RADIATION BUDGET INSTRUMENT (RBI) PERFORMANCE UPDATE

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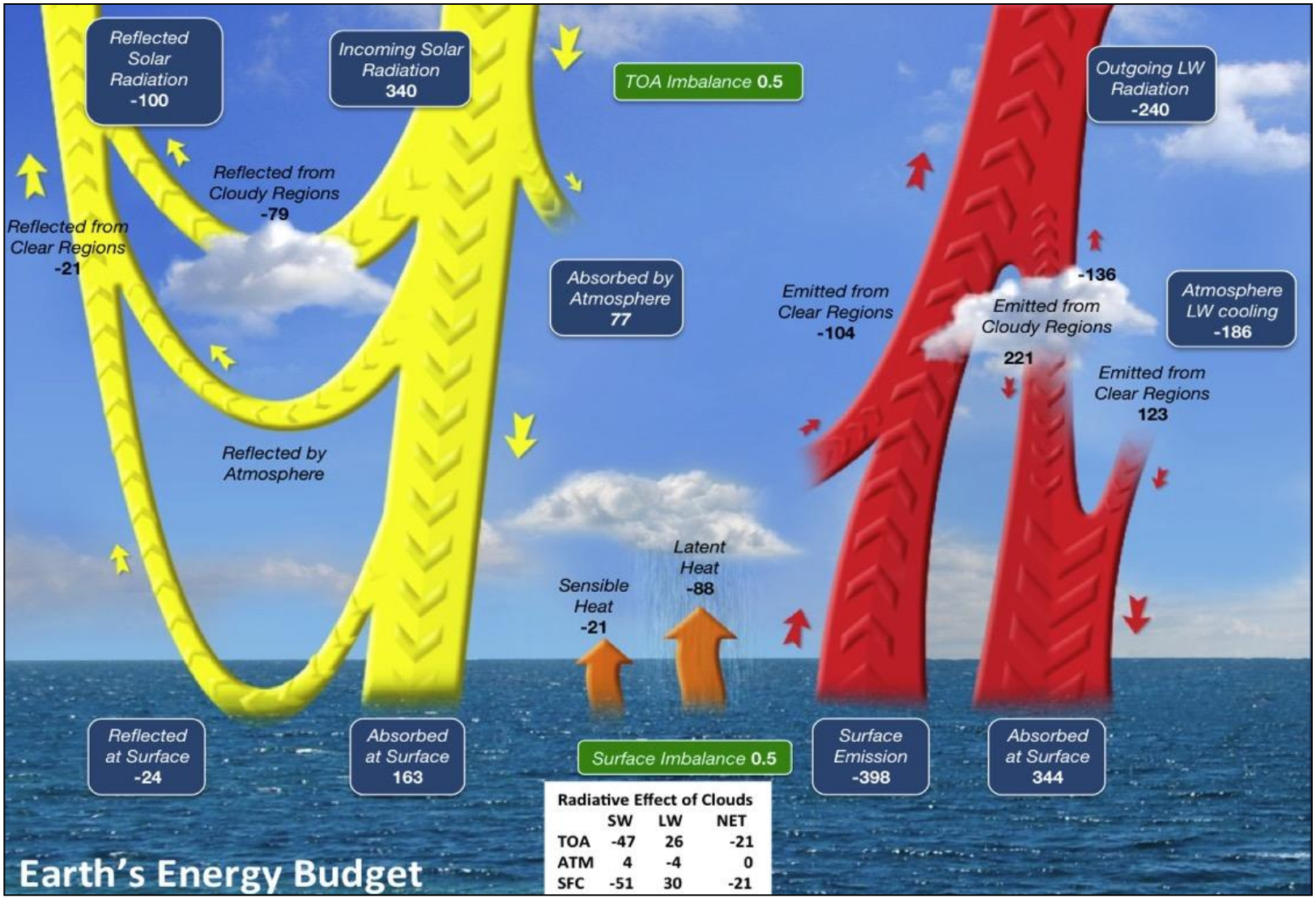
Agenda

- RBI Mission
- Key requirements for RBI Mission
- Instrument design
- On board calibration sources
- RBI predicted performance

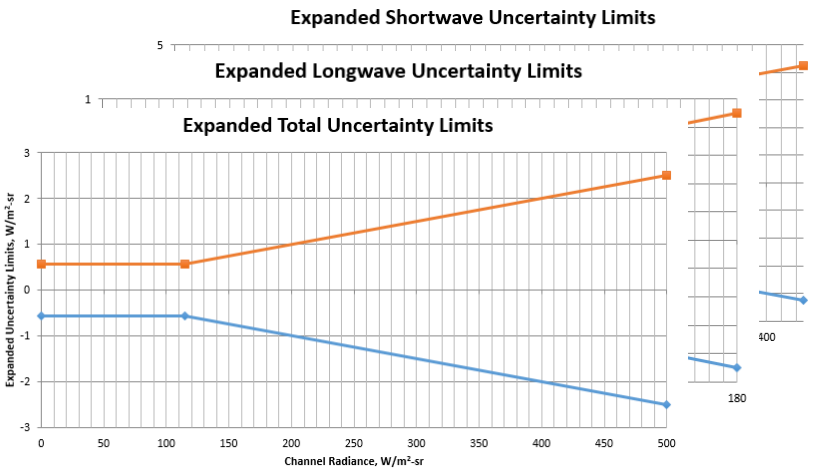
RBI's Mission: Earth's Radiation Budget Measurement Continuity



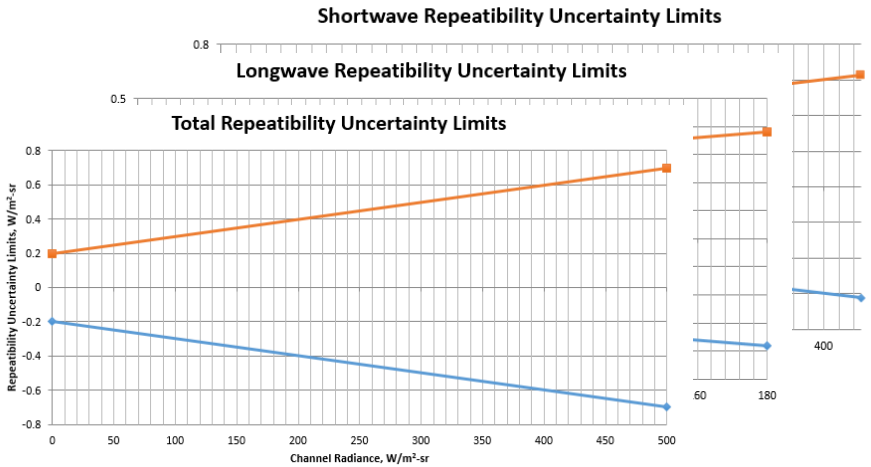
Key Requirements Drive Calibration and Traceability to CERES

- Radiometric Uncertainty (SW, LW and Total channels)

