# The BABAR-ERI Instrument
# Benefits, Applicability, and Readiness for Earth Science


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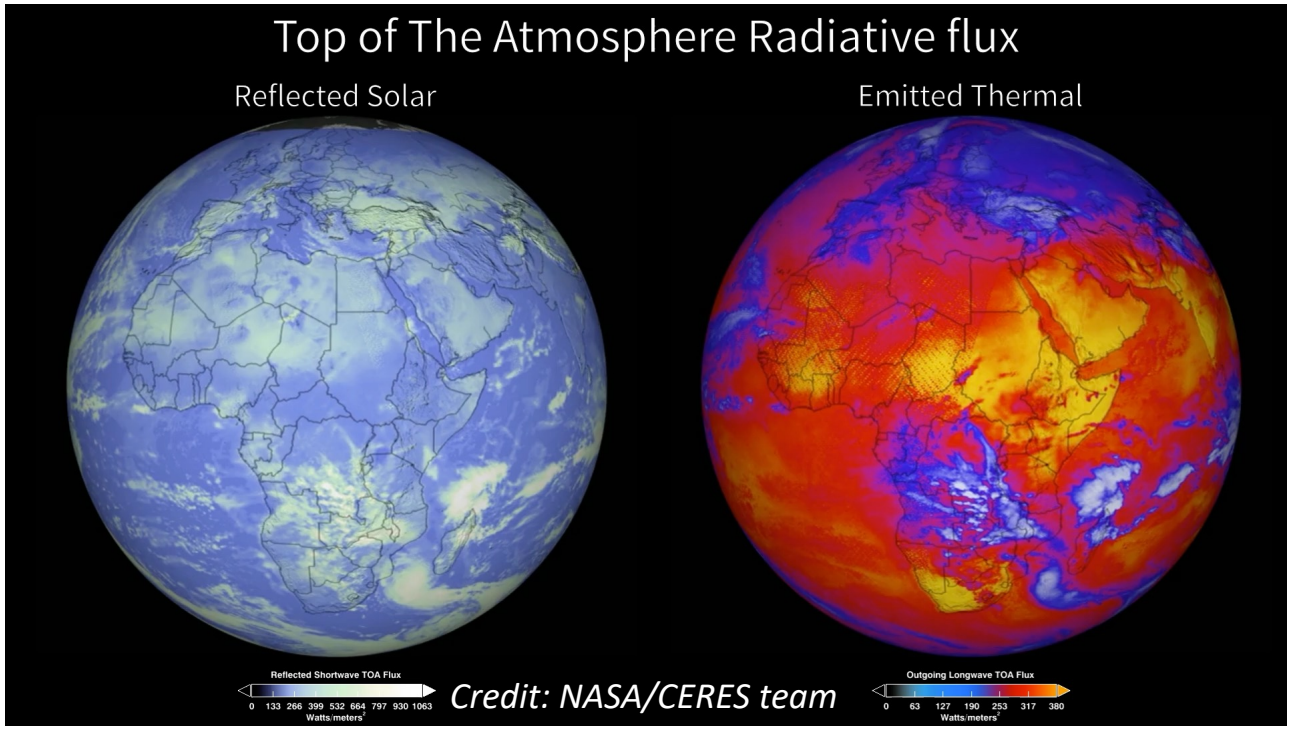
# The Earth Radiation Budget (ERB) Record

Broadband radiation budget measurements are the Program of Record for the *detection* and *attribution* of climate change

*[NASA Decadal Survey, 2017]*.

NASA/CERES has acquired the daily, global, ERB since 1997.
The Libera mission follow-on will commence in 2027.

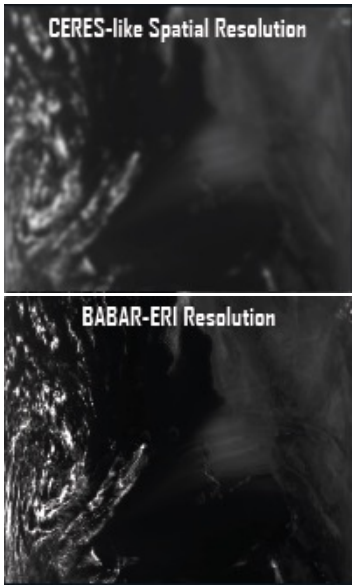


# BABAR-ERI

## Black Array of Broadband Absolute Radiometers – Earth Radiation Imager

### Providing key advances in measuring outgoing broadband radiation

32-element array of micromachined silicon, electrical substitution radiometers with high-efficiency broadband carbon nanotube absorber.


