# THE CANADIAN CONTRIBUTION TO THE LITEBIRD MISSION


Academic Affiliations

McGill University · University of Toronto · The University of British Columbia

Industrial Partners

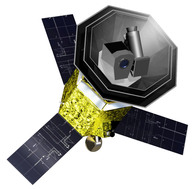
Honeywell — The Power of Connected · Three Speed Logic

Supported By

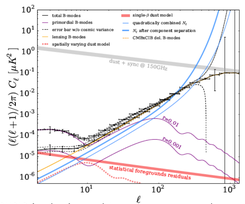
Canadian Space Agency / Agence spatiale canadienne


## Partners in LiteBIRD Science & Technology

The Canadian team is funded to plan **hardware** and **science** contributions to the LiteBIRD Cosmic Microwave Background (CMB) Polarization Survey.



The LiteBIRD Satellite



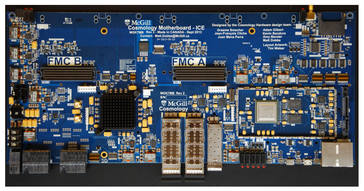

LiteBIRD is designed to measure or place the best upper limit on the signature of gravity waves from inclation.

Canadian scientists have been at the forefront of CMB science, including roles in breakthrough experiments such as the Cosmic Microwave Background Explorer (**COBE**), Wilkinson Microwave Anisotropy Probe (**WMAP**) and **Planck** satellite missions. Canadian researchers also play critical roles in ground-based observatories such as the **South Pole Telescope**, **POLARBEAR2/Simons Array**, and **Atacama Cosmology Telescope.**

Canadians are global leaders in Cosmic Microwave Background (CMB) **instrumentation**, and have spent years preparing our technology for a satellite mission such as **LiteBIRD**.

The POLARBEAR Telescope (Photo: J. Errard)

The South Pole Telescope (Photo: J. Montgomery)



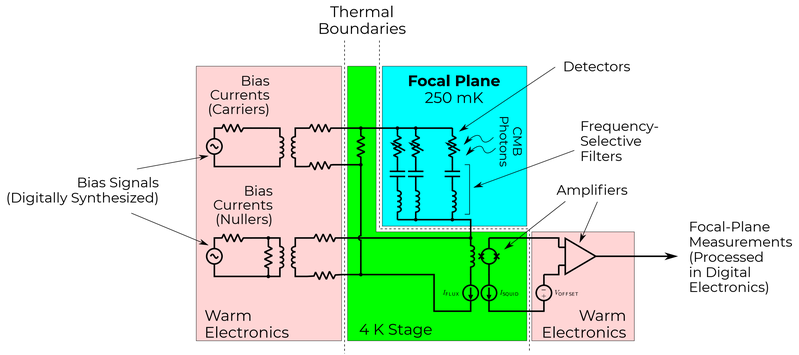

McGill's "IceBoard" Signal Processing Platform

## Digital Frequency-Domain Multiplexing (DFMUX) Technology

**Multiplexing** is a technique for biasing and measuring many detectors using only a few electrical conductors. Multiplexing is an essential part of the technological advancement of CMB telescopes, which require more and more detectors to achieve increasingly complex science goals. Without multiplexing, it would be impossible to keep LiteBIRD's focal plane cold.

Canadian **Dfmux** technology achieves multiplexing by assigning each detector a distinct frequency, similar to how many radio & television channels coexist on a single cable connection.

Experiments using frequency-domain multiplexing technology have been continuously deployed in telescopes around the world since 2005. Dfmux is currently operating in the **POLARBEAR2/Simons Array** in Chile and at the **SPT-3G** experiment in Antarctica.




A schematic of the cold electronics in a **Dfmux** system. Detectors act as time-varying resistors. Each detector is assigned a distinct frequency using a filter circuit. This filter allows bias signals to independently operate and measure each detector, even when many detectors share on a single set of wires. As a result, the number of conductors spanning thermal stages is minimized.

