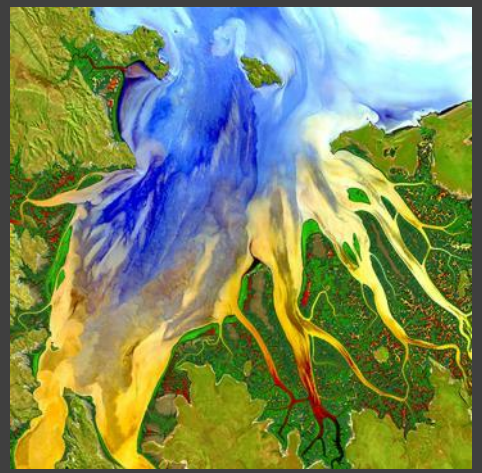
Radiometric Source Traceability for the Ground Calibration of OLI-2



Imagery Credit: **USGS/NASA Landsat**

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Outline

1. OLI-2 Calibration Overview
2. Calibration Process
3. Ball Radiometric Sources
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5. CXR Out-Of-Field (OOF) Correction
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7. DSS calibration – Ball Aerospace
8. Round Robin – Ball Aerospace
9. Conclusion – Keys to Success
10. Acknowledgements

Introduction

Calibration Test Equipment

Measurements and Results

Closing remarks

OLI-2 Calibration Overview

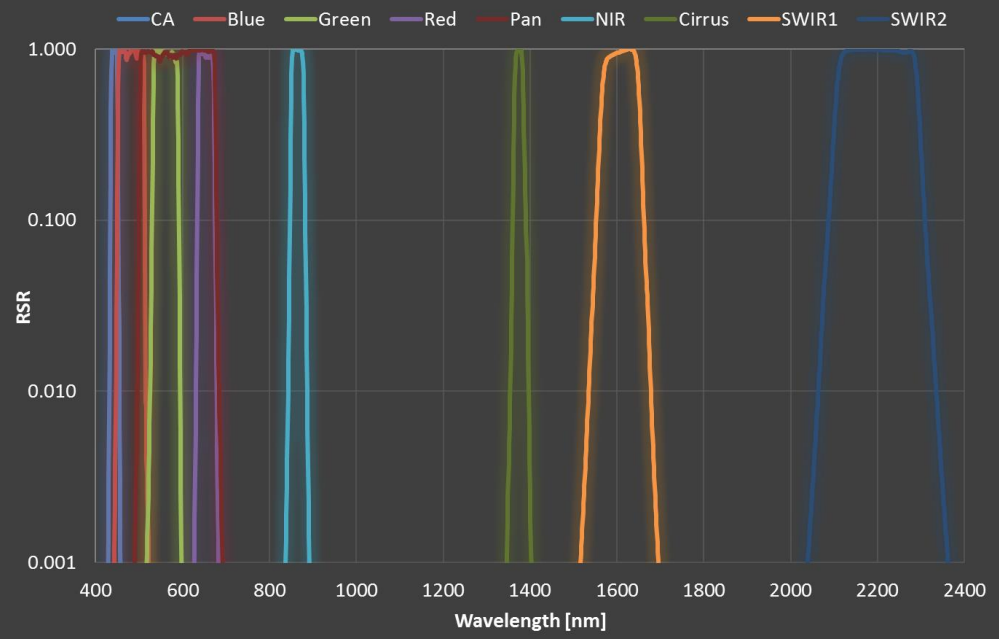
Spectrum

- **Operational Land Imager 2 (OLI-2) has 9 spectral bands**

#	Band Name	Label	Center Wavelength [nm]	Bandwidth [nm]
1	Coastal Aerosol	CA	443	20
2	Blue	B	482	65
3	Green	G	562	75
4	Red	R	655	50
5	NIR	NIR	865	40
6	SWIR 1	1SW	1610	100
7	SWIR 2	2SW	2200	200
8	Panchromatic	P	590	180
9	Cirrus	CRS	1375	30

