RADIATION BUDGET INSTRUMENT (RBI): FINAL DESIGN AND INITIAL EDU TEST RESULTS

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Agenda

Radiation Budget Instrument (RBI) mission

Key requirements for RBI mission

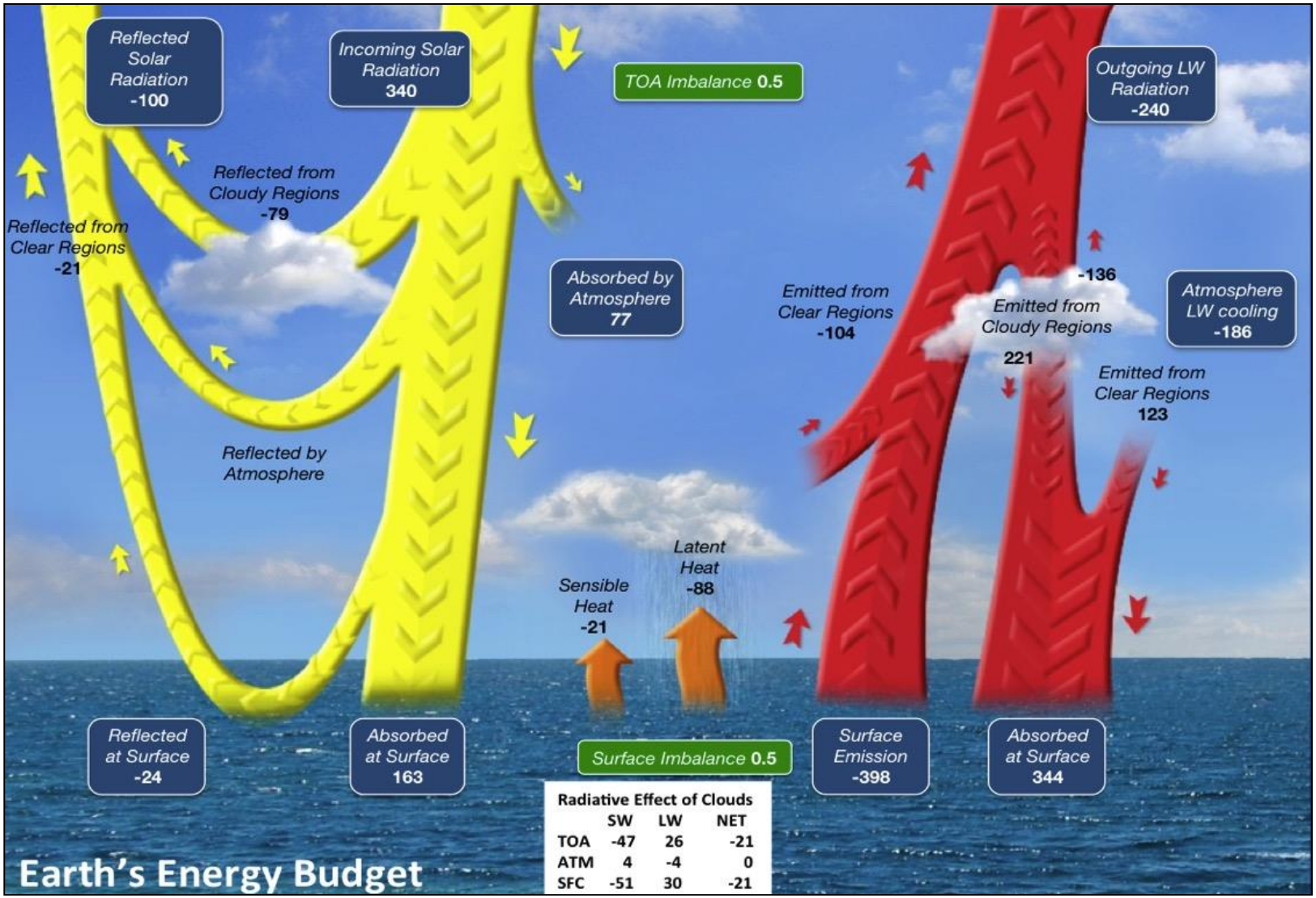
Final instrument design (recent changes)

Engineering Development Unit (EDU) test results

Updated RBI predicted performance

4:20: Progress in Meeting the Challenges of the RBI Spectral Calibration
James Peterson, Harri Latvakoski, Greg Cantwell, James Champagne, Joel Cardon – USU/Space Dynamics Laboratory

RBI's Mission: Earth's Radiation Budget Measurement Continuity



RBI Mission Summary

Scanning radiometer measuring Earth's radiation budget

- Measures reflected sunlight and emitted thermal radiation
- Extends global measurements provided by Clouds and the Earth's Radiant Energy Systems (CERES) instruments

Will fly in LEO on JPSS-2

Full coverage flexibility

- Cross-scan: swath of Earth, space, and internal calibration targets
- Azimuth rotation: bi-axial views of Earth, lunar cal, and solar cal
  - Observe all parts of Earth at every observation angle, not just cross-scan
- Intensive observation tracking single spot on Earth

