The OLI Radiometric Scale Realization Round Robin Measurement Campaign

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Abstract

- 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.

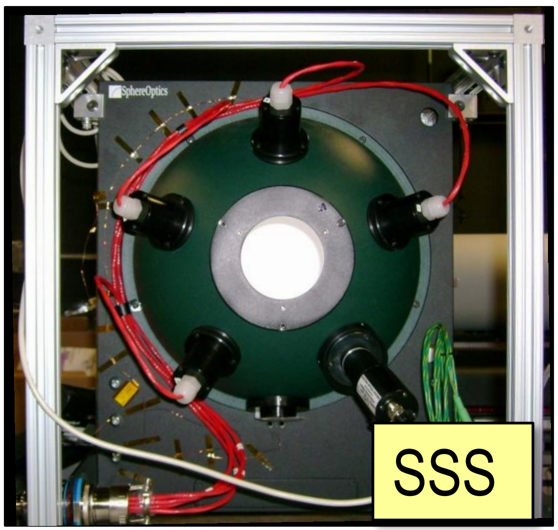
- ***Requirement: Sphere radiance uncertainty in test configuration <u>shall not exceed 2.4% 1σ</u>***

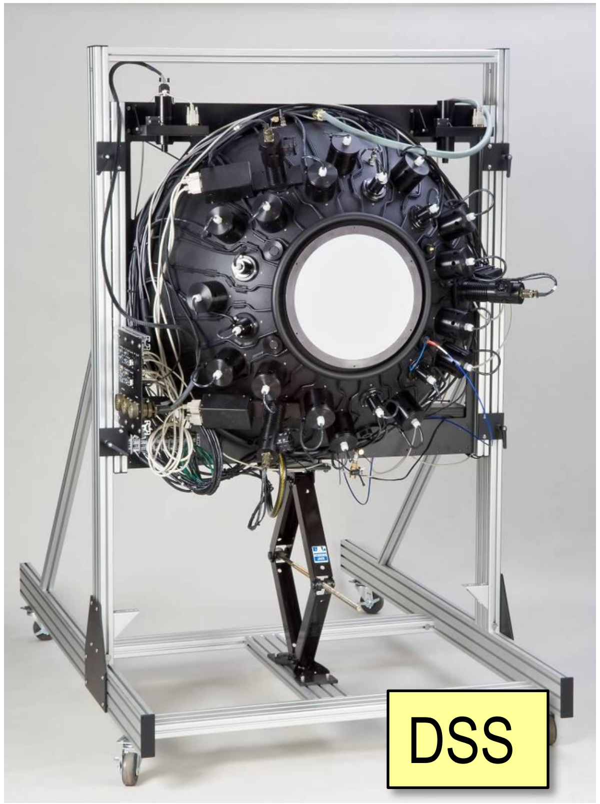
Assigned Integrating Sphere Uncertainties

OLI Band	Coastal Aerosol	Blue	Green	Red	NIR	SWIR 1	SWIR 2	Pan	Cirrus
Band Center (nm)	443	482	562	655	865	1610	2200	590	1375
1σ Uncertainty(%)	2.2	1.9	1.8	1.8	1.8	2.4	2.3	2.0	2.3

