The OLI Radiometric Scale Realization Round
Robin Measurement Campaign

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A round robin radiometric scale realization was performed at the Ball Aerospace Radiometric Calibration Laboratory in January/February 2011 in support of the Operational Land Imager (OLI) program. Participants included Ball Aerospace, NIST, NASA Goddard Space Flight Center, and the University of Arizona. The eight day campaign included multiple observations of three integrating sphere sources by nine radiometers. The objective of the campaign was to validate the radiance calibration uncertainty ascribed to the integrating sphere used to calibrate the OLI instrument. The instrument level calibration source uncertainty was validated by quantifying: 1) the long term stability of the NIST calibrated radiance artifact, 2) the responsivity scale of the Ball Aerospace transfer radiometer, and 3) the operational characteristics of the large integrating sphere.

**Requirement:** Sphere radiance uncertainty in test configuration **shall not exceed 2.4% 1σ**

<table>
<thead>
<tr>
<th>OLI Band</th>
<th>Coastal Aerosol</th>
<th>Blue</th>
<th>Green</th>
<th>Red</th>
<th>NIR</th>
<th>SWIR 1</th>
<th>SWIR 2</th>
<th>Pan</th>
<th>Cirrus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band Center (nm)</td>
<td>443</td>
<td>482</td>
<td>562</td>
<td>655</td>
<td>865</td>
<td>1610</td>
<td>2200</td>
<td>590</td>
<td>1375</td>
</tr>
<tr>
<td>1σ Uncertainty(%)</td>
<td>2.2</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>2.4</td>
<td>2.3</td>
<td>2.0</td>
<td>2.3</td>
</tr>
</tbody>
</table>
OLI Pre-launch Radiance Calibration Equipment & Process (Described Last Year)

1. Small Sphere Source (SSS): portable, NIST calibrated sphere
2. COTS Transfer Radiometer (CXR): hybrid filter/spectrometer transfer radiometer
3. Death Star Source (DSS): 40” sphere for system level calibration

Scale Realization measurements validate entire process

- **SSS 2-level spectral radiance calibration @ NIST FASCAL**
  - **Transfer SSS cal to CXR**
  - **Transfer CXR cal to DSS in system test configuration**
  - **Calibrate OLI w/ DSS in system test configuration**
  - **Confirm CXR & DSS scales with Radiometer Round Robin (BATC, U of A, NASA, & NIST)**
Scale Realization Campaign Validates the Majority of the Pre-launch Radiance Uncertainty Budget

Validation at this level incorporates lower level issues

OLI Scale Uncertainty

DSS Scale Uncertainty (CXR→DSS transfer done in System Test Configuration)

Supporting DSS & Chamber Characterizations made by CXR or OLI from within the TVAC chamber

CXR Scale Uncertainty

DSS Control Stability & Repeatability

SSS Scale Uncertainty

CXR Stability

SSS Stability

FASCAL Scale Uncertainty (given)

Remaining issues characterized by transfer radiometer & OLI itself
Simple table design & adjustment scheme worked very well
- 20’ table assembled in <8 hours
- Tables leveled & aligned to better than 0.1°
- Position repeatability <1mm
Accommodating Twelve Radiometric Assets is not Trivial
Four Filter Radiometers, Four Spectrometers, & One Hybrid

- Radiometer-source distance varies to accommodate FOV & distance requirements
- Lines of Sight true to master alignment laser to better than 0.1°
- Translational repeatability established by table markings and stop blocks
- NIST spectrometers shared a magnetic kinematic base
Two Sintered PTFE Spheres (NPR & SSS) & One BaSO$_4$ Sphere (DSS), All QTH Powered

Only one source illuminated for measurement at a time
One NPR, Two SSS, & Four DSS Levels, Each Measured Twice

Scale Realization scenes covered OLI Calibration scenes & majority of DSS dynamic range used during System Testing.
10 Very Busy Days

- ~20 days before start: prepare lab, receive equipment
- Day before start: travelers arrive in Boulder
- Day 1: unpack equipment, populate tables
- Day 2: source alignment, start radiometer alignment
- Day 3: complete radiometer alignment, measure NPR
- Day 4: measure SSS 5W & 90W
- Day 5: measure DSS NIR_87.40 & NIR_8.798 including OOF
- Weekend off
- Day 6: measure DSS NIR_209.8 & B_610.4 including OOF
- Day 7: measure SSS 5W, SSS 90W, & DSS B_610.4 including OOF iteration #2
- Day 8: measure DSS NIR_8.798 & NIR_87.4 including OOF
- Day 9: measure NPR & DSS NIR_209.8 including OOF
- Day 10: UA-SWIR Cirrus measurements & pack equipment
- Day 11: Fly home

Everything takes longer than you think it’s going to
### DSS Uncertainty Validation Plan (underway)