Standard scan designed to match CERES

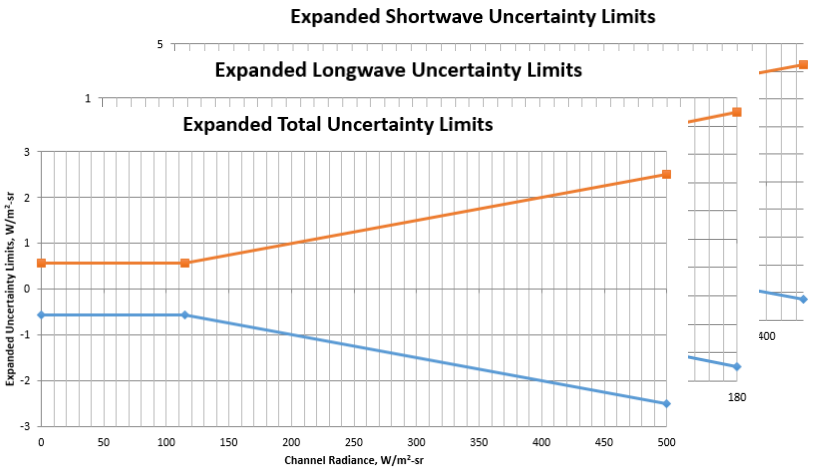
- Scan rate = 63.1 degrees/second
- Frame rate = 100 Hz; angular sample distance @ nadir = 9.1 km
- IFOV @ nadir: 37.4 (along track) x 18.7 km (cross track), hexagonal
- 6.6 s repetition interval (scan across and back)

Key Requirements Drive Calibration and Traceability to CERES

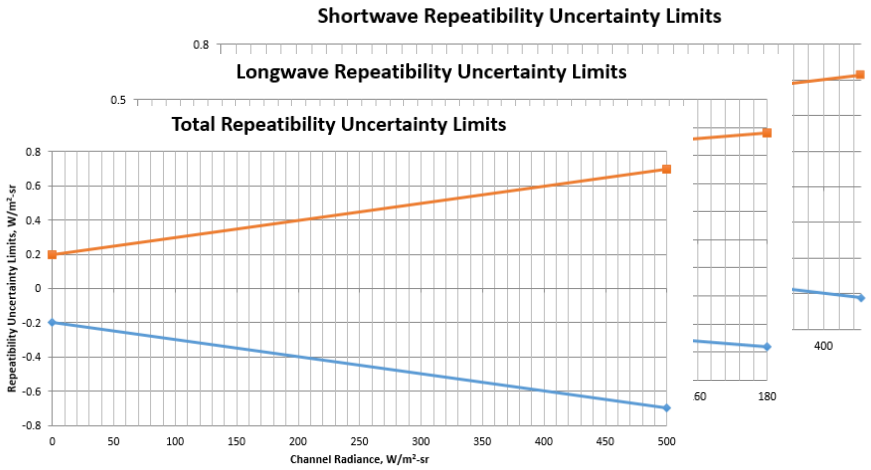
Radiometric uncertainty and repeatability

- Shortwave (SW), longwave (LW) and Total (TOT) channels

Long-Term Uncertainty



Repeatability



Relative spectral response by channel

- SW: 0.2 - 5 µm; LW: 5 - 50 µm; TOT: 0.2 - 100 µm

Point spread function (PSF): 95% match to CERES

Channel-to-channel registration of 98%

Calibration sources for SW, LW and solar calibration

Radiation Budget Instrument

Collects upwelling earth radiance over a wide spectral range

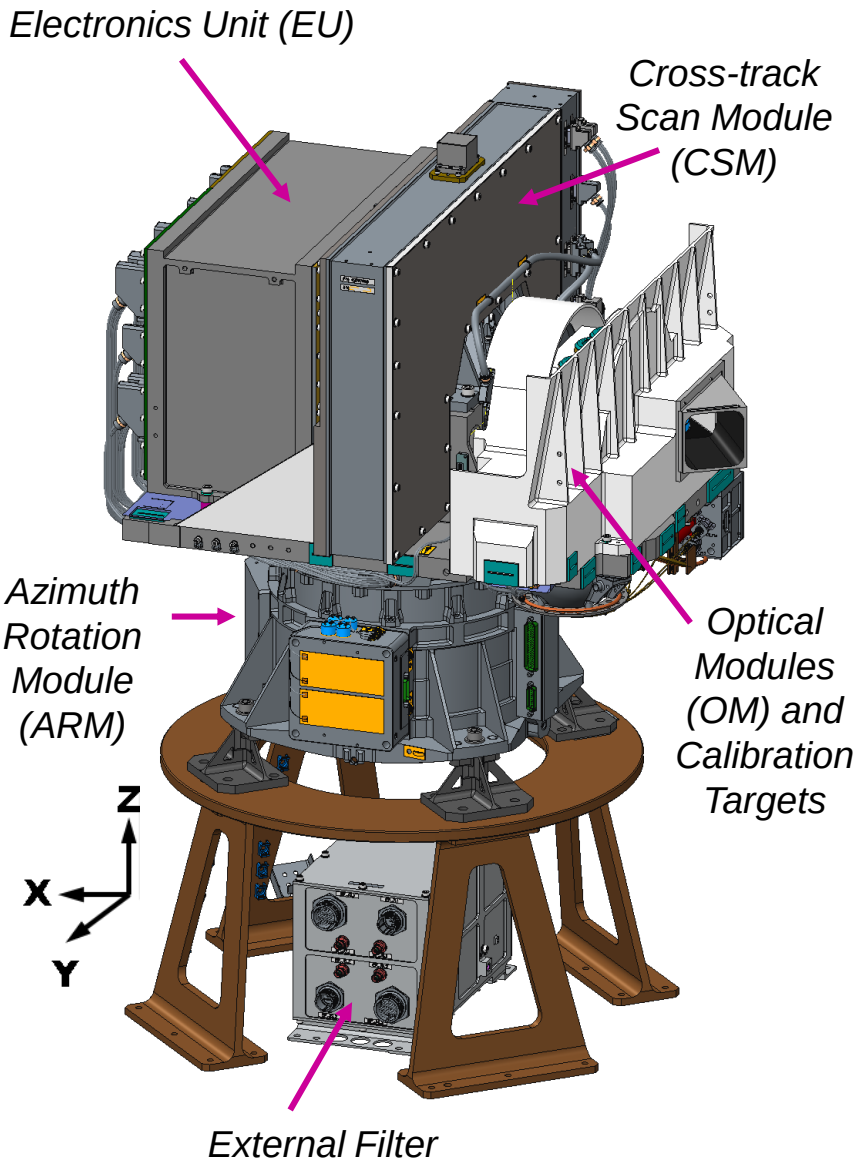
- Ultraviolet to far-infrared (100 µm)
- Continuous cross-track scans