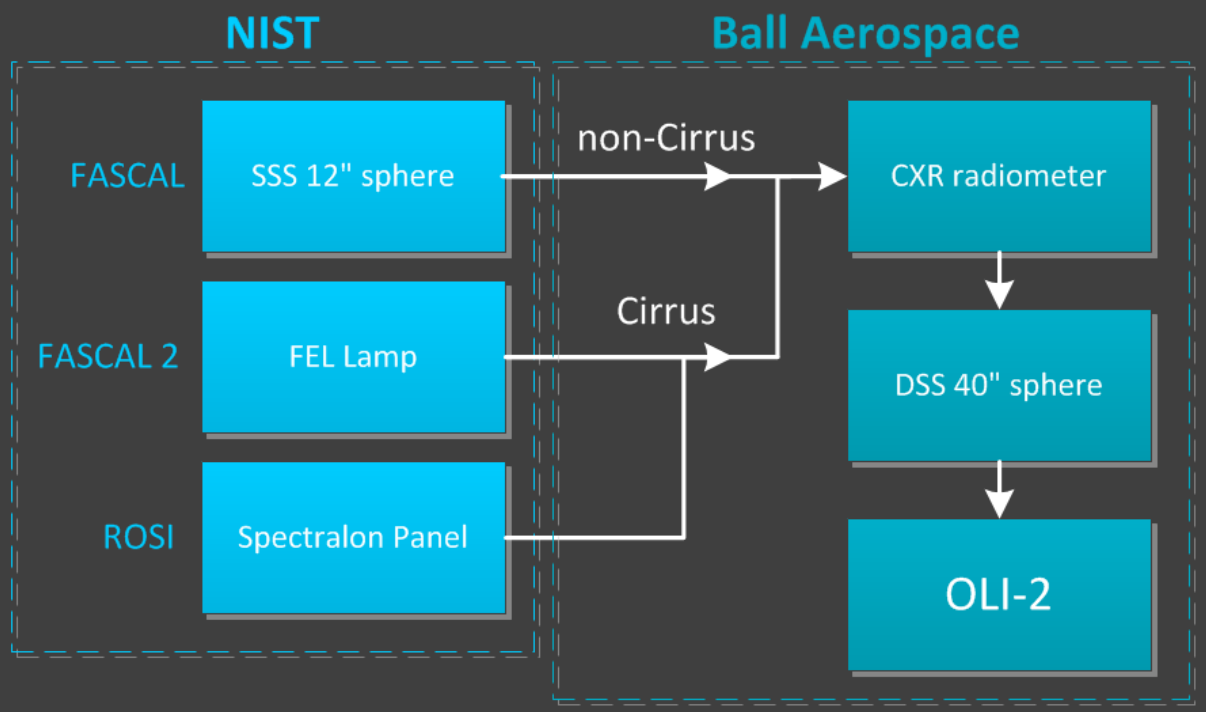
Requirements

- **NIST-traceable sources must contribute < ±2.5% (k=1) absolute band-weighted radiance uncertainty**
- **Radiance is calibrated at 20 levels per band:**
  - **10 levels L_{typ} span to L_{max}, where $L_{typ} \approx 0.06^* L_{max}$**
  - **10 levels down to $0.1^* L_{typ}$ (looser requirements)**



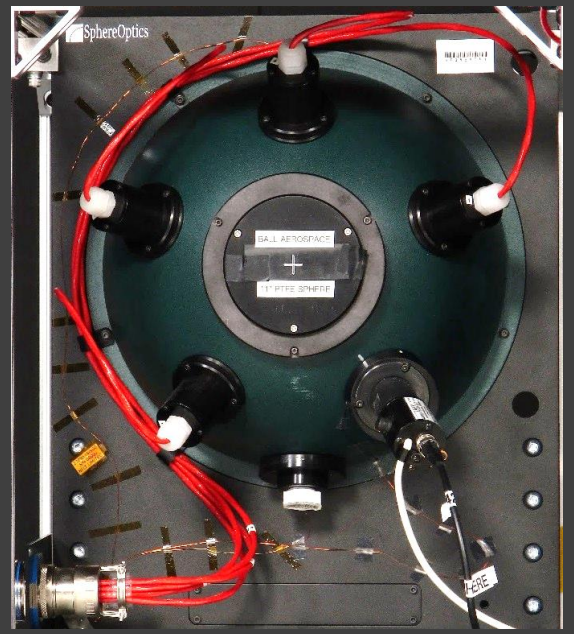
Calibration Process

- NIST-traceability via FASCAL, FASCAL 2, and ROSI
  - Ball SSS, 12” integrating sphere (non-Cirrus)
  - Ball FEL lamp & Spectralon panel (Cirrus)
- Radiometers
  - Ball CXR radiometer (350-2500nm)
  - GSFC LXR radiometer (440-860nm)
  - UA VNIR radiometer (440-860nm)
  - UA SWIR radiometer (870-2700nm)
- Source under calibration
  - Ball DSS, 40” integrating sphere



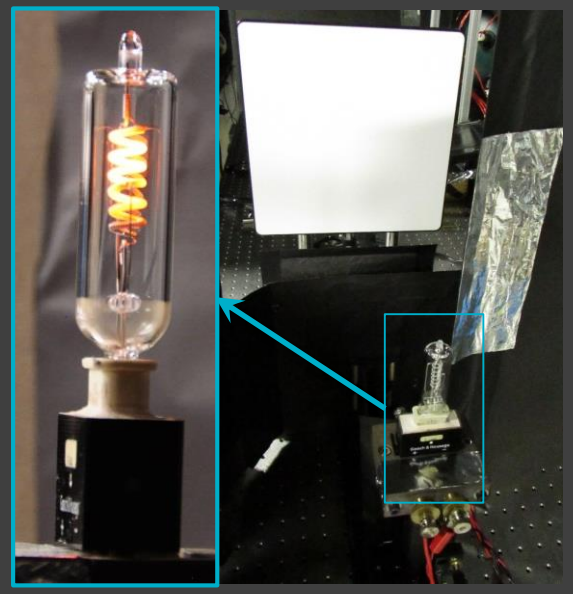
Ball Radiometric Sources

SSS



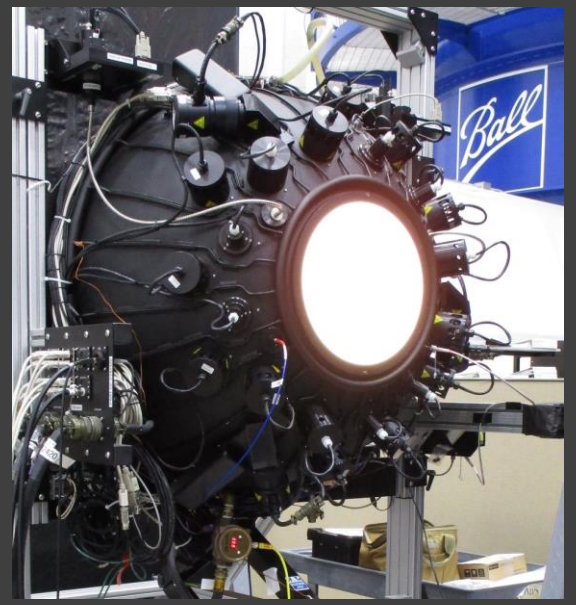
Diffuser	12” diam. PTFE
Aperture	3 in.
Lamps	3x 30W QTH
Cooling	passive
Power	constant current
Control	open (monitored)