Long Term Uncertainty



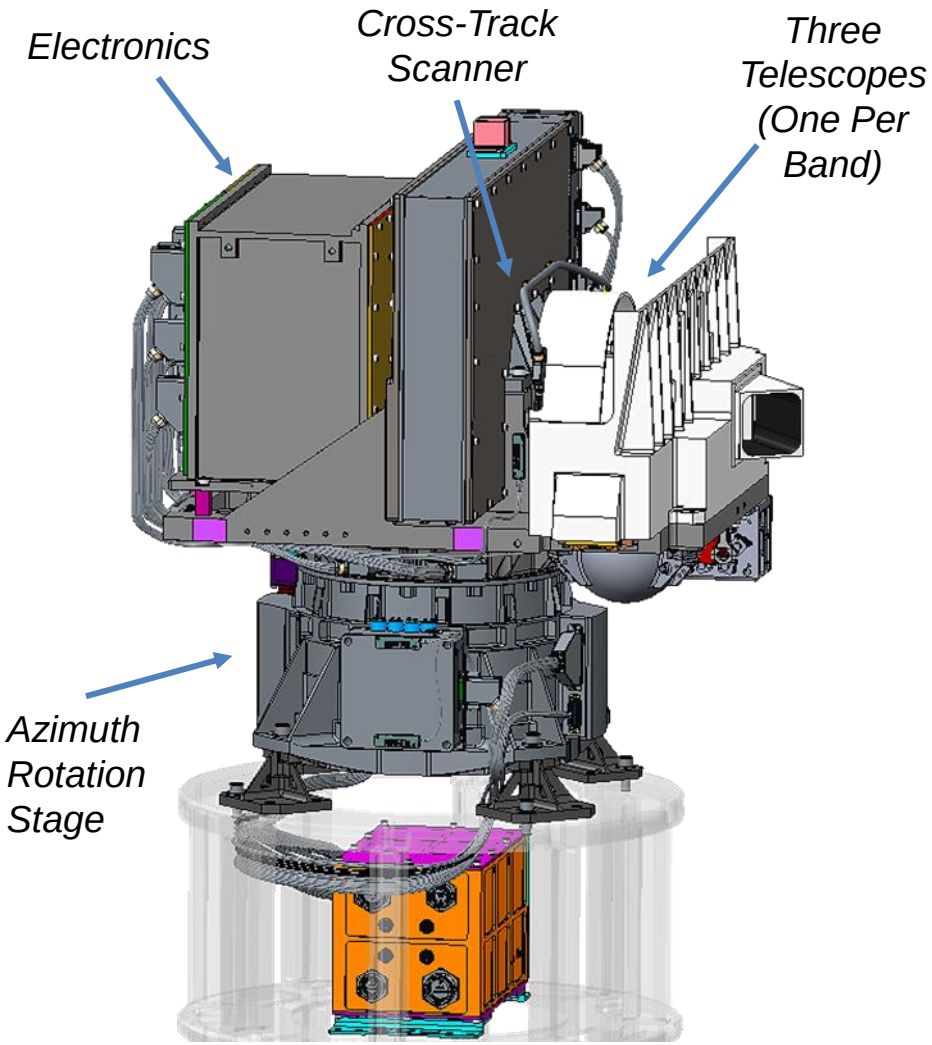
Repeatability



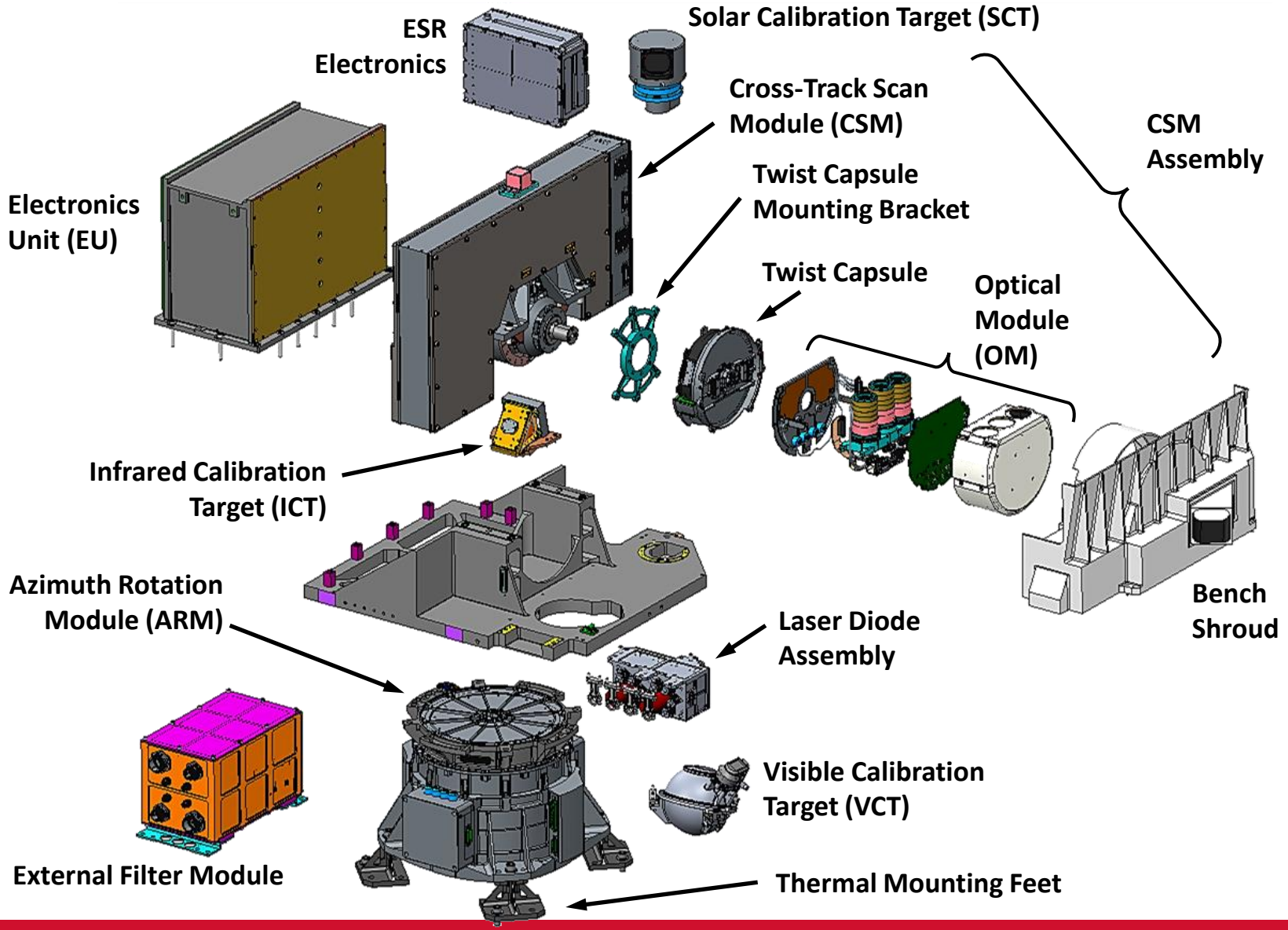
- Relative Spectral Response by channel
  - SW: 0.2 µm – 5 µm; LW: 5 µm – 50 µm; Total: 0.2 µm – 100 µm
- Point Spread Function (PSF) 95% match to CERES
- Channel to channel registration of 98%
- Calibration sources for SW, LW and solar calibration

Radiation Budget Instrument

- **Collects upwelling earth radiance over a wide spectral range**
  - Ultraviolet to far-infrared (100um)
  - Continuous cross-track scans
- **Three spectral bands**
  - Shortwave: reflected solar energy
  - Longwave: emitted earth energy
  - Total: 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