Three spectral bands

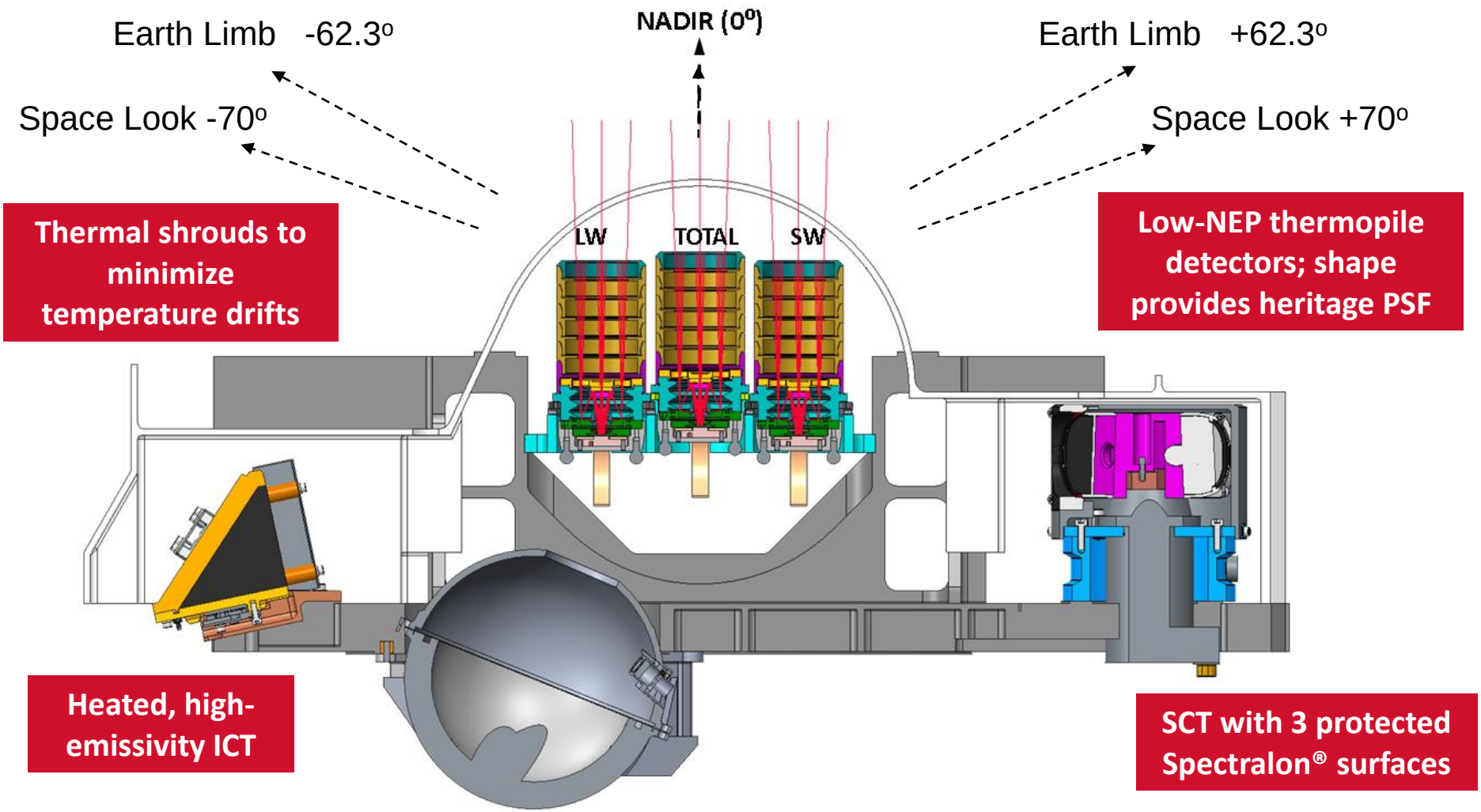
- Shortwave (SW): reflected solar energy
- Longwave (LW): emitted Earth energy
- Total (TOT): sum of reflected and emitted
- One telescope per band simplifies detectors and operations

Very precise calibration

- Extensive ground calibration program sets the calibration
- Multiple onboard targets maintain calibration over mission life