Lamp & Panel



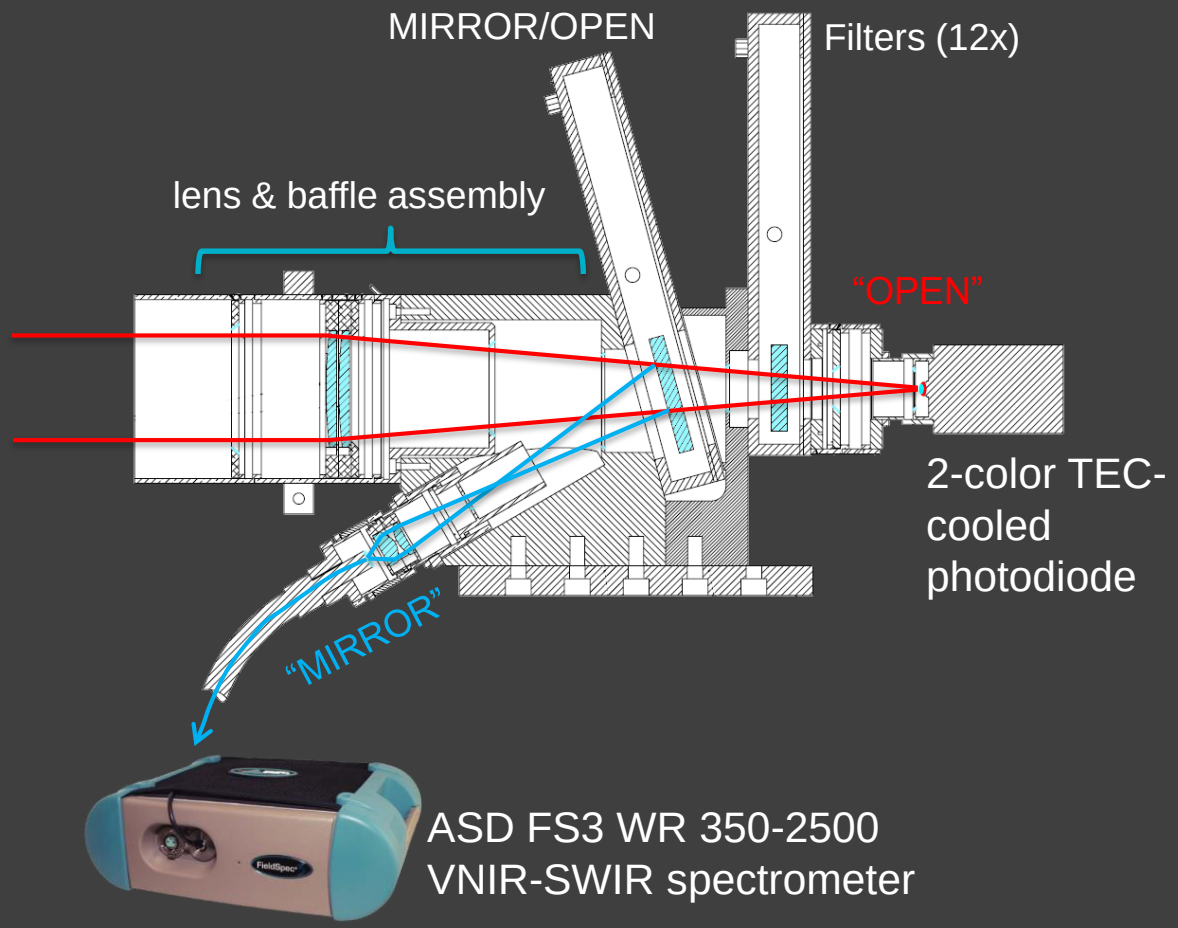
Diffuser	12” sq. Spectralon
Lamp	1000W QTH
Cooling	passive
Power	constant current
Control	open (monitored)

