Radiometric System Model Objectives

*Develop a tool to enhance the interpretation of Instrument performance*

- Model the end-to-end science signal chain: Photons in to bits/counts out.

- Simulate the science data stream output when viewing *calibration targets, earth scenes* or any *user-defined radiance*.

- Support and validate engineering design and fabrication phase

- Quantify the effects of various anomalous sources of energy: stray light

- Perform analyses as required to evaluate and quantify the impact to science data due to other uncertainties.
### Current RBI Project Phase

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<thead>
<tr>
<th>FORMULATION</th>
<th>IMPLEMENTATION</th>
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<td>Design &amp;</td>
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<td>System</td>
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<td>Design &amp;</td>
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**Engineering-Led Effort**

Phase C: Final Design and Fabrication
- Demonstrate that the detailed system design meets requirements

**Science-Led Effort**
Develop the end-to-end model of the science signal chain: Photons in to bits/counts out.
- To be correlated to the Engineering Development Unit at the end of Phase C
- To be correlated to the Flight Unit at the end of Phase
- Support Mission Operations and Data Analysis in Phase E
Model Development Schedule

<table>
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<th>Build 1</th>
<th>Build 2</th>
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<td>Individual modules complete</td>
<td>Broadband sources</td>
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<tr>
<td>Monochromatic sources</td>
<td>All Three telescopes</td>
</tr>
<tr>
<td>Single telescope (Total)</td>
<td>Double sided</td>
</tr>
<tr>
<td>Single sided</td>
<td>GUI</td>
</tr>
</tbody>
</table>

### Build 1
- Individual modules complete
- Monochromatic sources
- Single telescope (Total)
- Single sided
- GUI

### Build 2
- Broadband sources
- All Three telescopes
- Double sided

**Subsystems and Modules**
- Subsystem Module and GUI Design
- Virtual Interface Design
- Build 1 - Subsystem and sensor modules
- Build 1 - Subsystem and sensor module integration
- Build 2 - Subsystem and sensor modules
- Build 2 - Subsystem and sensor module integration
- Correlation with EDU results
Model Development Schedule

Build 1
- Individual modules complete
- Monochromatic sources
- Single telescope (Total)
- Single sided
- GUI

Build 2
- Broadband sources
- All Three telescopes
- Double sided

Timeline:
- 6/9/16: Subsystem Module and GUI Design
- 7/29/16: Virtual Interface Design
- 9/17/16: Build 1 - Subsystem and sensor modules
- 11/6/16: Build 1 - Subsystem and sensor module integration
- 12/26/16: Build 2 - Subsystem and sensor modules
- 2/14/17: Build 2 - Subsystem and sensor module integration
- 4/5/17: Correlation with EDU results
- 5/25/17
- 7/14/17
- 9/2/17
Typical Instrument Analytical Model

“Photons-in”

External Source

Optical Train

Detector

Signal Conditioning

“Bits-out”

Earth Scenes Calibration Targets

Stray Light (External/Internal)

L(λ) Unfiltered Radiance (Telescopes)

Net Radiative Contamination

S(λ) Spectral Response (Telescopes)

Net Conductive Contamination

Self Heating

Detecting Elements

Electronics

Counts
Numerical Modeling Tools

• Monte-Carlo Ray-Trace Model
  – Computes the distribution of radiation within the instrument.
  – Spectral characterization of the optical and radiative performance of the entire instrument.
  – Provides the necessary “Boundary” conditions for the thermal models.

• Finite-Element Thermal Diffusion Model
  – Three-Dimensional characterization of the transient thermal diffusion in instrument components

• Finite-Difference Electro-thermal Model
  – Three-Dimensional characterization of the transient thermal diffusion in the detectors
  – Two-Dimensional characterization of the transient electrical diffusion in the thermocouples.

• Electrical Circuit Model
  – Computation of the electronic Response of the electrical feedback control system.