Key RBI design elements

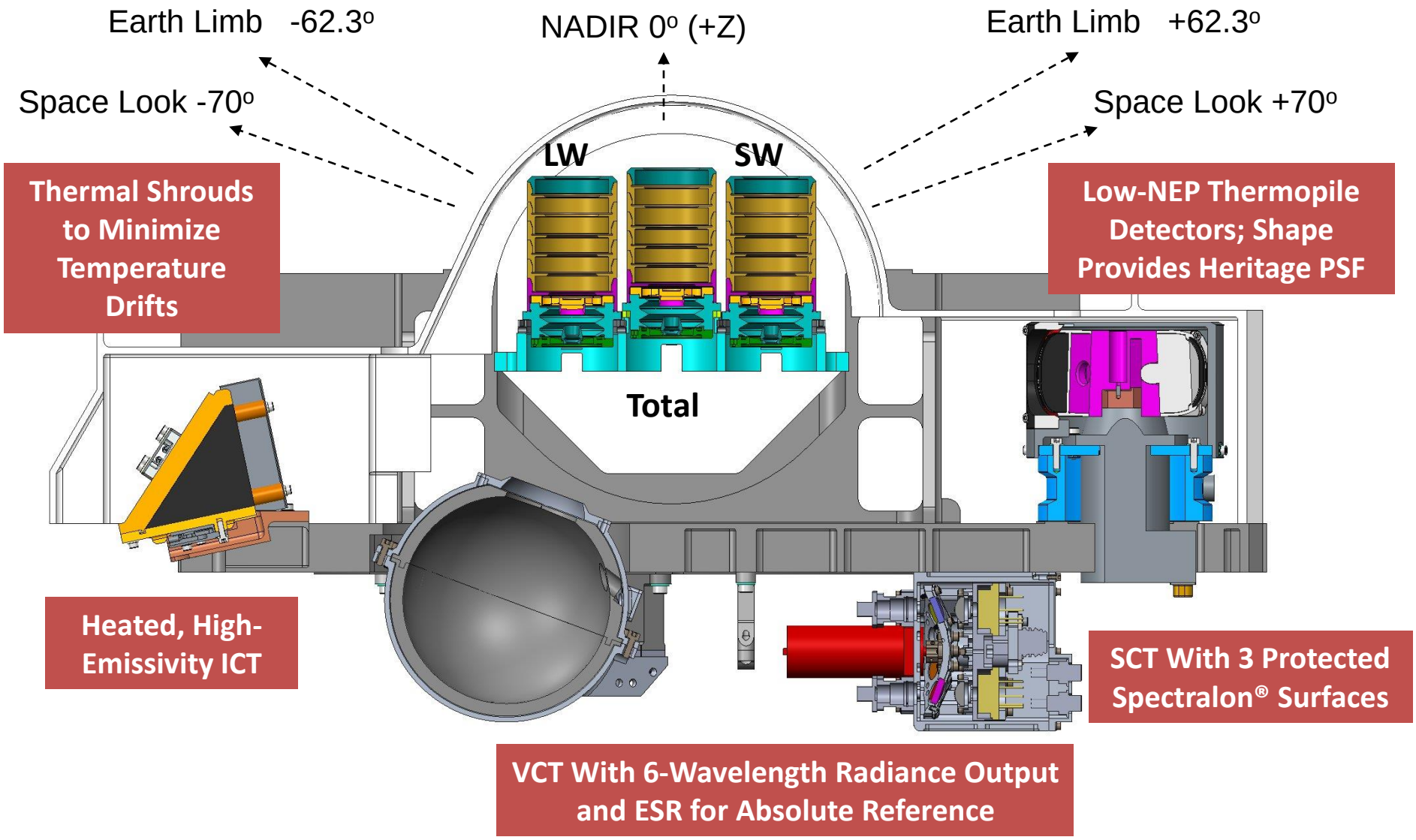


Enhancements to RBI Design Since 2015

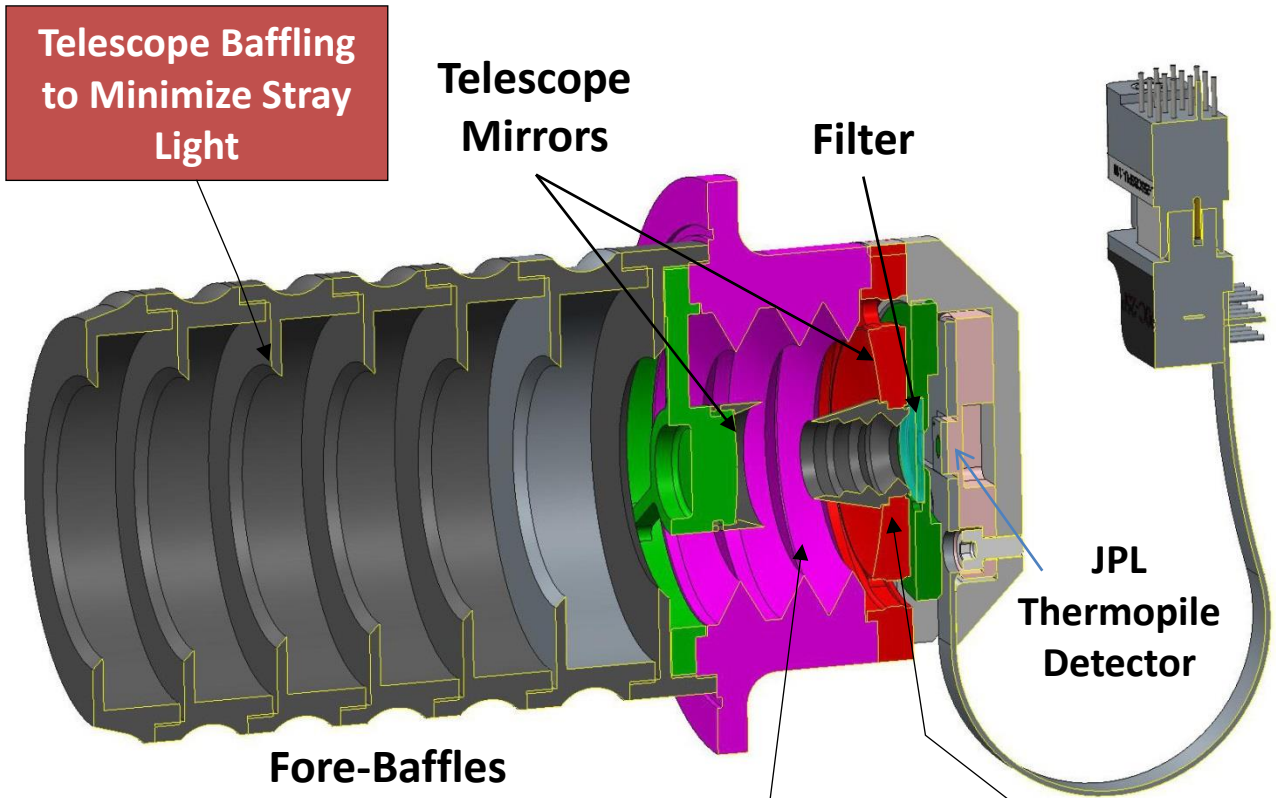
2015 Design	PDR (2016) Design	Benefit of Change
Single SW filter	Dual SW filters	Reduces thermal emissions from SW filter as seen by thermopile; reduces uncertainty
---	EU Test CCA	Improves ground test access to EU
---	Baffle for SCT	Improves thermal performance of OM
1 CCA in External Filter (EF)	2 CCAs in External Filter	Better match to RBI power levels
EF placed next to ARM	EF in RBI Stand	Preferred spacecraft accommodation geometry
ARM position: encoder	ARM Position: Resolver	Resolver provides increased resolution over encoder
VCT laser diode at 660 nm	VCT laser diode at 690 nm	Supplier availability

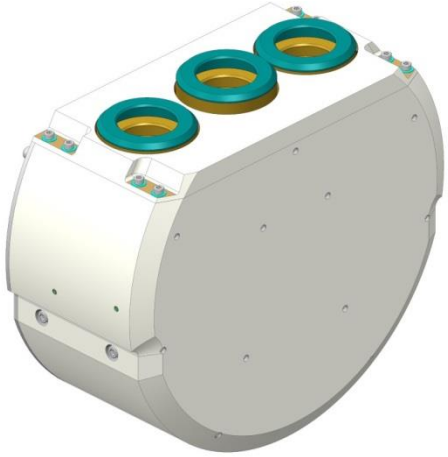
Changes Improve Mission Performance, Reduce Complexity, and Better Support Spacecraft Interface