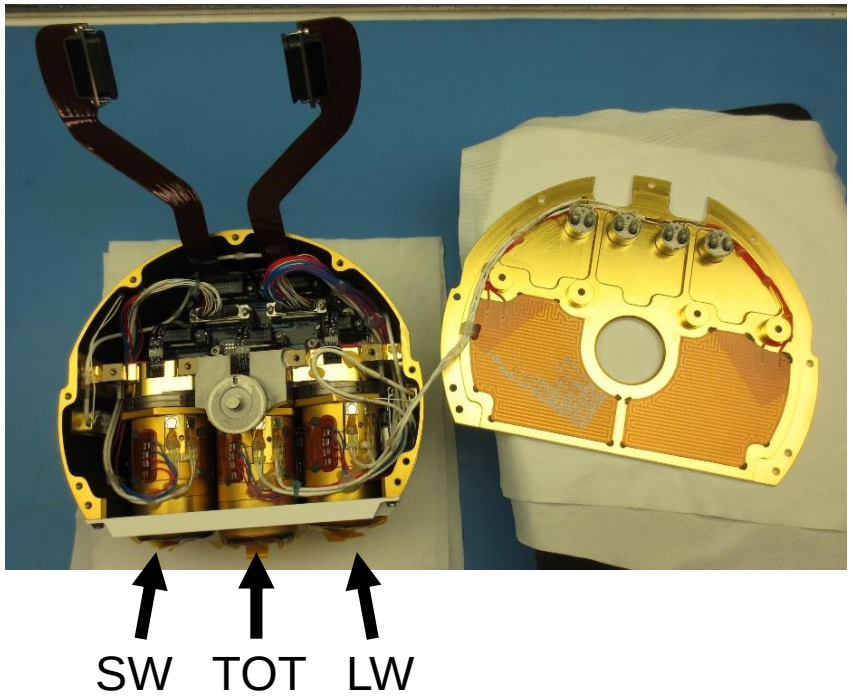
Optical Module and Targets Designed for Stability and Accuracy



Optical Module Overview

- **Focuses photons on the detector and converts to bits**
- **Minimizes stray light**
- **Provides low noise linear conversion of radiance to bits**
- **Athermalized design provides a stable uniform environment for low noise detectors**
- **Provides spectral selection into three bands**
- **Thermal control provides for long term stable environment**

RBI EDU



Robust VCT Architecture Ensures NIST Traceable Radiometric Scale Is Provided Over Mission Life

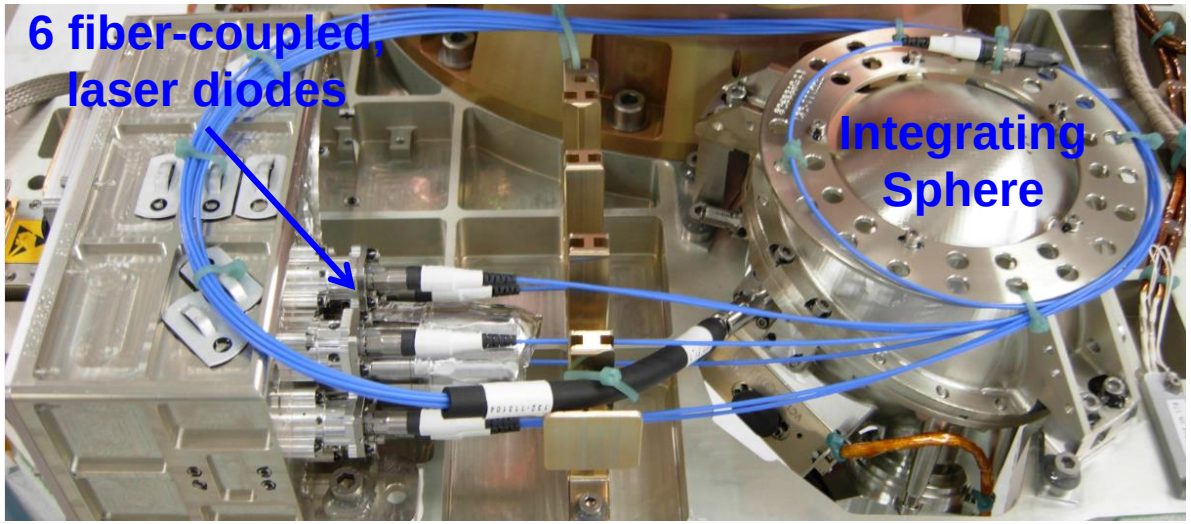
VCT provides six narrow band sources

- Wavelengths: 375, 405, 445, 680, 915, and 1470 nm
- Band source 680 nm changed from 690 nm due to availability
  - Additional benefit is higher power, hence improved calibration

Si and InGaAs photodiodes monitor sources and provide quick radiance reference

Electrical Substitution Radiometer (ESR) provides stable, long-term, absolute, NIST- traceable measurements