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

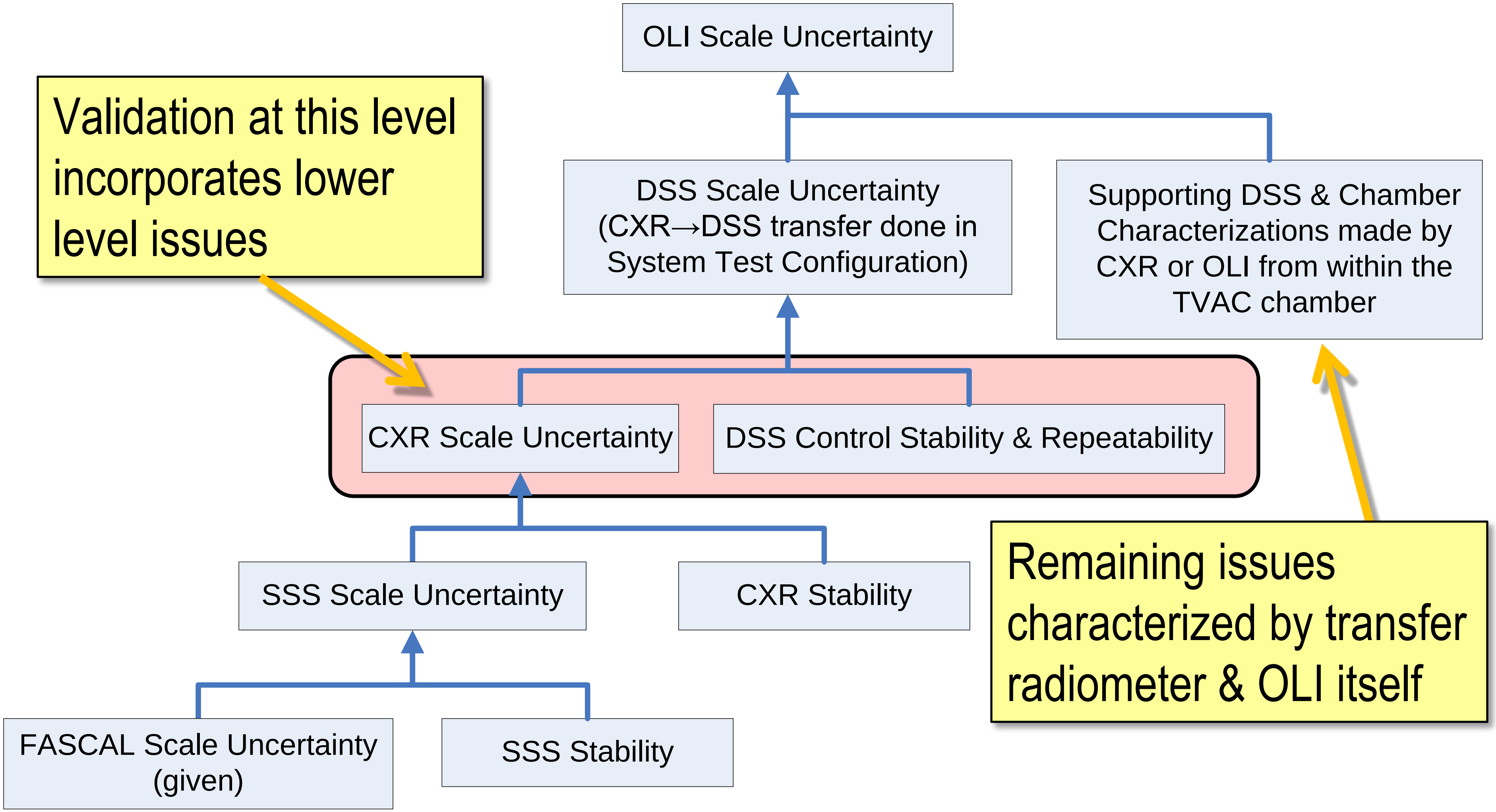
SSS 2-level spectral radiance calibration @ NIST FASCAL → Transfer **SSS** cal to **CXR** → Transfer **CXR** cal to **DSS** in system test configuration → Calibrate OLI w/ **DSS** in system test configuration → Confirm CXR & DSS scales with Radiometer Round Robin (BATC, U of A, NASA, & NIST)