## DFMUX Technology for LiteBIRD

In 2018, with support from the **Canadian Space Agency (CSA)**, we completed a **Mission Contribution Study (MCS)** describing the architecture of a complete Dfmux readout tailored to **LiteBIRD**. This readout centers on two units: the **Signal Processing Unit (SPU)**, and the **SQUID Controller Unit (SCU)**.

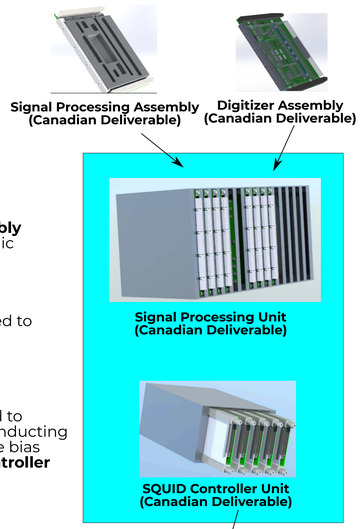
**1.** Electronics on the spacecraft receive commands from the ground and instruct the readout electronics to tune the focal plane.

**2.** Bias signals for the detectors are digitally synthesized within the **Signal Processing Assembly** using a programmable logic chip called an **FPGA**.

**3.** Bias signals are converted to analog currents within the **digitizer assembly**.

**4.** Control currents needed to manage sensitive superconducting amplifiers are added to the bias currents in the **SQUID Controller Unit**.

**5.** Bias currents pass through the detector array. As light from the CMB influences each detector on the **focal plane**, it leaves an electrical imprint of the sky signal on the bias currents passing through.

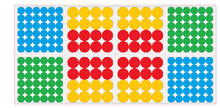



**9.** Science data is streamed from the Signal Processing Unit to spacecraft electronics for storage and downlink.

**8.** Algorithms in the **Signal Processing Assembly** recover, demodulate, and separate the sky signals from each detector on the focal plane.

**7.** Analog currents are converted to digital form by the **Digitizer Assembly**.

**6.** The received currents, which are extremely faint, are amplified in the **SQUID Controller Unit**.



**Focal Plane (LFT shown)**

## Canadian Involvement in LiteBIRD Science

Canadians have been involved in all 3 of the previous CMB satellite missions (**COBE**, **WMAP** and **Planck**), as well as most of the international ground-based and balloon-borne CMB projects (**BAM**, **Boomerang**, **EbEx**, **POLARBEAR, Spider**, **ACT**, **SPT**, and others.)

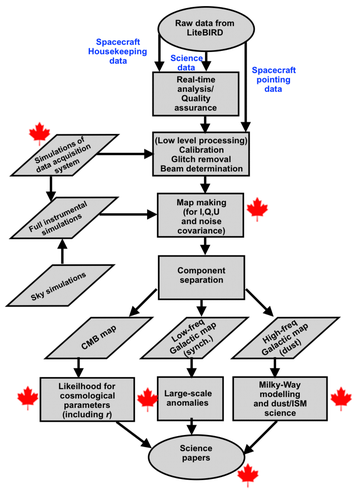
The Canadian team anticipates supporting the mission with personnel to:

**1.** Provide mission **simulations** to optimize the mission design, mapping instrument requirements and performance parameters onto science outcomes with a focus on the Canadian readout system and overall mission architecture.

**2.** Co-develop the software and real-time analysis tools to monitor the science **payload health** and assess the **performance** of the mission on fast (hourly, daily, weekly) timescales.

**3.** Co-develop the **processing pipeline** for **map-making and foreground separation**, in collaboration with the international team.