Optical Modules and Targets Designed for Stability and Accuracy



Optical Module Provides a Stable Thermal Environment



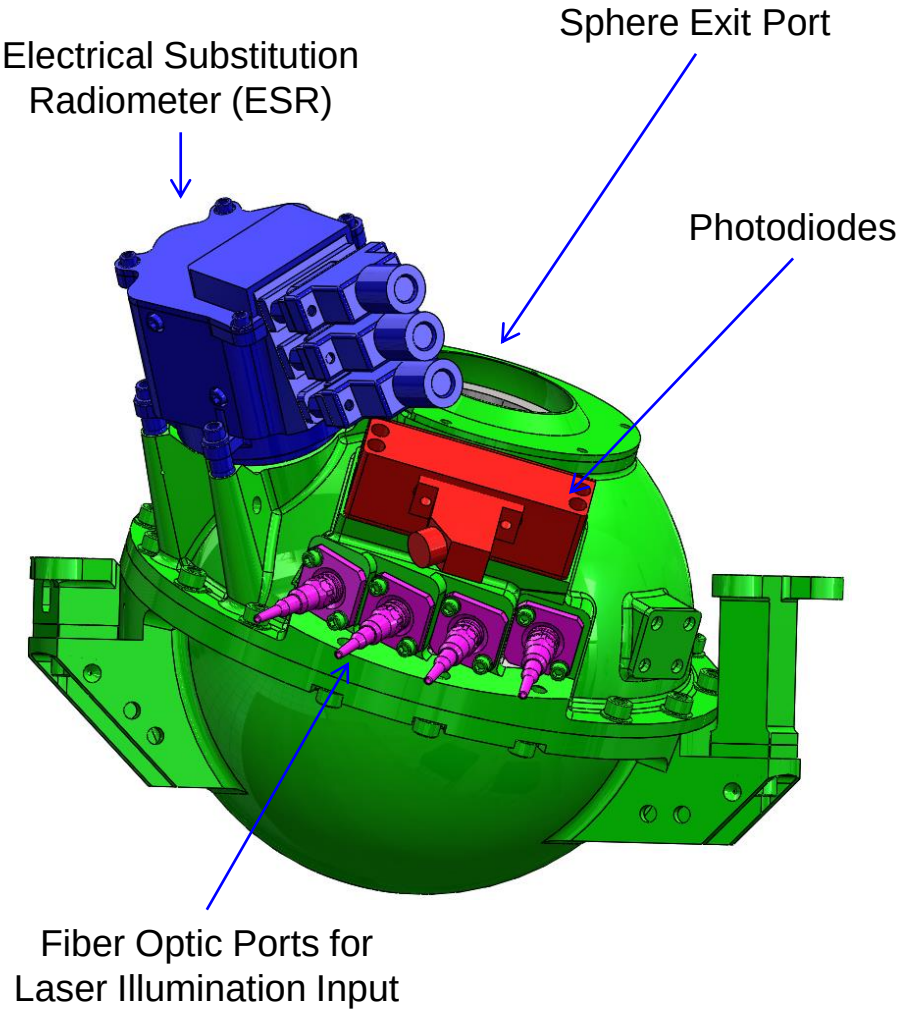


Optical Module

One Telescope Per Band Simplifies Detector Design While Providing Maximum Mission Flexibility

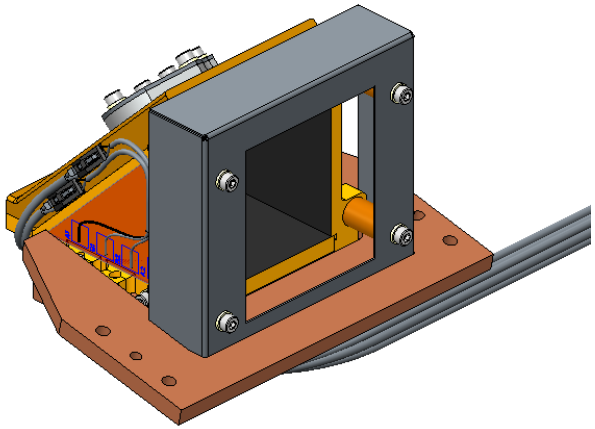
Visible Calibration Target Provides SW and Total Calibration Standard

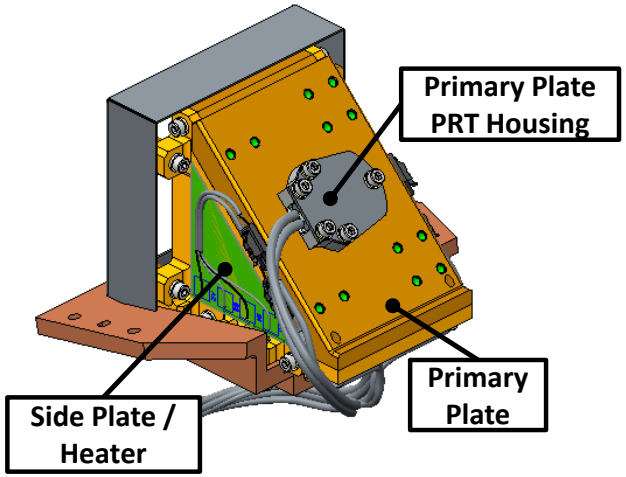
- VCT provides 6 laser diode sources
  - 375, 405, 445, 690, 915, 1470 nm
  - Radiometric calibration uses 915nm laser only
  - RSR characterization uses all 6 wavelengths sequentially
- Si and InGaAs photodiodes provide short-term radiance reference
- ESR provides stable absolute radiance traceable to NIST
  - Used monthly to calibrate photodiodes and SW / Total channels
- Laser diodes are remotely located, fiber coupled, providing thermal stability of diodes and sphere



ICT is a High-Quality Infrared Radiance Source for Precise Calibration

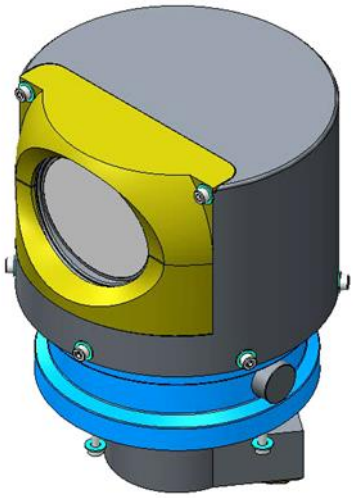
- Provides IR calibration source for LW and Total channels
- Harris-patented Specular Trap design provides >0.995 emissivity in a compact, easy to manufacture package
- PRTs are carefully calibrated to NIST standard on the ground prior to installation
- Heaters enable linearity measurements while on-orbit
- Beryllium minimizes thermal gradients
- Flight heritage design from CrIS and AHI-8



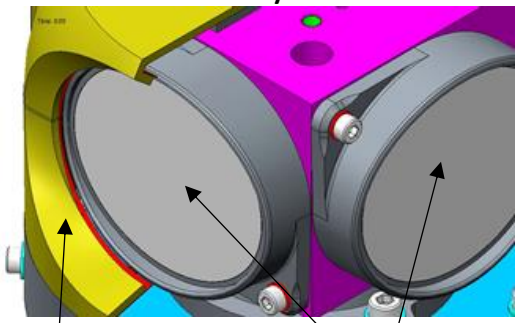


Solar Cal Target Provides an Additional Independent Check of SW/Total Calibration

