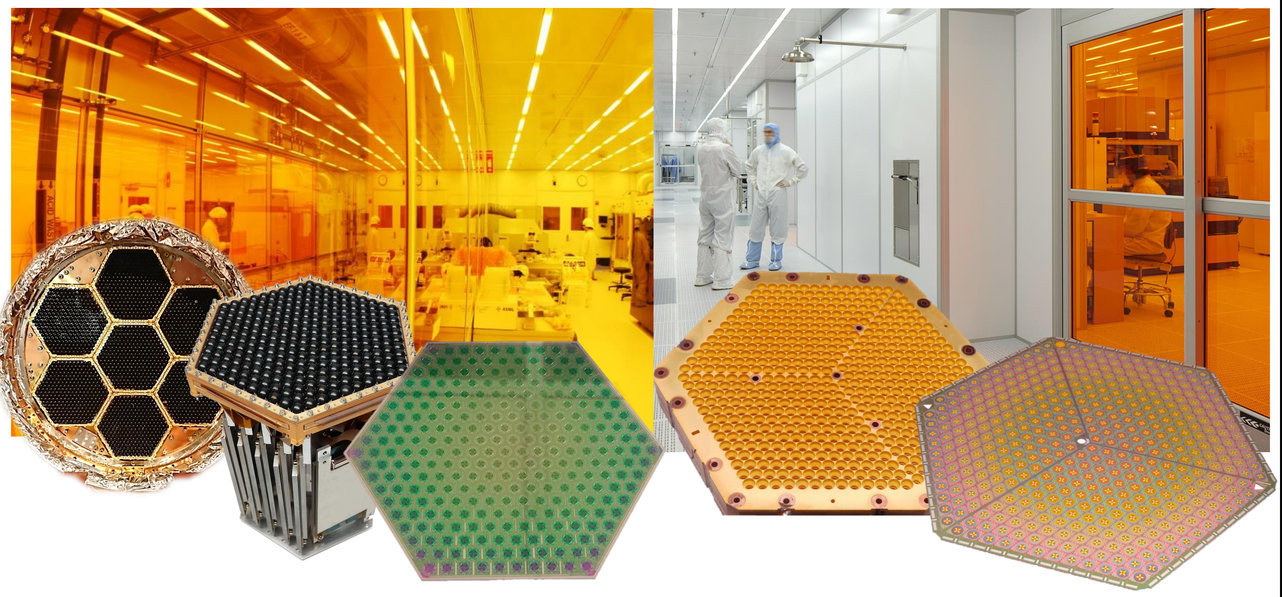
- U.C. Berkeley (Lead institution) – Detector fabrication, integration and test, data management
- NASA Goddard Space Flight Center – Adiabatic demagnetization refrigerator
- NIST – Detector fabrication
- Stanford – Focal plane structure and detector module characterization
- U.C. San Diego – Cryogenic readout electronics
- U of Colorado – Detector module characterization

The U.S. team is currently in a technology development phase supported by NASA. We are raising technology readiness levels by designing, simulating, fabricating, and testing U.S. contributed parts

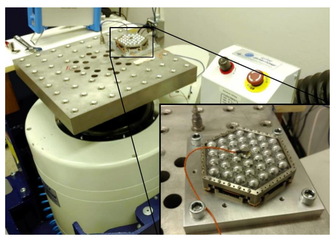
Focal Planes and Detector Module

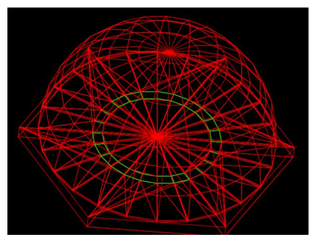


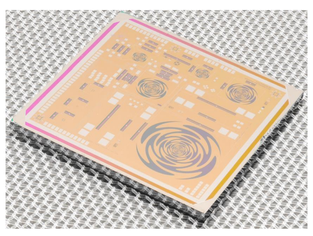
LiteBIRD instrument will have three focal planes (LFT, MFT, HFT)
LFT and MFT will use lenslet coupled sinuous antenna technology to utilize its broadband pixel performance. HFT will use horn coupled detector for its high TRL in high frequency channels.
Support structure is designed to achieve high thermal isolation, low mass, and high stiffness

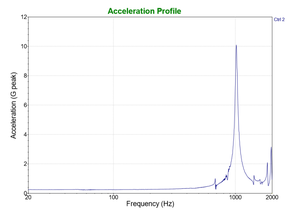


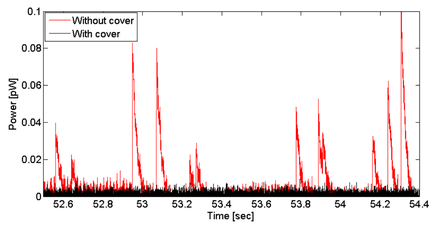
Detectors will be fabricated at U.C. Berkeley Marvell Naofabrication Laboratory (Left) and NIST Boulder Microfabrication Facility (Right). The combined teams have fabricated a large fraction of CMB detectors deployed in the field, including: AdvACT, ACT-Pol, SPT-Pol, SPIDER, APEX-SZ, POLARBEAR-1, EBEX, POLARBEAR-2/ Simons Array