- Used monthly to calibrate SW and TOT channels and VCT's monitoring photodiodes



ICT Provides High-Quality Radiance Standard for Infrared Bands

Onboard, stable, and uniform infrared radiance standard for LW and TOT channels

- Similar designs flying on GOES-R ABI, Himawari-8/9 and NPP CrIS

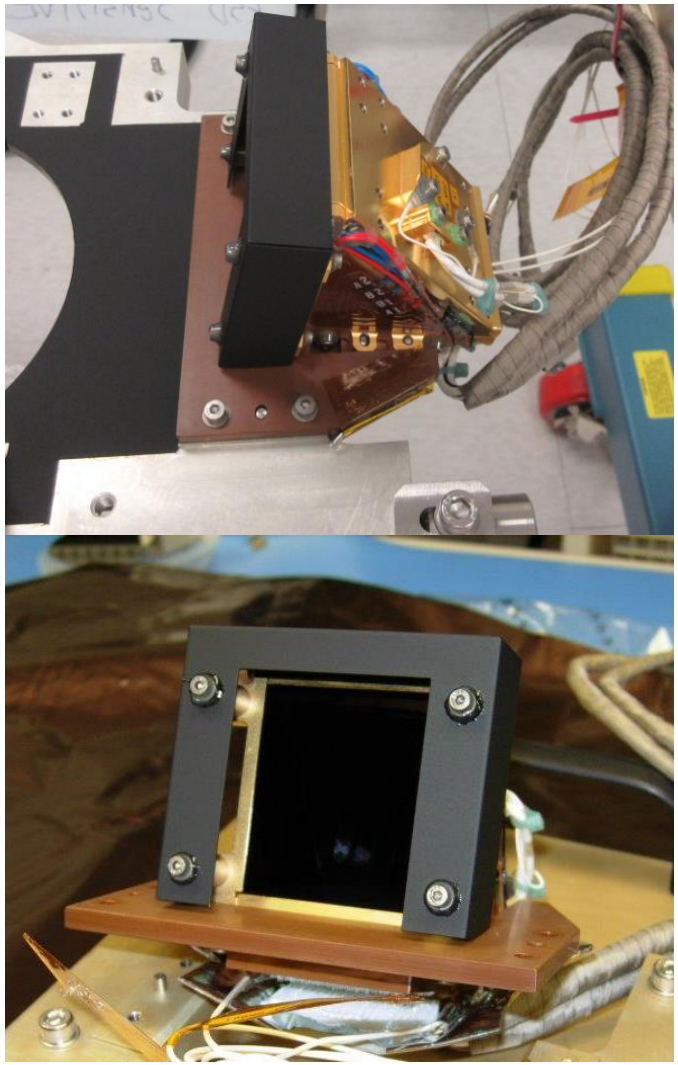
Characteristics:

- Highly stable emissivity
- Known, stable surface temperature
  - Commandable temperatures
  - Closed loop control
- Yields stable, known radiance
- Results in low radiometric uncertainty

Provides daily calibration and monthly linearity testing

NIST traceable standard

- Platinum resistance thermometers (PRTs) calibrated to ITS-90 scale
- ICT paint calibrated to gold reference standard



EDU ICT (3-bounce blackbody)

Solar Calibration Target (SCT) Provides Indirect Solar Illumination to RBI For Trending

Secondary calibration visible monitor for TOT and SW channels

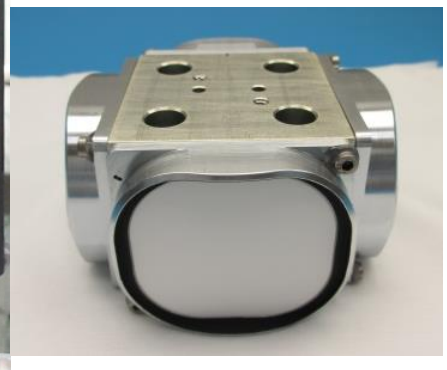
- Used for long-term trending, not absolute calibration

Full aperture source of diffusely reflected solar spectral irradiance

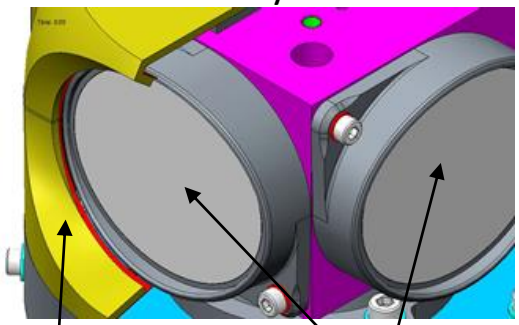
Cover protects Spectralon surfaces from contamination

Three diffusers used to monitor Spectralon reflectance degradation over life

- Daily, quarterly, and yearly



Cutaway View



RBI Calibration Ensures Radiometric Performance Compliance Over Mission Life

Daily calibration: maintain short-term repeatability

- TOT and SW channels view Visible Calibration Target
- TOT and LW channels view Infrared Calibration Target

Monthly calibration: maintain long-term uncertainty

- Electrical Substitution Radiometer calibrates Photodiodes in VCT
  - Multiple illumination levels used to characterize linearity/gain for TOT and SW
  - Laser diodes at multiple wavelengths used to characterize spectral response of Vis/NIR portion of TOT and SW
- Multiple illumination (temperature) levels of blackbody source used to characterize linearity/gain for TOT and LW

Additional collections:

- Lunar images – map field-of-view response
  - Once a month, several orbits per day, two to three days near full moon
- Solar calibration – long term trend of response
  - Measurements daily, quarterly, and annually