Previous Earth Radiation Budget (ERB) programs, such as CERES, have used these modeling tools for End-to-End characterization of the instrument.
During System Level TVAC testing we will simulate the test execution with the model to complete an end-to-end correlation. If the Model and Hardware do not converge, we will perturb model parameters within their allowed tolerances to bring the model and hardware into agreement.
RBI Instrument End-to-End Model

Model Graphical User Interface (GUI)

User Defined Scene

Scene Power Distribution

Telescope

Detector

Electronics

Science Data (Counts)

W/m^2

Power Distribution Focal Plane (W)

Detector Output (V)

Thermal model / Analysis
Optical Model Parameters

Preamp (FPM)
DE Board
FPGA
Sources

- On-board Calibration sources are currently being modeled with MATLAB and/or Zemax Optics Studio
  - **Infrared Calibration Target (ICT)** - Using MCRT techniques to compute the distribution of radiation within the ICT and as distributed on the telescope aperture.
  - **Visible Calibration Target (VCT)** - Similar techniques as the ICT
  - **Solar Calibration Target (SCT)** – Similar techniques as the ICT
- Parameters such as optical prescription, viewing geometry, and paint specs are also being modeled.
- Thermal analysis are being conducted in parallel.
Infrared Calibration Target Module

- ICT positioned to be viewed by both Total and Longwave Detectors
- ICT spatial and spectral output distribution imaged on the Focal Plane
- Thermal gradients within the ICT can produce ambiguous radiance
- Degradation of Z-302 will reduce effective emissivity over lifetime
Visible Calibration Target Module

- VCT positioned to be viewed by both Total and Shortwave Detectors
- VCT spatial and spectral output distribution imaged on the Focal Plane
- Thermal gradients within the VCT can produce IR background signal on the Total Channel
Solar Calibration Target Module

- SCT positioned to be viewed by both Total and Shortwave Detectors
- SCT spatial and spectral reflected radiance distribution imaged on the Focal Plane
- Thermal gradients across the SCT can produce IR background signal on the Total Channel

| SCT | Total 98.7° | SW 84.3° |
Optical Module

- Being developed by Virginia Tech’s Thermal Radiation Group
- Using Monte-Carlo Ray-Trace techniques to model the geometry and compute the distribution of radiation within the telescope and on the detector
- Has helped identify possible sources of stray light and has been used to study effects of certain design changes.
- Transient Thermal analysis is being conducted in parallel to assess background IR signal
Optical Module

- Extensive Telescope Baffling Minimizes Stray Light
- Telescope Mirrors
- Filter
- JPL Thermopile Detector
- Rear Enclosure Provides Thermally Stable Environment
- One Telescope Per Band Simplifies Detector Design

Materials Minimize Thermal Gradients
Optical Module

Radiance in → Fore Baffle → Telescope (Includes Primary & Secondary Baffles) → Spectral Filter (SW and LW) → Detector → Electrical signal out

Telescope
Secondary Mirror Baffle
Primary Mirror Baffle
Focal Plane Model

- Detector, or Focal Plane Module, also being modeled by Virginia Tech
- Finite-Difference Electro-Thermal model that inputs given knowledge of detector properties to convert a power distribution on the detector to a voltage.
Focal Plane Module

Focal Plane Module is a Thermal Detector that compares heat sink temperature with a membrane coupled to the radiation from the telescope

Passive Thermopile Detector
AD8629 single op-amp analog gain circuit
Customer supplied PRT for heat sink monitoring
- Model developed in MATLAB/Simulink
- Model accepts the signal voltage (time series) and provides 20-bit science data at 100 samples per second.
- The signal at any node in the signal chain can be tapped out for viewing/analysis.
- First revision of the model is complete. New iterations to come pending design updates from Harris’ electrical design.
Signal Conditioning Electronics

PSF Simulation
Graphical User Interface

• MATLAB interface between the individual blocks will be defined
• Goal: provide any time-varying user-defined input or outputs from calibration sources and observe the time series at the output of the detector electronics block.
• Data points from each block (and from within each block) will be available to plot/analyze
Current Status and Future Work

• Currently in Build 1 phase: All subassemblies are being developed in their respective platforms.
  ✓ Design changes are being incorporated as engineering drawings become available
• Electronics model is nearly complete to the current design specifications
• Scene generator between calibration targets and telescope currently being defined and developed
• On-going thermal analysis supports and validates contractor’s derived requirements for individual subsystems (ICT, telescope)
• Short-term studies that can influence instrument design are also being carried out in parallel
  ✓ Stray light studies
  ✓ SW filter heating and re-emission
  ✓ Temperature variations in telescope baffles due to material change
  ✓ Uncertainties in radiance arriving at telescope aperture due to:
    • View angles for all three telescopes to the sources.
    • Uncertainties in knowledge of the system parameters- ICT temp, paint absorptivities, BRDFs, etc.
Questions?