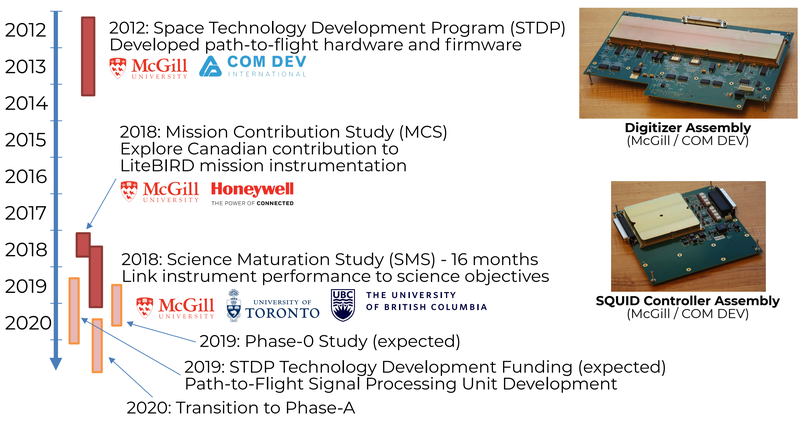
**4.** Develop software to **fit cosmological parameters, interpret the results**, and combine the data with ground-based mm-wave telescopes in collaboration with the international LiteBIRD team.




Planned Canadian contributions to the Mission operations and science are highlighted with Maple Leaves.

## Science & Technology Development to Date

The Canadian LiteBIRD instrumentation team has a history of successful partnerships with the **Canadian Space Agency (CSA)** and colleagues in industry.






**Digitizer Assembly**
(McGill / COM DEV)



**SQUID Controller Assembly**
(McGill / COM DEV)

We have developed **flight-representative prototypes** for the **SQUID controller** and **digitizer electronics** needed for a satellite mission such as LiteBIRD. We also developed radiation-mitigation technology that detects and corrects errors induced by radiation in digital logic.

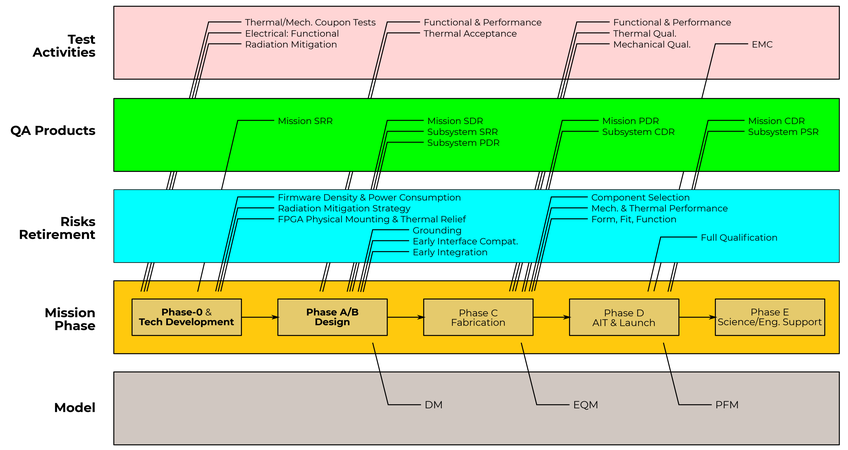
Dfmux readout with **radiation-mitigation technology** flew in the **EbEx** stratospheric balloon experiment in 2012. The radiation environment experienced by EbEx informs the design choices for LiteBIRD.

Dfmux **electronics and firmware** have advanced significantly over the past few years. Advanced radiation mitigation design techniques are being implemented for the FPGA firmware. Strategies to flag and subtract **cosmic rays** in detector timestreams are being developed.

## Planning for the Future

The next steps for the Canadian team are:

- **Summer 2019 (8 months)**: CSA funded Phase-0 study, to develop and cost the contribution plan;
- **2019 (18 months)**: CSA funded Technology Development, to support de-risking of instrumentation and development of the Signal Processing Assembly Demonstration Model
- **2020**: Transition to Phase-A activities.




The **Development Approach** for Canadian LiteBIRD deliverables. To track the international LiteBIRD schedule, and to retire development risks early, **prototype hardware development must be delivered early** in the program.