SSS internal monitor & external radiometers

CXR filters & photodiode

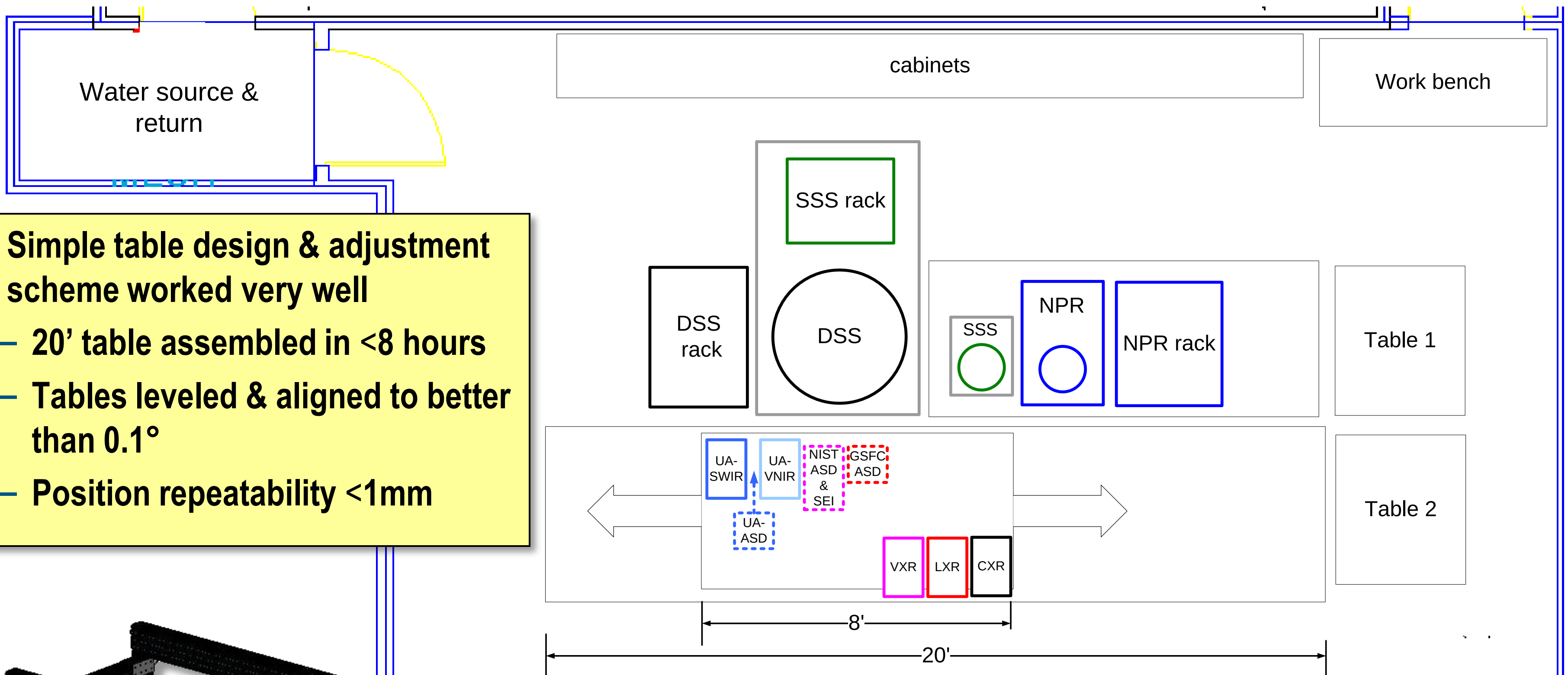
DSS internal monitors

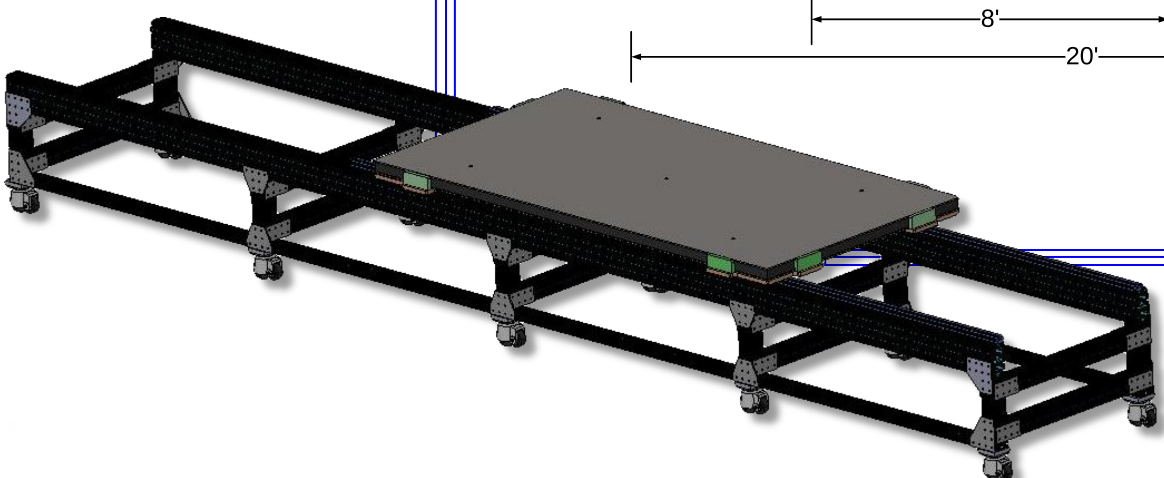
Scale Realization Campaign Validates the Majority of the Pre-launch Radiance Uncertainty Budget