**Detection & Attribution**

**· Absolute calibration each pixel · 1 kHz imaging speed · Ambient Temperature · 1 km footprint imaging**

**Ensuring Continuity**

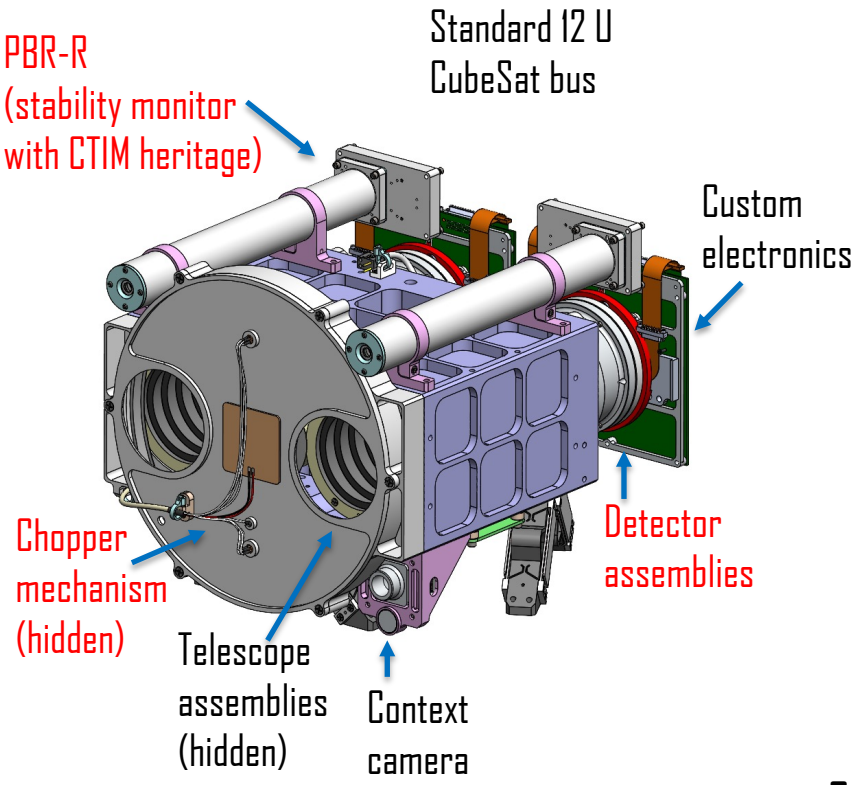
**· Absolute sensors (CTIM heritage) for stability monitoring**