- SCT contains three protected Spectralon® solar diffusers for on-orbit calibration checks
  - Targets are in a cube orientation within a sealed enclosure, which protects them from solar degradation
  - At least one surface can be maintained in a pristine condition to track and correct for changes in the "daily" surface
  - The 4th face blocks incoming solar radiation and contamination when the SCT not in use
    - Eliminates solar glints
- SCT mechanism is space-qualified
- Proven Spectralon® solar diffuser material, also used by ABI, AHI, COMS, and GOSAT programs



Cutaway View

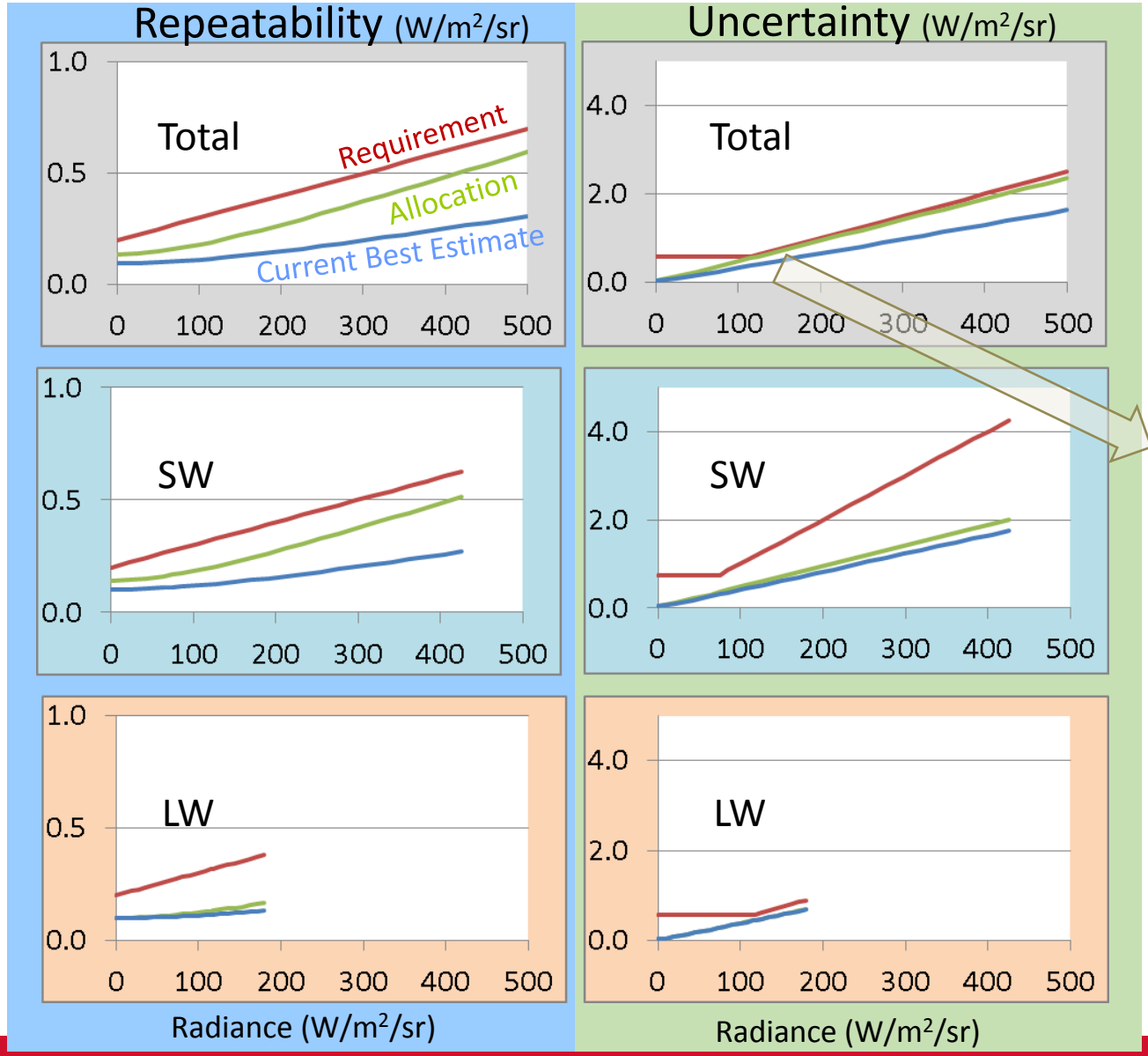


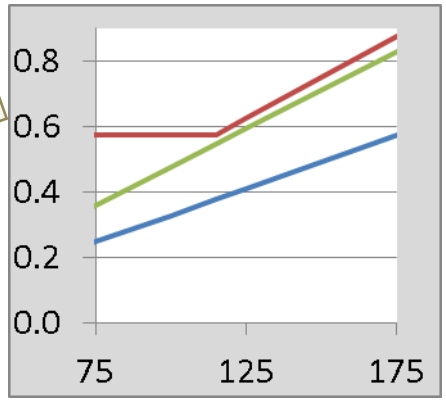
RBI Calibration Ensures Radiometric Performance Compliance Over Mission Life

- Daily: maintain short-term repeatability
  - Total and Shortwave channels view Visible Calibration Target
  - Total and Longwave channels view Infrared Calibration Target

- Monthly: maintain long-term uncertainty
  - Electrical Substitution Radiometer calibrates Photodiodes in VCT
    - Multiple illumination (filter) levels using one laser diode source are used to characterize linearity/gain for Total and SW
    - Laser diodes at multiple wavelengths are used to characterize the spectral response of the Vis/NIR portion of the Total and SW
  - Multiple illumination (temperature) levels of blackbody source are used to characterize linearity/gain for Total and LW