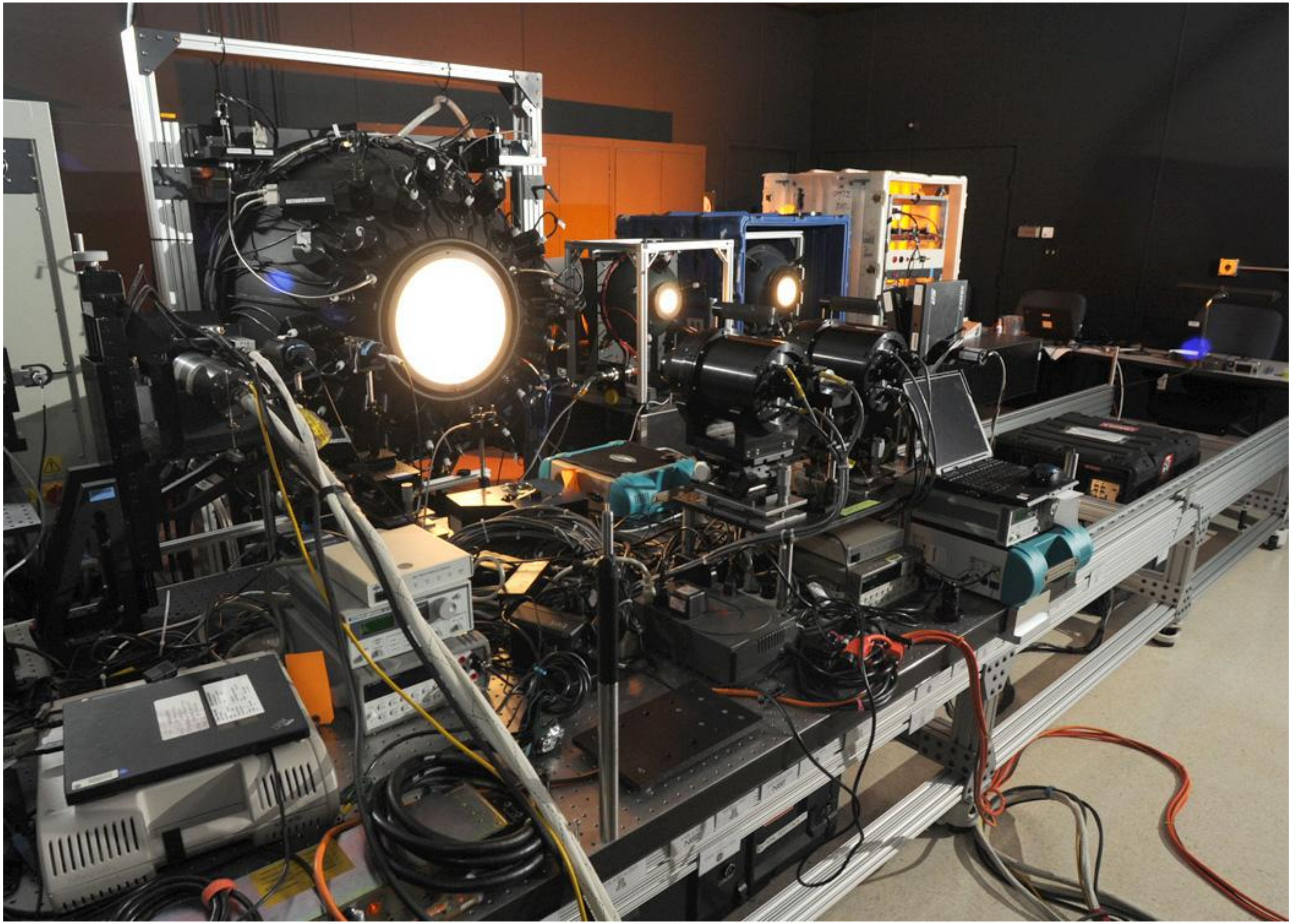
BATC Radiometric Calibration Laboratory Reconfigured for This Activity