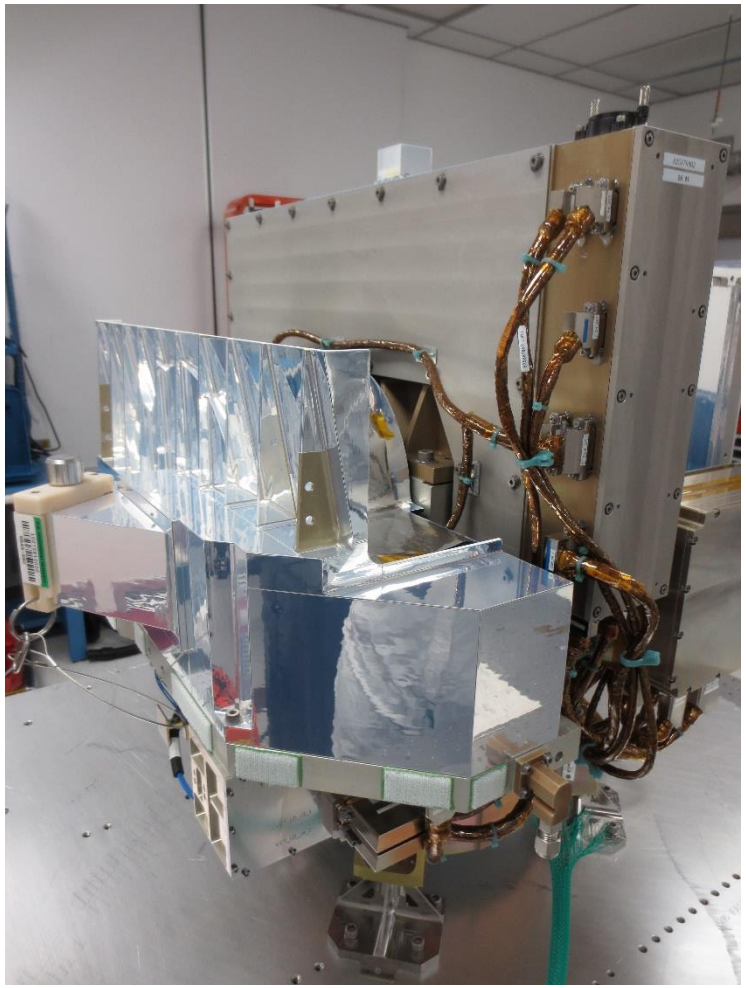
EDU is Pathfinder for Flight; Reduces Technical and Schedule Risks

Benefits:

- Pathfinder for calibration
  - Radiometric design virtually identical to RBI flight design
  - Manufacturing processes validated
  - Performance requirements demonstrated
  - Calibration approach demonstrated
- Pathfinder for test execution
  - “Dry Run” of TVAC test program
- Protects flight schedule
  - Early discovery allows response time to incorporate into flight payload

Status:

- EDU bench testing completed
  - Results provided in following charts
- EDU TVAC testing ready to begin



EDU Bench Testing

EDU Bench Test Performance Demonstrates Readiness To Proceed to TVAC Testing

	TOT	SW	LW	Units
Responsivity	182*	282	272	counts/ ($W/m^2/sr$)
Noise viewed at park (measured)	20	20	20	counts
NER unfiltered in ambient (expected**)	<0.19	<0.12	<0.12	$W/m^2/sr$
NER unfiltered in ambient (measured)	0.11	0.071	0.071	$W/m^2/sr$
NER unfiltered in TVAC (estimated)	0.033	0.021	0.021	$W/m^2/sr$

* Total channel responsivity intentionally lower than SW or LW since it has a larger dynamic range requirement

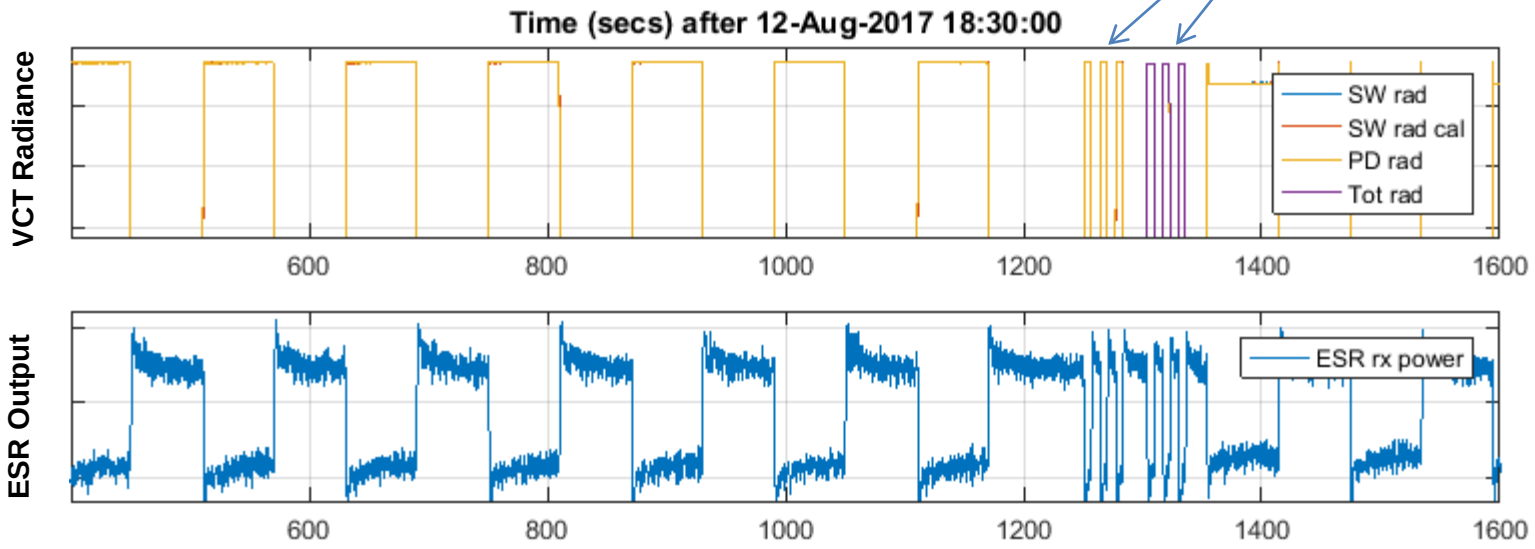
** Based on Radiometric Test Model (RTM) testing in TVAC and at ambient pressure