<table>
<thead>
<tr>
<th>#</th>
<th>Objective</th>
<th>Verification Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Demonstrate stability of participating radiometers</td>
<td>Compare observed trends in SSS output from 6 measurement campaigns (Jan. 2009 – Aug. 2011) &amp; evaluate consistency amongst the radiometers</td>
</tr>
<tr>
<td>#2</td>
<td>Validate CXR responsivity scale uncertainty</td>
<td>Quantify differences between CXR &amp; the other radiometers data for the 8 DSS scenes Scale Realization scenes. Evaluate using multiple radiometer calibration paths (e.g. SIRCUS, NPR, &amp; lamp &amp; panel) wherever possible</td>
</tr>
<tr>
<td>#3</td>
<td>Quantify DSS operational issues that contribute to DSS uncertainty beyond those addressed by the CXR scale uncertainty.</td>
<td>Use Scale Realization data to evaluate DSS stability &amp; repeatability including spectrum outside control band. <em>Note: only inside control band calibrations required for OLI calibration</em></td>
</tr>
</tbody>
</table>

Most measurements (>90%) complete, analysis & documentation still ongoing
CXR/SSS Stability Measurements Illustrate Challenges in Using Spheres as Artifacts

First trip to NIST (CXR stayed home)

Normalization point (1st FASCAL calibration)

2nd FASCAL calibration

8 months of inactivity
High long term transfer radiometer stability eliminates need for long term transfer source (SSS) stability.
Closed Loop Radiance Control Helps at Control Wavelength, May Hurt Elsewhere

Day to Day Change (CXR Observations)

Spectral variations appear proportional to fraction of total power delivered by VA

Cirrus variability
Disparate Apertures Require Size of Source Effect Measurements and Corrections

- Process requires calibration transfer from a 3” aperture source to a 14” aperture source
- Observations of a 3” black “lollipop” used to quantify out-of-field (OOF) contribution & evaluate important radiometer spatial response characteristics
- The OOF was independent of sphere level (as expected)
- Additional measurements confirmed lollipop signals are genuine OOF contribution and not reflected stray light
UA-SWIR Radiometer Utilized for Cirrus Band Calibration

- Baseline SSS→CXR→DSS transfer process inadequate for Cirrus Band (3.2% vs. ≤2.4% requirement). Alternative approach adopted:
  1. Populate UA-SWIR radiometer & DSS monitor with OLI Cirrus Band filter witness samples
  2. Calibrate UA-SWIR Cirrus band responsivity using traditional lamp & panel technique
     - FEL Lamp calibrated by NIST FASCAL; Spectralon panel calibrate by NIST STARR
  3. Transfer UA-SWIR Cirrus band responsivity to DSS Radiance Monitor Cirrus band at all 10 system test levels
     - Must still deal with Infrasil chamber window transmission using traditional techniques
  4. Validate UA-SWIR Cirrus radiances with other radiometers during Scale Realization

- FASCAL irradiance calibration of FEL F-560 & STARR BRDF calibration of 10" Spectralon panel
- Transfer panel radiance to UA-SWIR radiometer
- Transfer UA-SWIR cal to DSS monitor in RCL
- Calibrate OLI w/ DSS in system test configuration
- Confirm DSS Cirrus scale with Radiometer Round Robin (BATC, U of A, NASA, & NIST)

- Lamp stability, current accuracy, panel stability, MODTRAN correction
- UA-SWIR filters & photodiode
- DSS internal monitors
- Characterize chamber window transmittance
- Characterize UA-SWIR & transfer setup
Internal Stabilization Using Instrument Filters Greatly Improves Cirrus Calibration

- Active control based on DSS’s internal Cirrus band monitor is a good way to mitigate variable atmospheric effects
  - Very important that control system has the same RSR as system being calibrated
- Narrow Cirrus band widths and low scene radiances limit low level DSS monitor performance & force independent level calibrations. OLI calibration not affected.
  - Monitor performance breaks down at lowest levels due to background stability & subtraction precision

![Graph showing monitor nonlinearity vs. spectral radiance](image)

**Independent level calibrations required to mitigate monitor performance issues**
Additional Plans & Lessons Learned

**Additional Plans**
- Additional stability checks at NIST Remote Sensing Laboratory (5 of 6 complete)
- Additional SSS FASCAL calibration (complete)
- Comparison with SIRCUS-based radiometer absolute responses (in progress)

**Lessons Learned**
- Low complexity & low risk configuration proved to be the right choice
  - Keep everything as simple as possible
- Flexible *plans* work better than rigorous *procedures* in this context
  - Permissible only because the data was not used in BATC requirements verification
  - If you have to follow a rigorous procedure you’ll need much more planning
- More real-time analysis & incorporation of this into the daily plan
  - Requires mature analysis & presentation tools
- Realistic schedules, better estimates beforehand, & better allocation of time required for ancillary measurements
  - e.g. lollipop measurements not done in previous gatherings
- DSS’s abundant telemetry & flexibility are powerful but potentially dangerous
- Integration of more complete DSS use plan
Questions?