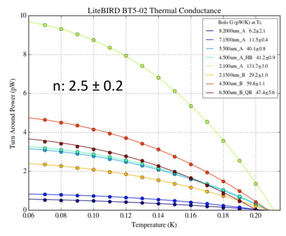








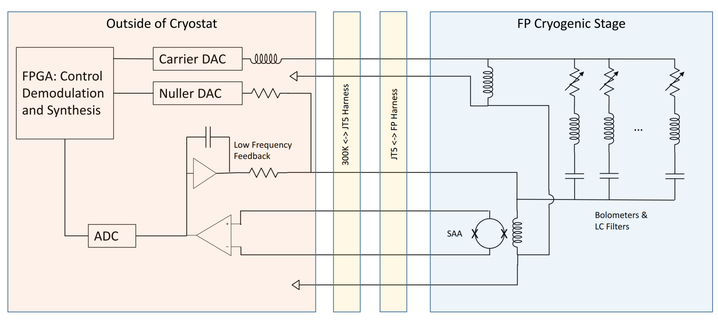




We are working on satellite mission specific challenges to raise Technology readiness level. They include:

- (Left) Vibration resonance and survivability test
- (Center) Cosmic ray mitigation
- (Right) Optimize TES bolometer design for low optical loading condition

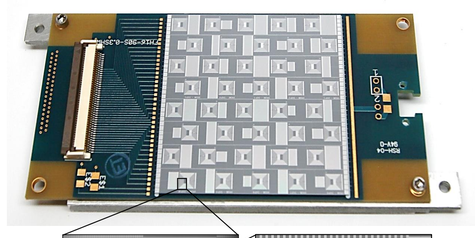
Cryogenic Readout Electronics



Transition Edge Sensor detectors will be readout by digital frequency multiplexing readout (DfMUX) technology.

Multiplexing saves on electrical power consumption, cryogenic cooling power requirement, and total mass. LiteBIRD will read out ~100 detectors with a cryogenic amplifier.

This readout technology has been deployed in multiple sub-orbital experiments including a balloon experiment. U.S. team members played key roles in the development of the readout technology for these experiments.



Superconducting resonators

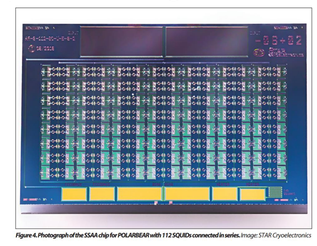
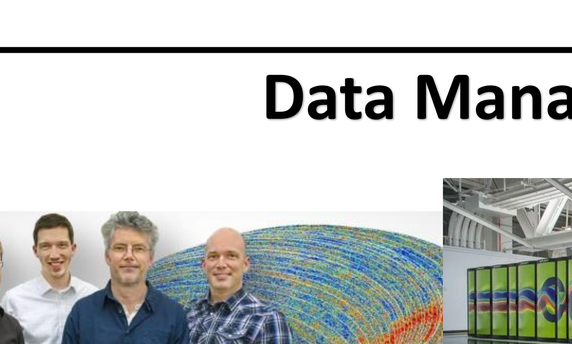


Figure 4. Photograph of the SSAA chip for POLARBEAR with 112 SQUIDs connected in series. Image: STAR Cryoelectronics

SQUID amplifier

1.8 Kelvin Continuous Adiabatic Demagnetization Refrigerator



LiteBIRD cryo chain

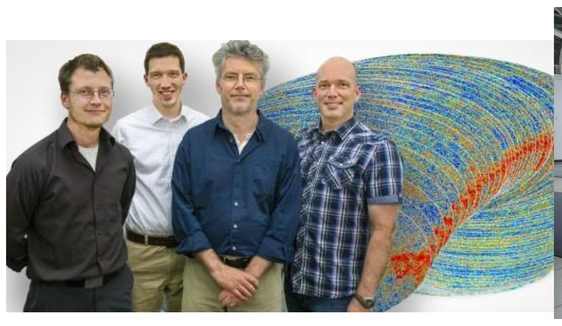
3-stage ADR

The Litebird instrument involves a series of refrigeration stages extending from room temperature to the focal planes at 100 mK. The cryo chain is divided as follows:

1) Stirling and Joule-Thomson (JT) cryocoolers provided by JAXA for the 4.5 Kelvin stage
2) Continuous ADR provided by NASA for the 1.8 Kelvin stage
3) An ADR provided by CEA will produce cooling at 300 mK and 100 mK for the focal planes

NASA GSFC will provide a 1.8 Kelvin ADR that will be the bridge between the CEA ADR and the JAXA JT cryocooler. The 1.8 K ADR will use three ADR stages, identical to one of the stages built for Astro-H (Hitomi), to achieve continuous cooling at 1.8 K and to accommodate the periodic heat flows from the CEA ADR

Data Management



Data management team members

NESRC cluster

National Energy Research Scientific Computing Center (NERSC) will be a center for high performance computation that is necessary for success of the mission. NERSC center has been used by most of ground based CMB experiments and satellite missions including the Planck CMB satellite mission.

Data management/analysis team is developing a pipeline to simulate various scenarios to understand how non-idealities in the system will affect final data.