RBI uses 18-bit A/D converter

All measured responses and noise levels are as expected

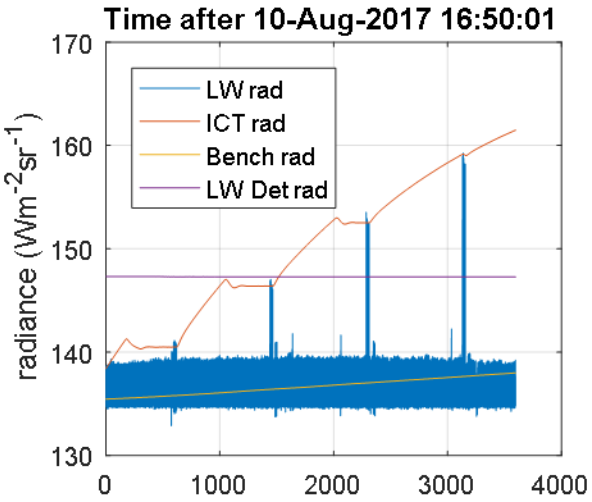
VCT Performance Is As Expected

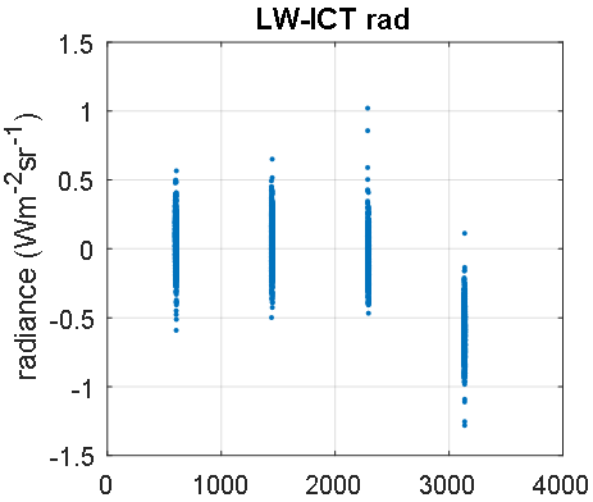
Photodiode radiance agrees very well with TOT and SW



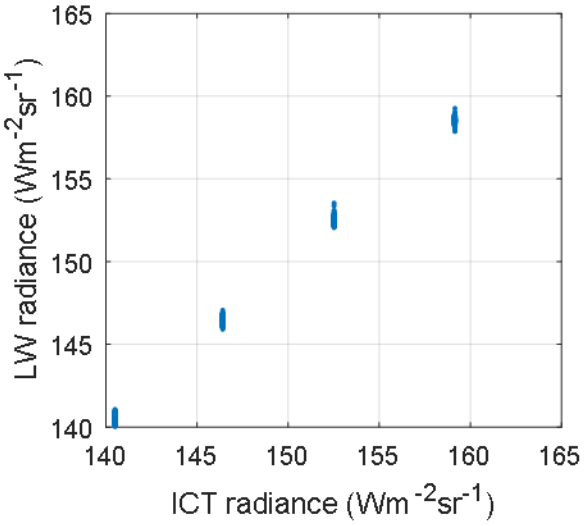
All measured responses are as expected

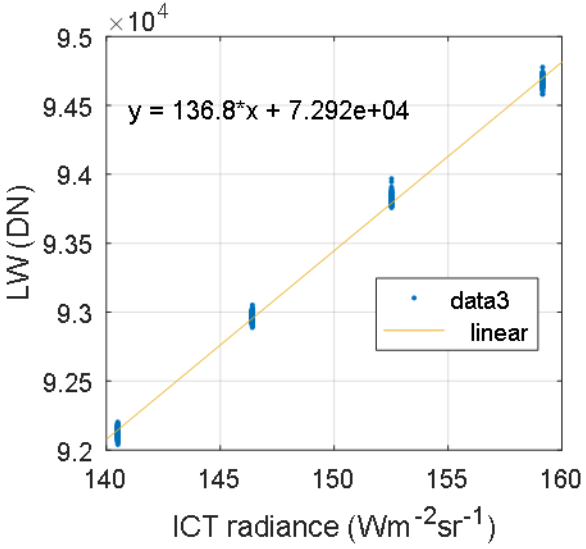
LW Performing As Expected In Ambient Environment