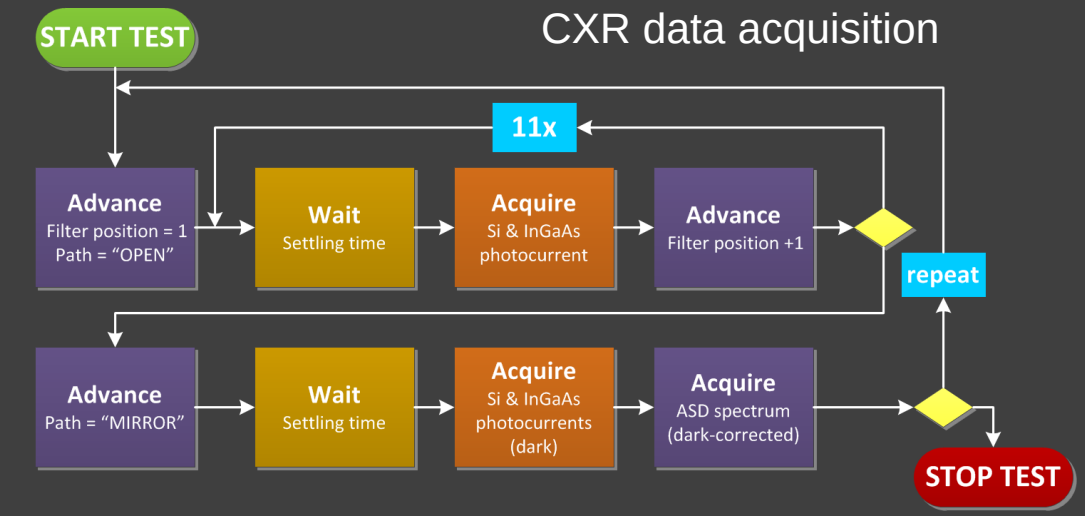
DSS

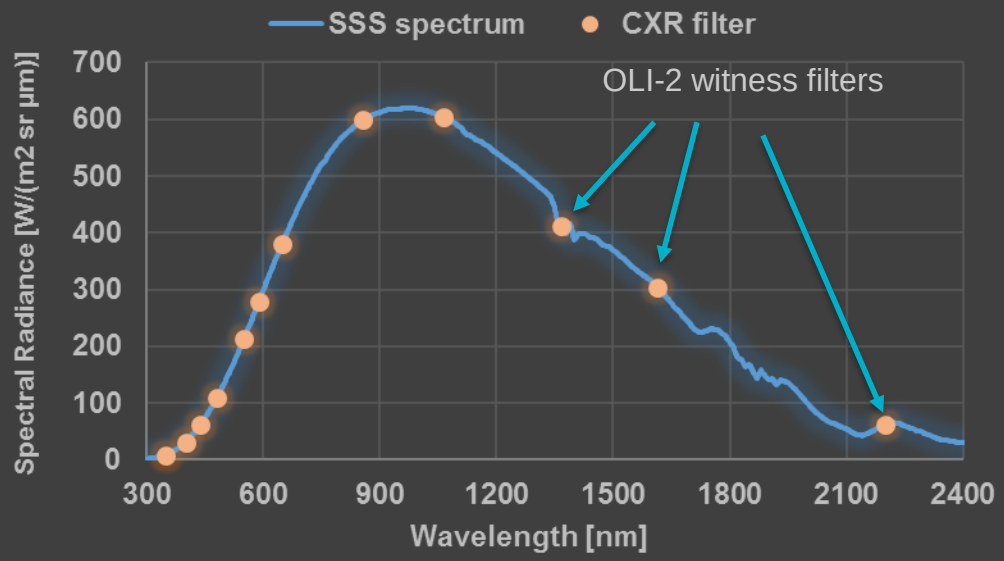


Diffuser	40” diam. $BaSO_4$
Aperture	14 in.
Lamps	18x QTH (150-600W)
Cooling	water manifolds
Power	constant current
Control	lamp attenuators

CXR Radiometer

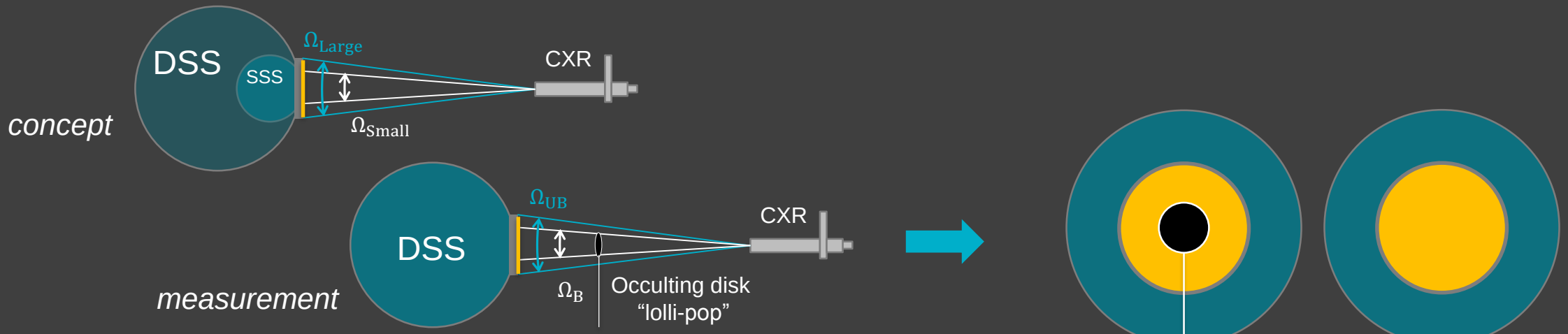






CXR Out-Of-Field (OOF) Correction

- **CXR is susceptible to "out-of-field" response**
  - **Stray light from *within* source aperture, but *outside* nominal CXR field of regard**
  - **Photocurrent biased by apparent source extent, i.e. larger for DSS Ω_{Large} vs. SSS Ω_{Small}**
  - **Bias correction: subtract photocurrent contribution outside small region**
- **Signal from outside Ω_{Small} is measured by blocking inner region:**