- **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**

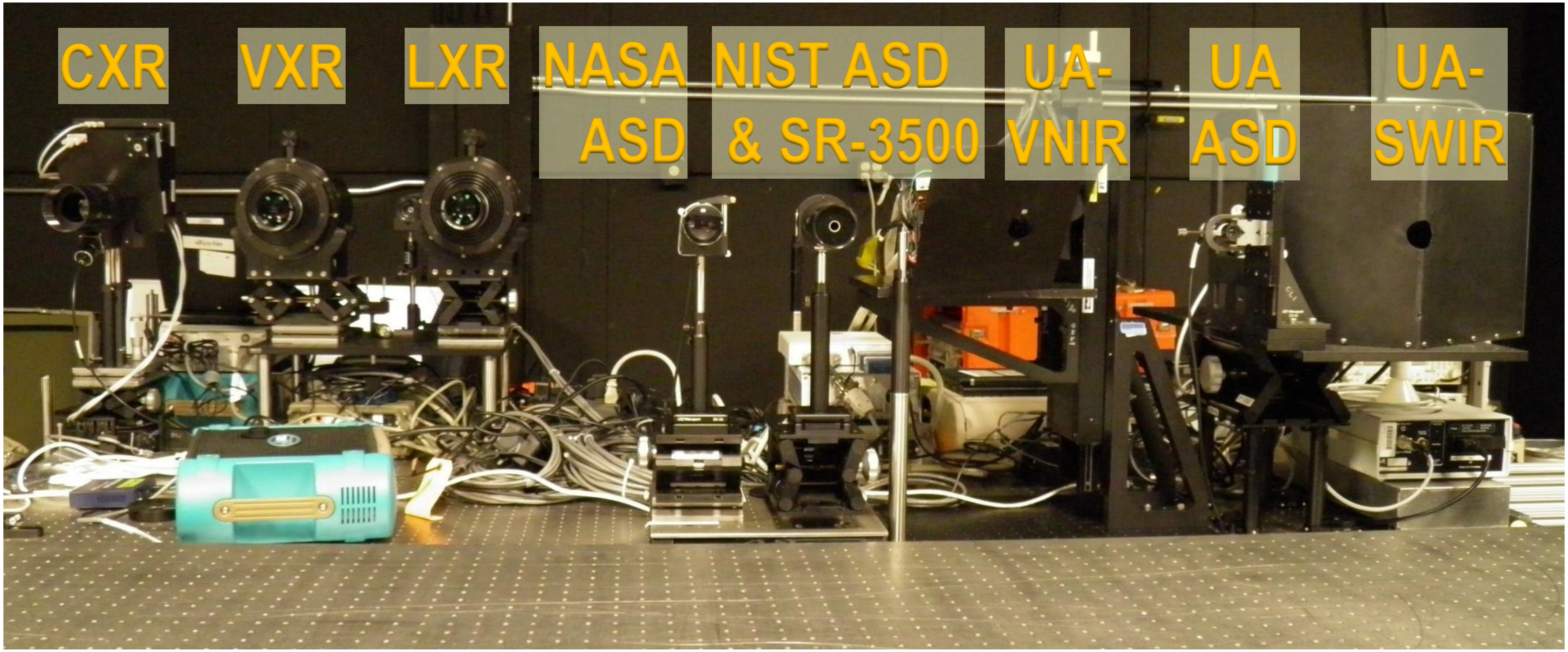




Accommodating Twelve Radiometric Assets is not Trivial

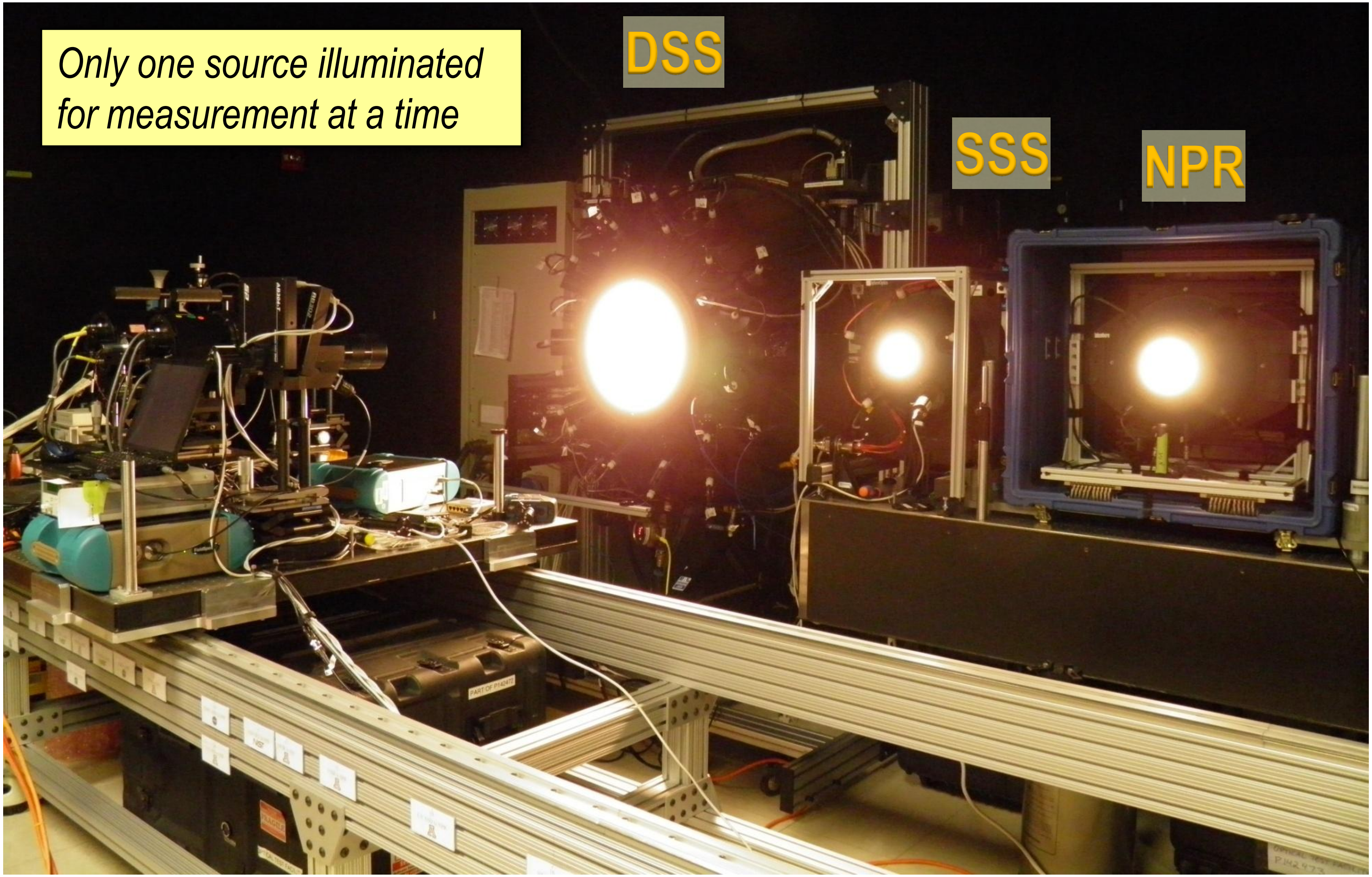