Radiometric Repeatability and Uncertainty Meet Requirements with Margin





Allocation:
5% margin

CBE:
20% margin

Requirement

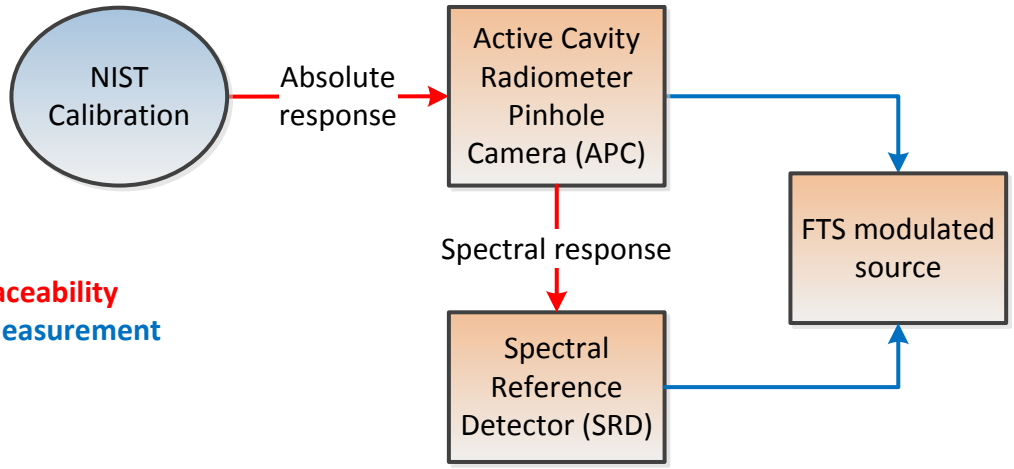
Allocation

Current Best Estimate

RBI Spectral Response is Measured by a Traceable Process at SDL

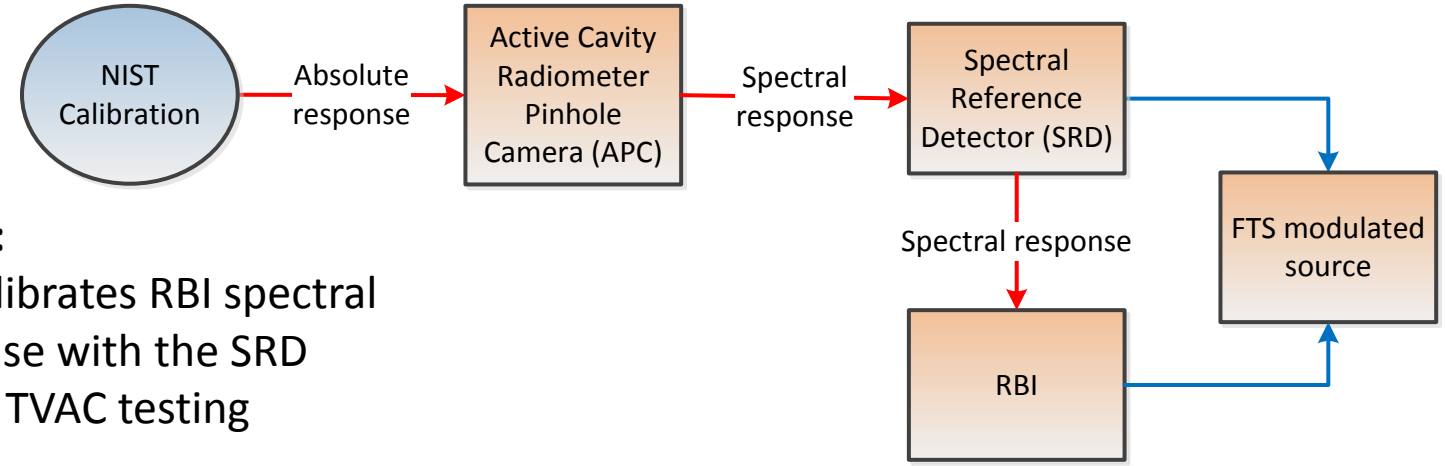
Step 1:
APC is calibrated by NIST

Step 2:
SDL calibrates SRD with the APC for each source/ beamsplitter setup



Red line = traceability
Blue line = measurement

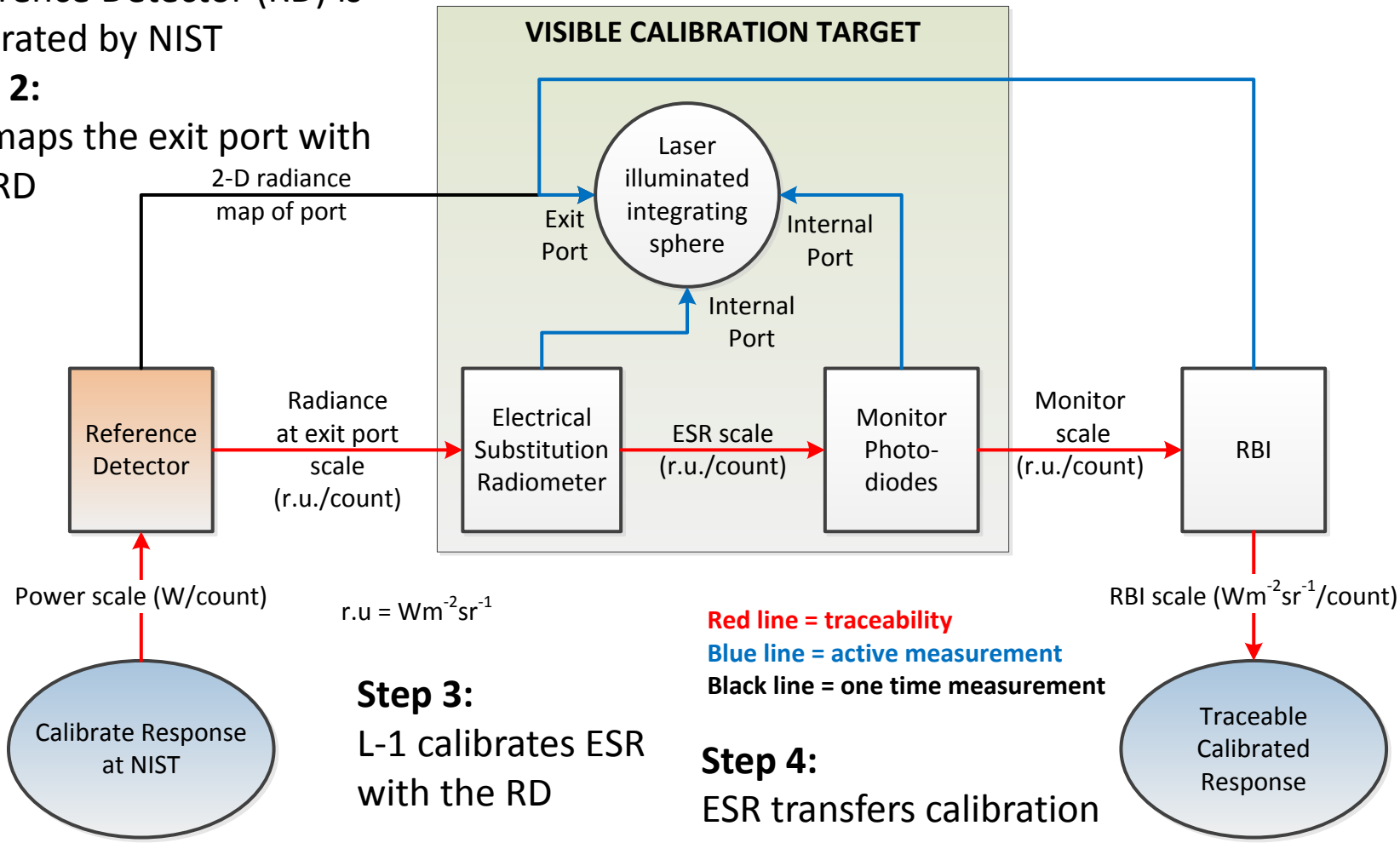
Step 3:
SDL calibrates RBI spectral response with the SRD during TVAC testing