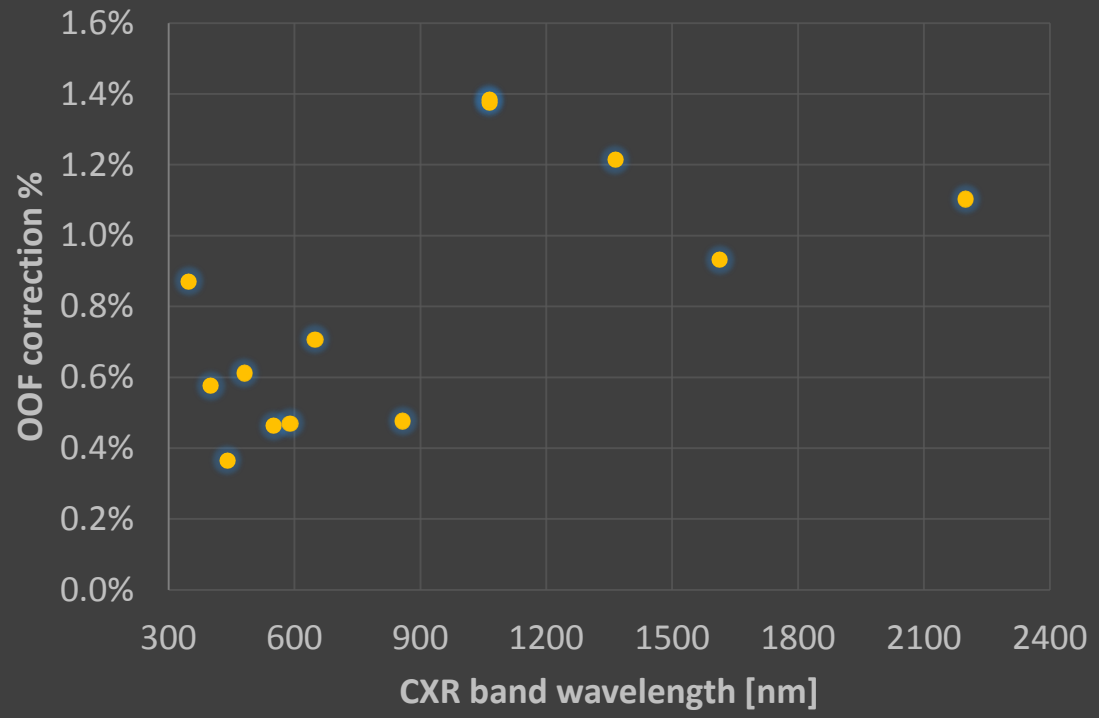


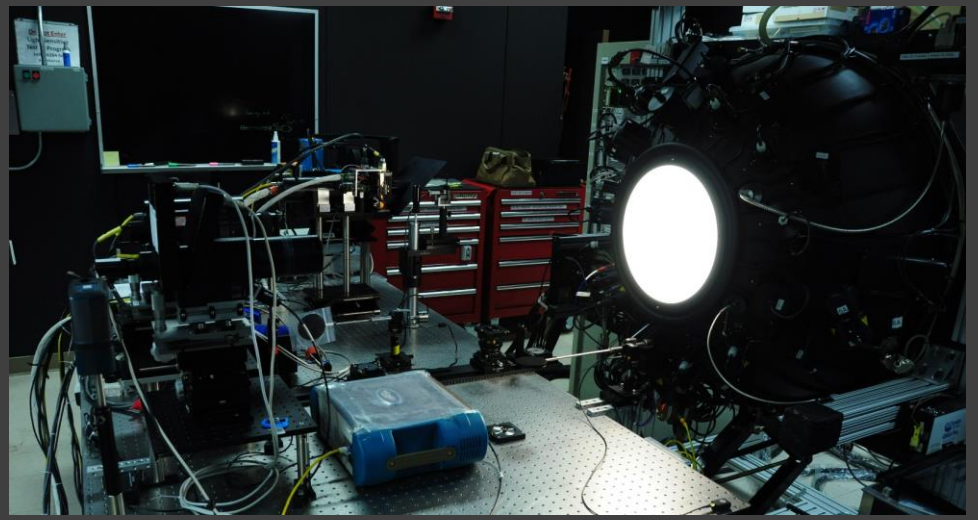
For each band *n*,

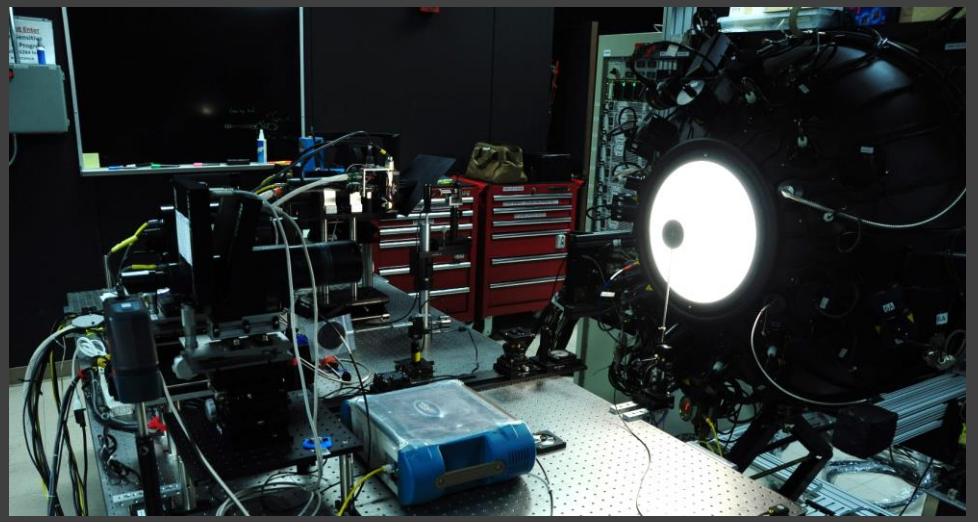
$$\zeta_{OOF,n}(\Omega_{Large},\Omega_{Small}) = \zeta_{OOF,n}(\Omega_{UB},\Omega_B) = \left(1 - \frac{I_{B,n}}{I_{UB,n}}\right)$$