Four Filter Radiometers, Four Spectrometers, & One Hybrid

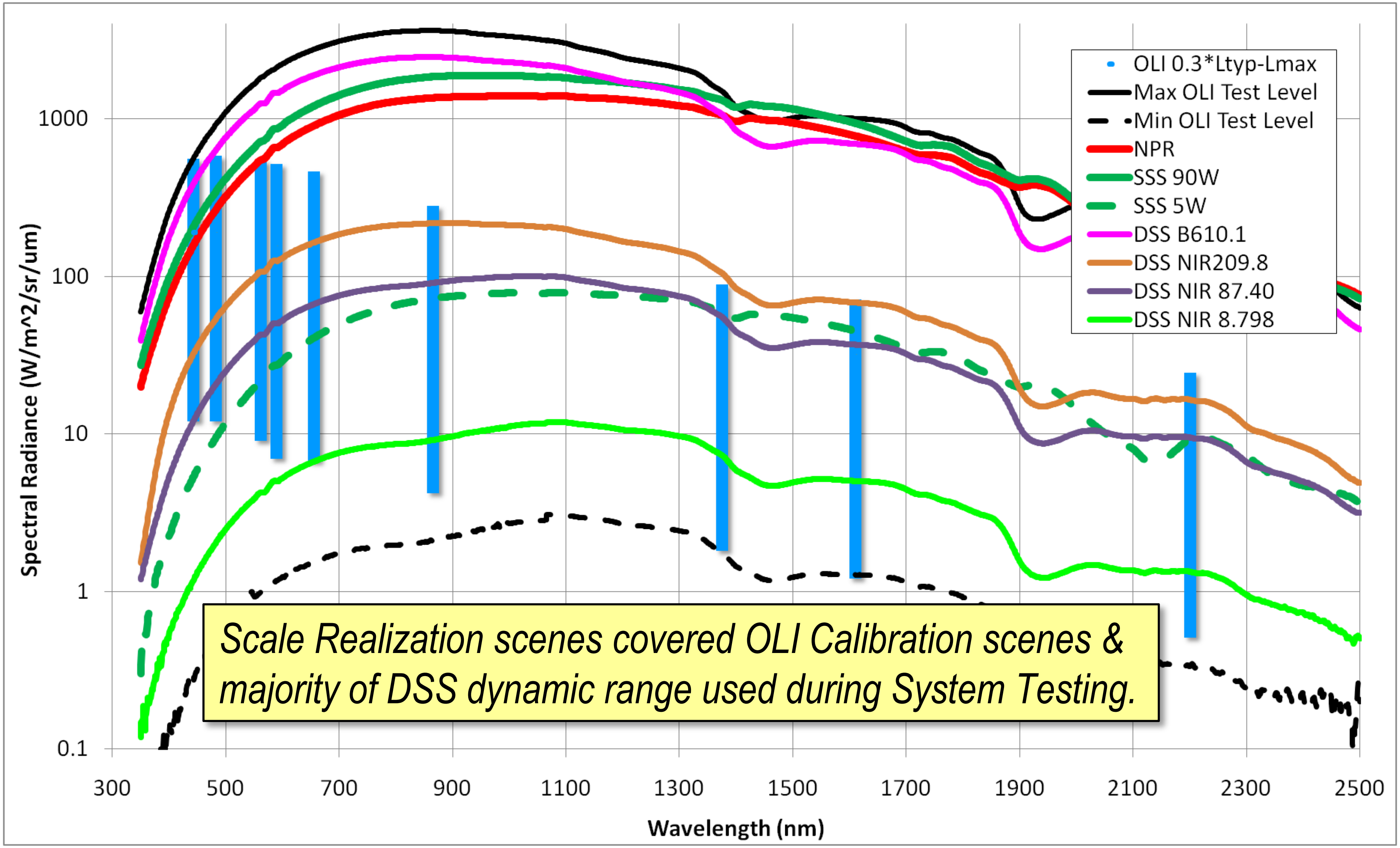


- Radiometer-source distance varies to accommodate FOV & distance requirements
- Lines of Sight true to master alignment laser to better than 0.1°
- Translational repeatability established by table markings and stop blocks
- NIST spectrometers shared a magnetic kinematic base

Two Sintered PTFE Spheres (NPR & SSS) & One $BaSO_4$ Sphere (DSS), All QTH Powered