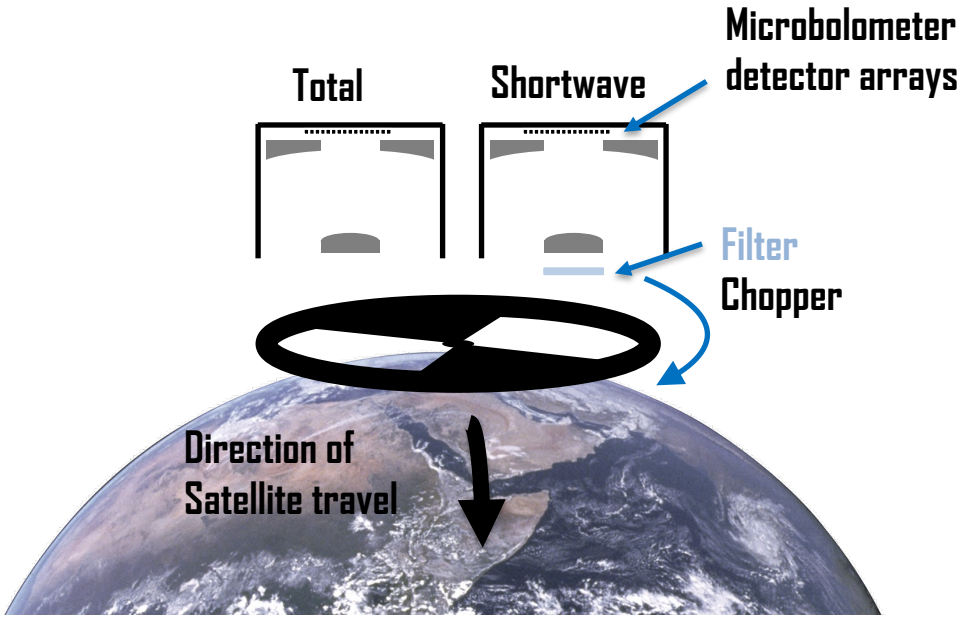
**· Small volume, weight and power**

Reduces risk of data gaps by enabling flexible observing and implementation strategies. Degradation tracking/correction from a single platform at the footprint-level.

# Basic Instrument Design

## A 2019 NASA ESTO Instrument Incubator Program (IIP) award




* *Innovative Components*

**8" (wide) x 8" (tall) x 9.25" (deep)**

**· Pushbroom Imager · 2 Cassegrain Telescopes**

**· 32-element arrays · Electrical Substitution at Each Pixel**

**· Co-registered Footprints · Simultaneous Total and Shortwave Imaging**

**· Longwave = Total - Shortwave**

# Requirements & Predicted Performance

The requirements for ERB-science are Radiation Budget Science Working Group criteria.

| **Instrument Requirements** | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | Field of View | Spectral Range [µm] | Dynamic Range [W/m²/sr] | Noise [W/m²/sr] | Accuracy [%] | Stability [%/year] |
| Performance | 20 km | SW: 0.3-5 | SW: 350 | 1 | SW: 1.0 | <0.03 |
| | | LW: 5-50 | LW: 450 | | LW: 0.5 | |
| | | TOT: 0.3-50 | TOT: 500 | | TOT: 0.5 | |
| Predicted Performance | 32x1km (binned to 20 km) | SW: 0.3-4 | SW: >350 | < 0.1* | SW: <1.0** | <0.01 (goal) |
| | | LW: 4->100 | LW: >450 | | LW: <1.0** | |
| | | TOT: 0.2->100 | TOT: >500 | | TOT: <1.0** | |

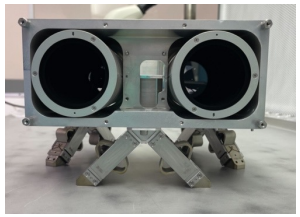
* From a demonstrated noise equivalent power of < 70 pW/ √Hz up to 10 Hz equating to noise equivalent radiance of 0.03 W/m²/sr, when coupled with BABAR-ERI telescope and 7-Hz chopper.
** Accuracy limits are to be determined over the next year of the IIP development.

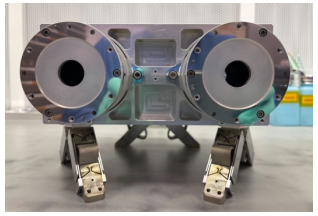
# Status & Schedule

## All key technologies are in integration & test.

**Integration & Test**

- Chopper Life Test
- Telescope Alignment
- Detector Characterization
- Component Calibrations (mirrors, filter, VACNT)

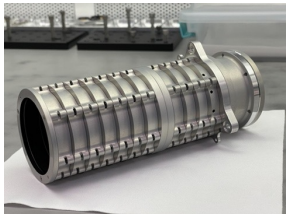




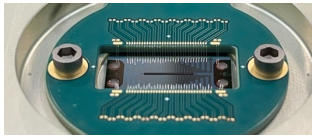
Front (left) and back (right) of optical bench on bipod struts.

**In Development & Production**

- Blackbody Sources (x2)
- Flight PBR-R detectors (x2)
- Camera Optical System



Telescope assembly

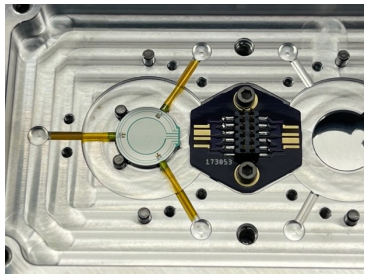


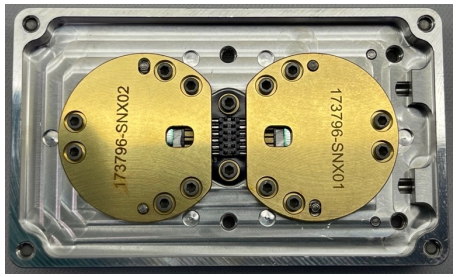
32-element microbolometer ESR

Chopper wheel w/ Singularity paint

**Project Completion**

Key Technologies at TRL 5, Aug. 2023
Final Calibrations~ Mar. 2024
Complete System at TRL 5, Mar. 2024