CXR Out-Of-Field (OOF) correction

- CXR OOF correction measurement in practice:
- Uncertainty allocation = (correction %) / 2

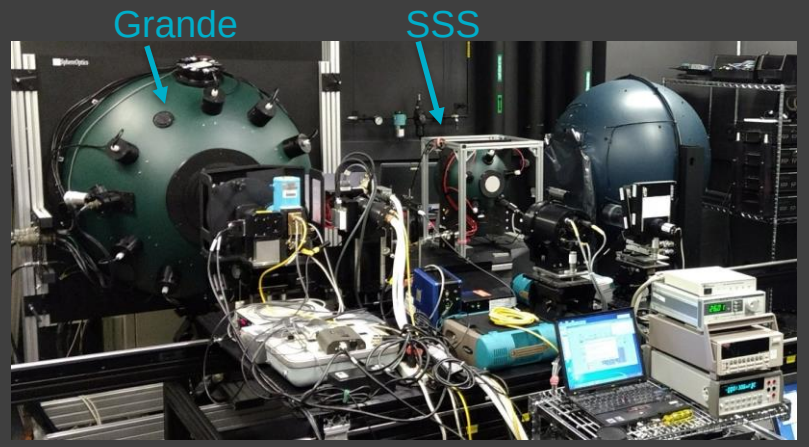


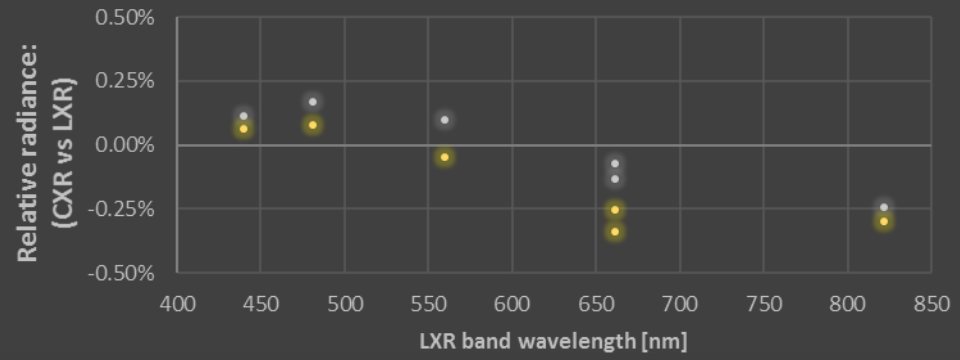


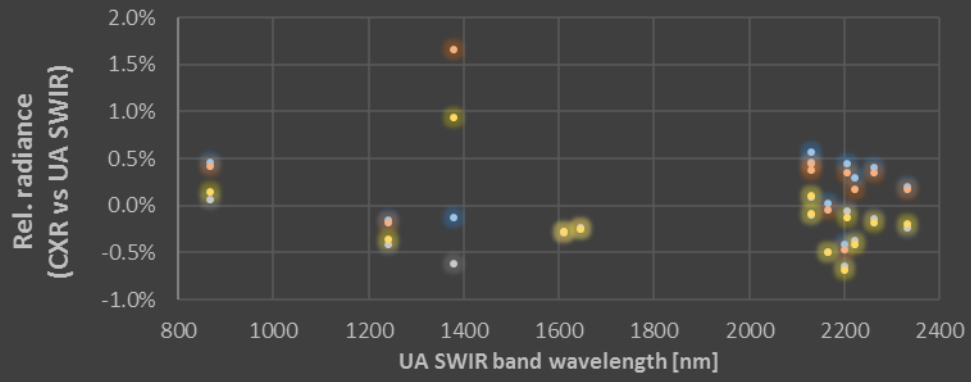


Round Robin - GSFC

- Radiometers: CXR (Ball), LXR (GSFC), UA VNIR and UA SWIR (U of A)
- Sources: SSS (30W and 90W), GSFC Grande sphere (4 lamps and 9 lamps)
- All radiometers measured all source levels 2-3x
  - SSS 90W used as standard, non-Cirrus band source stability within ±0.2%
  - RSR data for LXR, UA VNIR, UA SWIR provided to Ball
  - RSR-weighted CXR radiances compared to other radiometers' in-band radiance results
  - Radiometers generally within ±0.5% of CXR radiance
  - Exceptions: SWIR2 within ±0.75%, Cirrus within ±1.75%