Total & SW Calibration Traceability are Provided by the VCT's Ground Calibration

Step 1:
Reference Detector (RD) is calibrated by NIST

Step 2:
L-1 maps the exit port with the RD



Step 3:
L-1 calibrates ESR with the RD

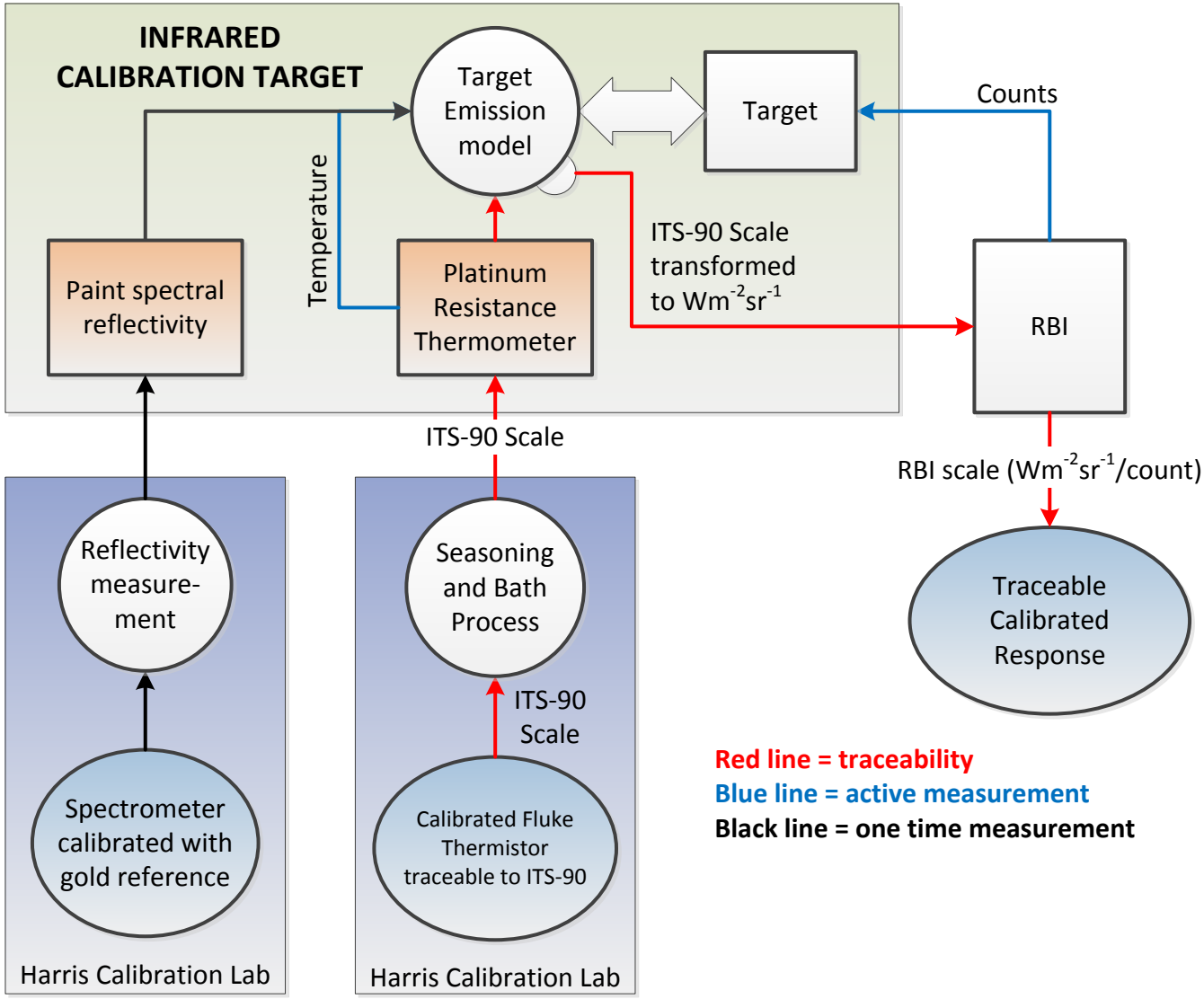
Step 4:
ESR transfers calibration to RBI using PDs on-orbit

LW Calibration Traceability is Provided by the ICT's on Ground Calibration

Step 1.
Harris calibrates PRTs in a bath using traceable thermistor

Step 2.
Harris measures ICT paint reflectivity against gold reference

Step 3.
ICT model transfers PRT temperature to RBI observed radiance on-orbit

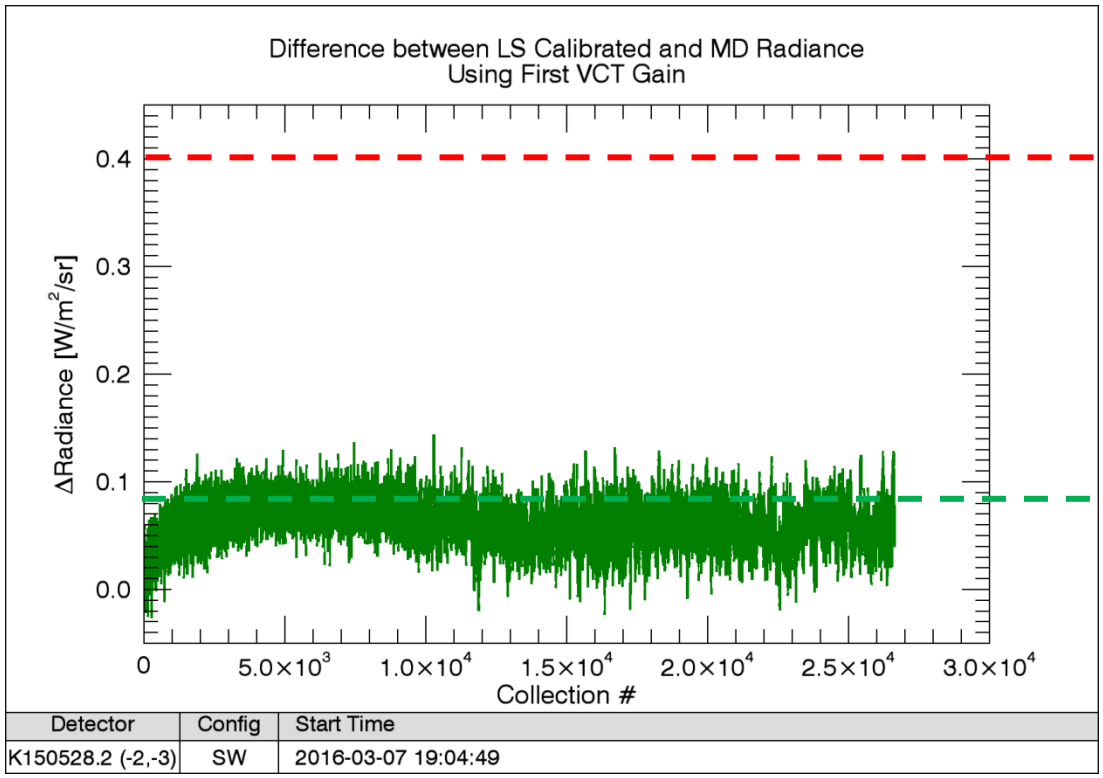


RTM Testing Demonstrates Path to Compliance for Key Flight Performance Requirements

Requirement Title	Flight Requirement Value	RTM Total Channel Measured	RTM SW Channel Measured
Repeatability (1) @ 110 $W/m^2/sr$	0.31 $W/m^2/sr$	0.099 $W/m^2/sr$	-
Repeatability (1) @ 200 $W/m^2/sr$	0.40 $W/m^2/sr$	-	0.084 $W/m^2/sr$
Linearity (1)	0.30%	0.12% *	0.10% *
Gain stability (2)	0.035%	0.010%	0.015%
Noise equivalent power (2)	3.0 nW	1.0 nW	1.0 nW
(1) = System requirement, (2) = Derived requirement, * Scaled to estimate full dynamic range value			

Results demonstrate performance with margin for both the RTM Optical Module and the RTM calibration targets