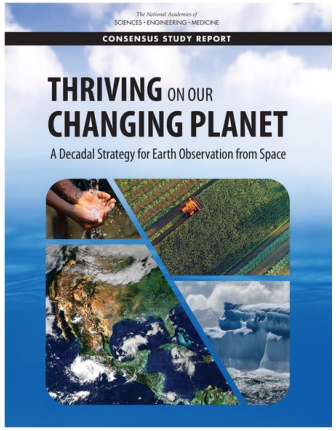

PBR-R Detector Engineering Model: 1.5” x 2.5”

# Mission Concepts & Science Objectives

Addressing key science objectives that demand enhanced spatial resolution and accuracy in measuring outgoing broadband radiation to reduce uncertainty in future climate warming and climate intervention strategies.

## From a Single Instrument…

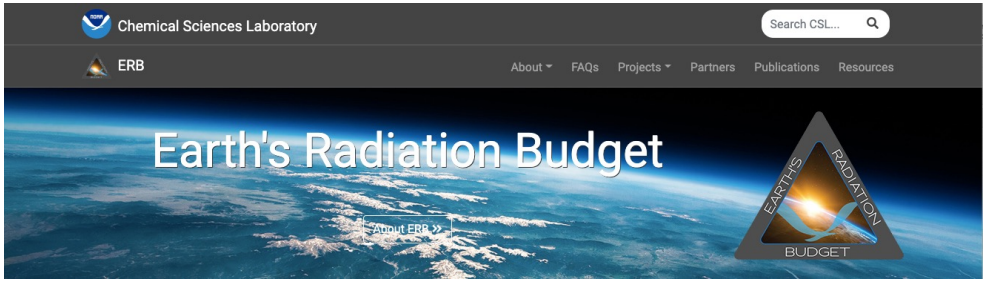
- Improve the process-level understanding of climate drivers (clouds, aerosols)
  - Reduce the uncertainties in climate forcings & feedbacks
- Pathway to observe impacts of future climate intervention strategies
- Validation of CERES, Libera, MODIS and/or VIIRS
- Flexibility in "targeting" specific Earth-locations (via ground-commanding)



NASA Decadal Survey

## …To an Instrument Constellation…

- Increase the information content (spatial resolution, accuracy) of ERB observations
- Enhance temporal coverage of ERB record



NOAA Earth Radiation Budget Initiative

# Summary

- **The BABAR-ERI instrument is the first step towards a low-cost strategy for remote sensing observations and long-term continuation of Earth radiation budget measurements with enhanced spatial and temporal resolution and stability monitoring.**
  - Will observe broadband radiation at the spatial scales typical of spectral imagers
  - Designed from the outset as a small volume, weight, and power instrument to facilitate more implementation strategies.
    - **Payload Estimates**
      - ◎ **Size: 12 U**
      - ◎ **Power: 30 Watts**
      - ◎ **Mass: 25 kg**

- **Key Technologies at TRL 5 in Aug. 2023**

# Backups

# Calibration Plan

## Measurement equation relating measured Power ($P$) to Radiance ($L$).

$$L = \frac{1}{R_M^2(\lambda)T_F(\lambda)\alpha(\lambda)} \frac{P - P_D}{A\Omega}$$

**Component Level Calibrations**

- Optical witness sample characterization
- Telescope area-solid angle product
- Detector Characterization

**End-to-End Calibration**

- Absolute Spectral Response Calibration
- Absolute Reference Detector: 0.3-15 μm
- Absolute Blackbody Sources (x2): 15-100 μm

**Absolute Reference Detector**

- Planar Bolometric Radiometer for Radiance (PBR-R)
- Ambient Temperature VACNT ESR detector (i.e., CTIM)
- SI-traceable to NIST POWR via calibrated trap detector
- Also used in tracking/correcting on-orbit degradation