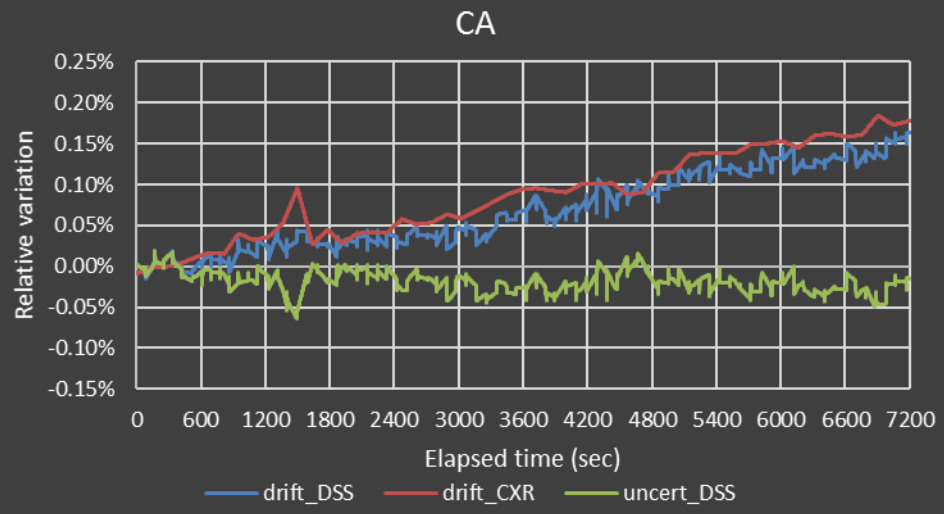


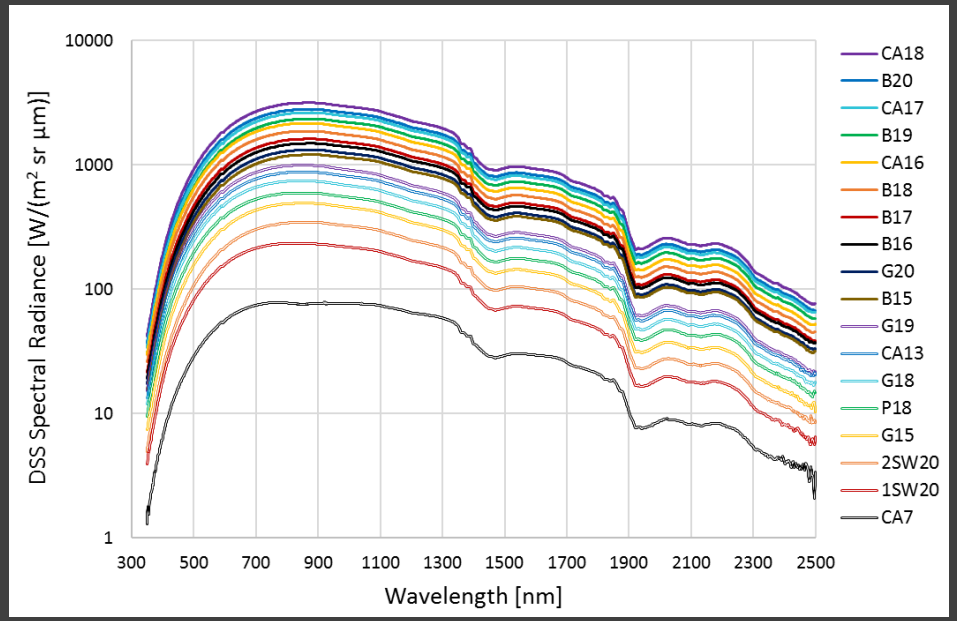




DSS Calibration – Ball Aerospace

- Calibration performed with CXR
- SWIR relative radiance validated by UA SWIR
- Initial baseline/checkout measurements
  - Validated functionality and radiance range
  - Linearized variable light control
  - Planned setpoints for instrument test
- Calibrated DSS from OLI-2 TVAC test location
- In situ cal reduces uncertainty from:
  - TVAC chamber window transmission
  - Chamber stray light effects
- Calibrated 180 levels:
  - In-band monitor 2hr stability: < ±0.05%
  - Relative radiance knowledge: < ± 0.5%
  - Absolute radiance knowledge: < ± 2.0% (non-Cirrus)
    < ± 2.4% (Cirrus)