<0.5 Wm^{-2}sr^{-1} (3-sigma) Agreement is very good

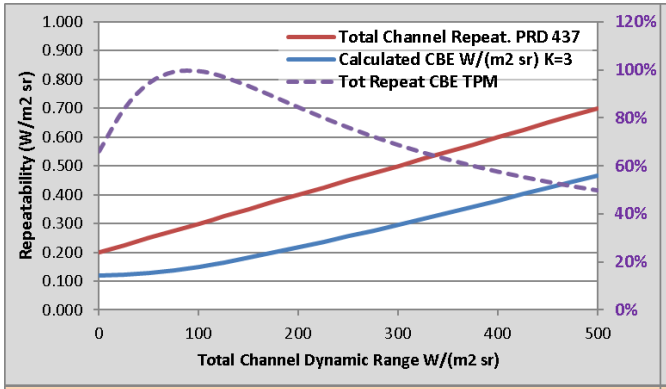


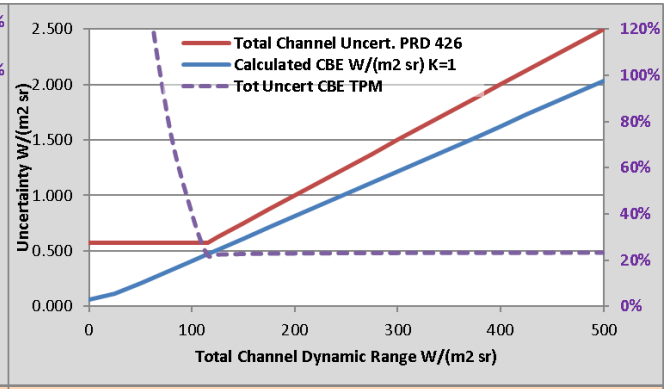


Instrument response is very linear

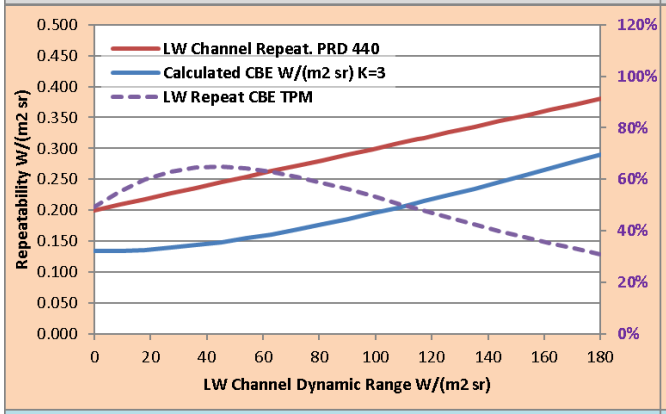
Radiometric Repeatability and Uncertainty Predictions Meet Requirements with Margin

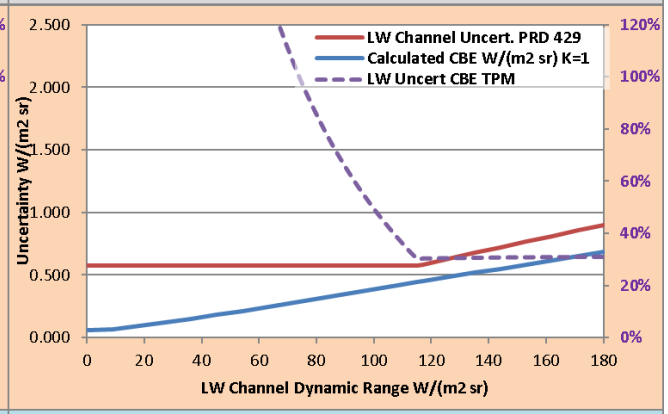
TOT



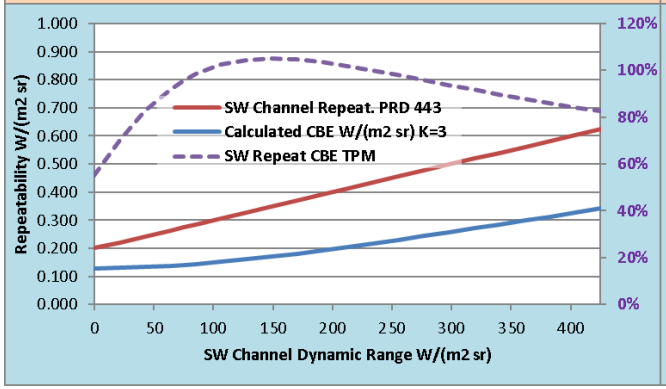


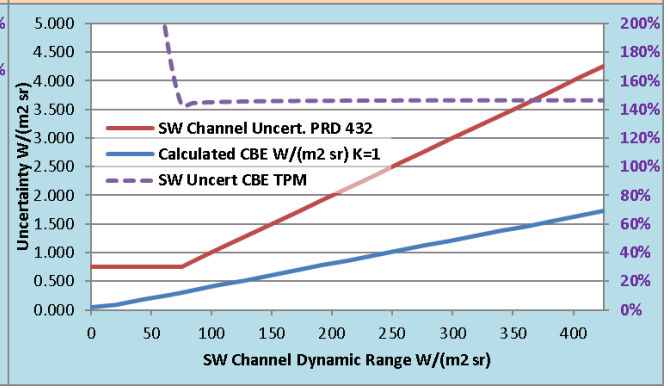
LW





SW





Predictions will be updated following TVAC

Requirement

Current Best Estimate

Margin

RBI Summary

EDU ambient testing at Harris completed

- Performance consistent with expectations
- Demonstrated readiness for TVAC phase

EDU being delivered to USU/SDL this week for TVAC testing

CDR planned for later this year

Flight delivery in December 2018

Instrument flies on JPSS-2, launch 2021

RBI will continue the important Earth Radiation Budget Experiment (ERBE) and CERES data records

Thanks to the NASA LaRC RBI program team

Program On Track for Successful Delivery of RBI FM1