RTM SW Channel Shows Expected Compliance to Flight Repeatability Requirement



Detector	Config	Start Time
K150528.2 (-2,-3)	SW	2016-03-07 19:04:49

Repeatability requirement is 0.4 W/m^2/sr (k=3) at 200 W/m^2/sr

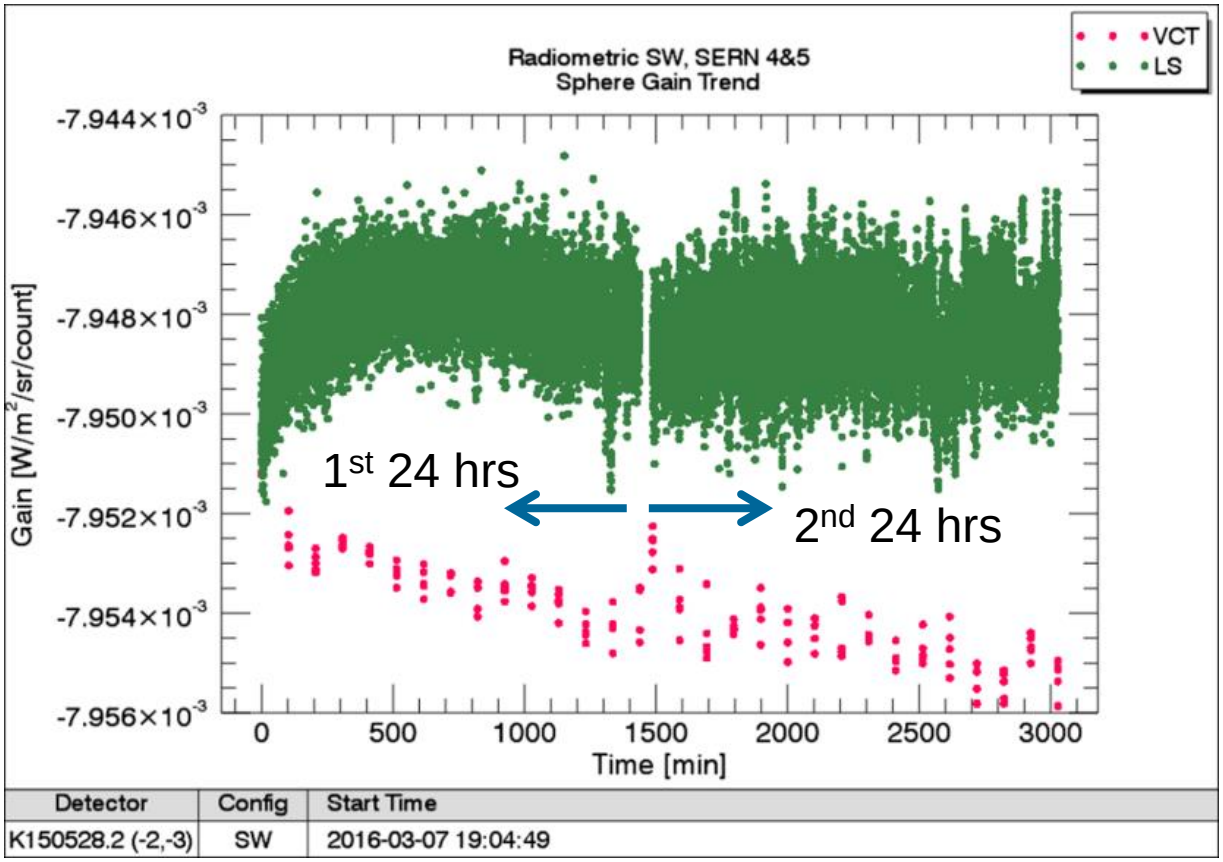
Measured Standard Deviation over **2** days is 0.084 W/m^2/sr (k=3)

RBI will calibrate **once** a day

RTM SW Channel Shows Expected Compliance to Gain Stability Derived Requirement

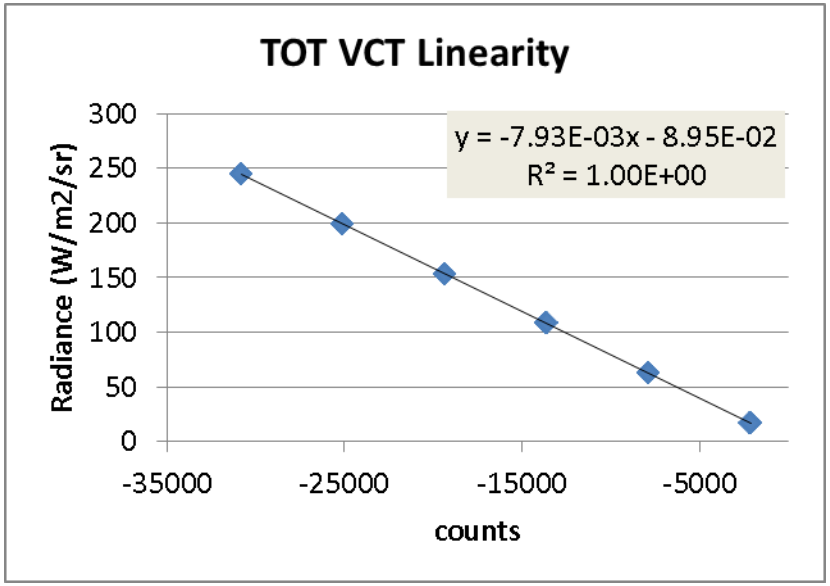
Each green data point is a 100 sample average Light ON minus 100 sample average Light OFF within the 6.6 second cycle

Each red data point is a 150 sample average Light ON minus 150 sample average Light OFF within the 6.6 second cycle

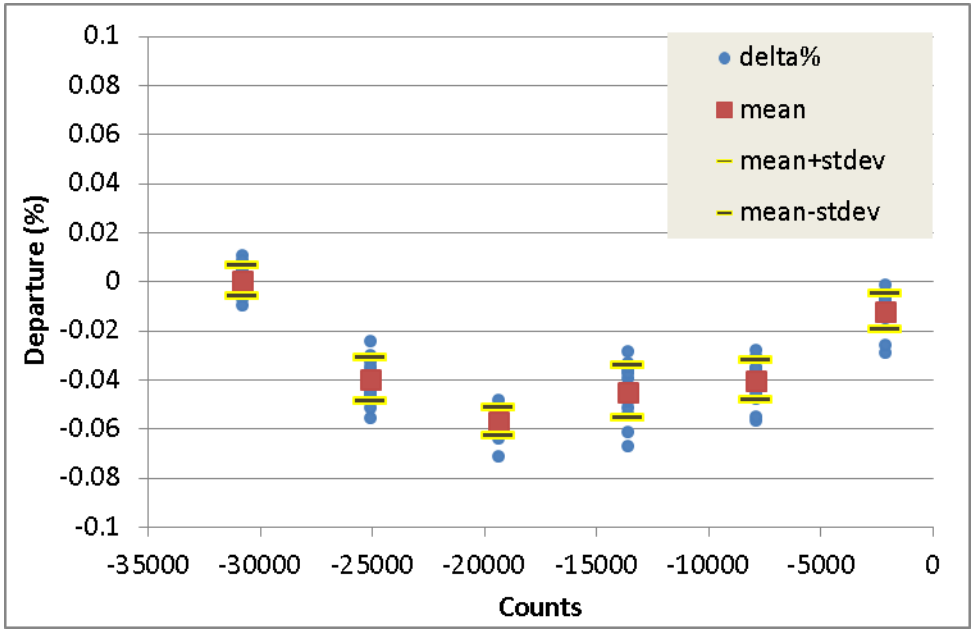


Gain variation over 24 hrs (%, k=1)	
Flight Derived Requirement	0.035
RTM measured	0.015

RTM Total Channel Shows Expected Compliance to Flight Linearity Requirement



Linearity (%)	
Flight Requirement	0.30
RTM measured [1]	0.06
Estimate for flight [2]	0.12



[1]: Dynamic range is less than requirement, 244 vs 500 W/m²/sr

[2]: 0.06% value scaled to full dynamic range assuming quadratic

RBI Summary

- SRR was held Dec 2014
- PDR was held May 2016, KDP-C approved July 2016
- CDR planned for Q1 – 2017
- Flight delivery date November 2018
- Instrument flies on JPSS-2, launch 2021

- RBI will continue the important ERBE and CERES data records
  - PSF and spectral coverage traceable to CERES
  - RBI has an enhanced shortwave calibration source providing accurate multi-wavelength sources with a NIST-traceable reference detector

- Thanks to the NASA LaRC RBI program team

Program is on Track for Successful Delivery of RBI FM1