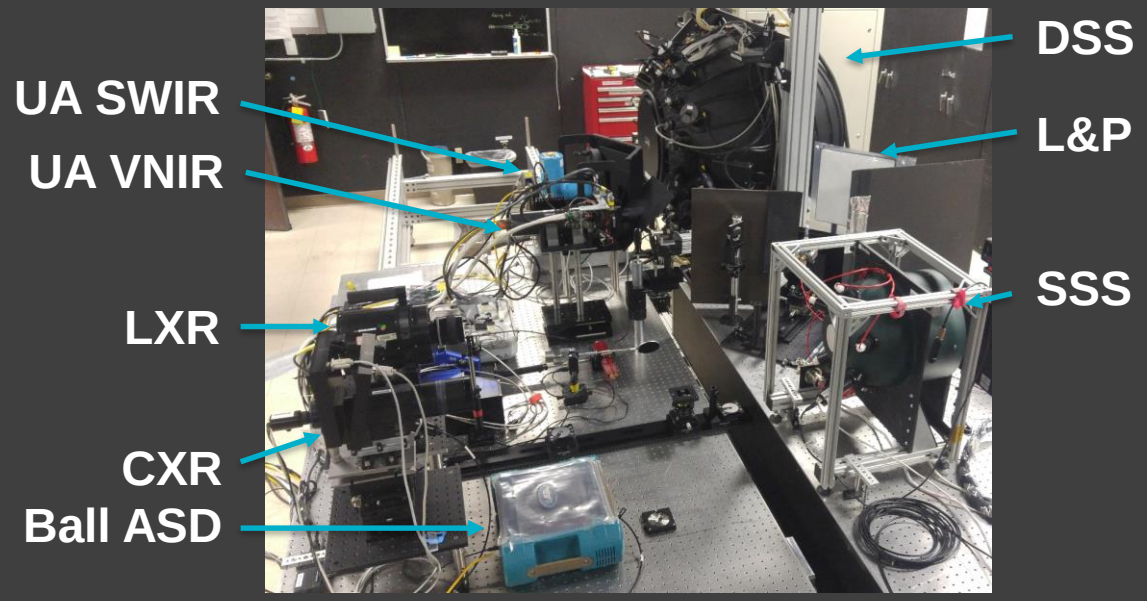


DSS Calibration Error Budget

	Coastal Aerosol	Blue	Green	Red	NIR	SWIR 1	SWIR 2	Pan	Cirrus
Traceability	443	482	562	655	865	1610	2200	590	1380
NIST SSS calibration	±0.6%	±0.49%	±0.41%	±0.4%	±0.4%	±0.67%	±0.74%	±0.41%	±0.84%
SSS to CXR transfer	±0.74%	±0.75%	±0.74%	±0.74%	±0.74%	±0.75%	±0.78%	±0.75%	±1.33%
CXR to DSS transfer	±0.99%	±0.83%	±0.74%	±0.71%	±0.7%	±0.75%	±0.86%	±0.97%	±1.43%
DSS to OLI transfer	±0.33%	±0.28%	±0.28%	±0.28%	±0.3%	±0.3%	±0.54%	±0.37%	±1.04%
Expected error (k=1)	**1.76%**	**1.57%**	**1.46%**	**1.43%**	**1.42%**	**1.61%**	**1.82%**	**1.68%**	**2.37%**

Round Robin – Ball Aerospace

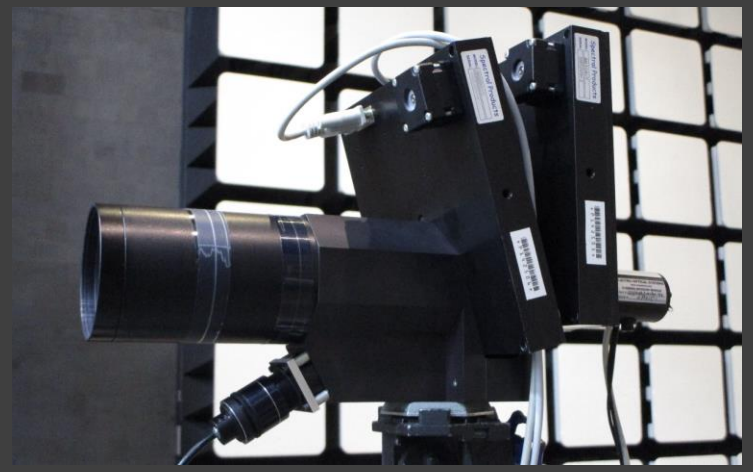
- Radiometers: CXR (Ball), LXR (GSFC), UA VNIR and UA SWIR (U of A)
- Sources: SSS (90W), DSS, FEL Lamp & Panel (L&P)
- SSS – confirmed mutual stability of radiometer responsivity < 0.2%
- Lamp and Panel – CXR and UA SWIR Cirrus results match to < 0.4%
- DSS – Relative radiance knowledge confirmed by LXR, UA VNIR and UA SWIR to < 0.5%
- DSS – Absolute radiance confirmed at L_{typ} by LXR, UA VNIR and UA SWIR to < 0.4%



Radiometer	DSS Control Band	CXR Bias
LXR	Coastal Aerosol	-0.28%
UA VNIR	Coastal Aerosol	-0.33%
LXR	Blue	-0.25%
LXR	Green	0.09%
LXR	Red	0.04%
LXR	NIR	-0.14%
UA SWIR	SWIR 1	0.13%
UA SWIR	SWIR 2	0.22%

Conclusion – Keys to Success

- ***Efficiency*** | **CXR Radiance Transfer Algorithm**
  - Improved data processing flow
  - Quick-turn and repeatable results
- ***Stray Light Mitigation*** | **CXR Out-Of-Field correction**
  - Validated correction method ahead of DSS calibration
  - Applied methodology to *all* radiance transfers
- ***Spectral Accuracy*** | **CXR SWIR band OLI-2 witness filters**
  - RSR matching mitigates low SWIR spectrometer resolution
  - Allows accurate radiance transfer between dissimilar spectra
- ***Stability*** | **DSS in-band monitoring and control**
  - Mitigates source spectral drift
  - Careful planning of levels for minimal lamp state changes



Acknowledgements

- **OLI-1 Calibration** – Hansford Cutlip et al, “OLI Radiometric Calibration: Ground Support Equipment Characterization and Calibration” (CALCON 2010)
- **Ball calibration specialists** – Hansford Cutlip, Geir Kvaran, Sandra Collins
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