One NPR, Two SSS, & Four DSS Levels, Each Measured Twice



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

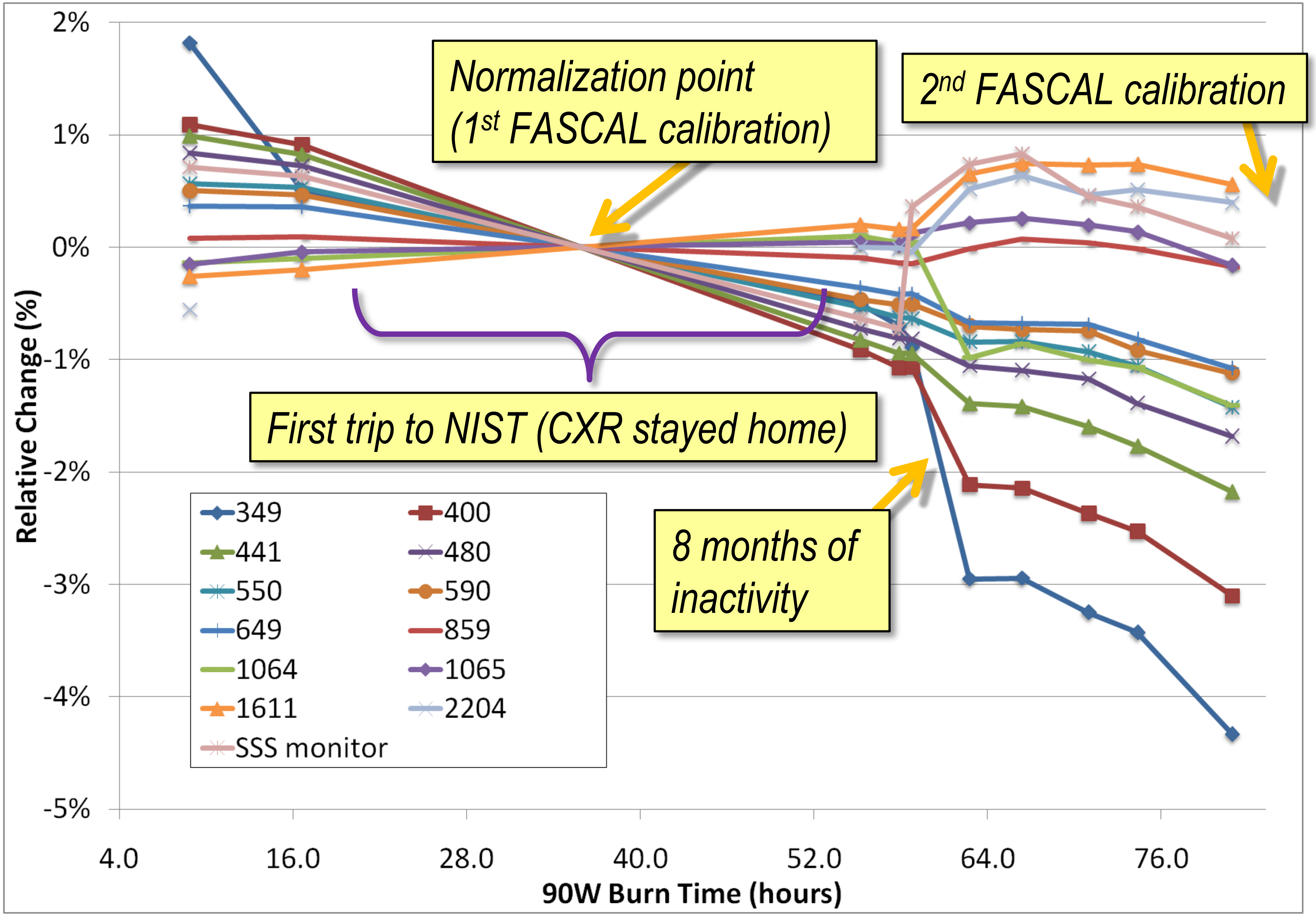
Everything takes longer than you think it's going to

DSS Uncertainty Validation Plan (underway)

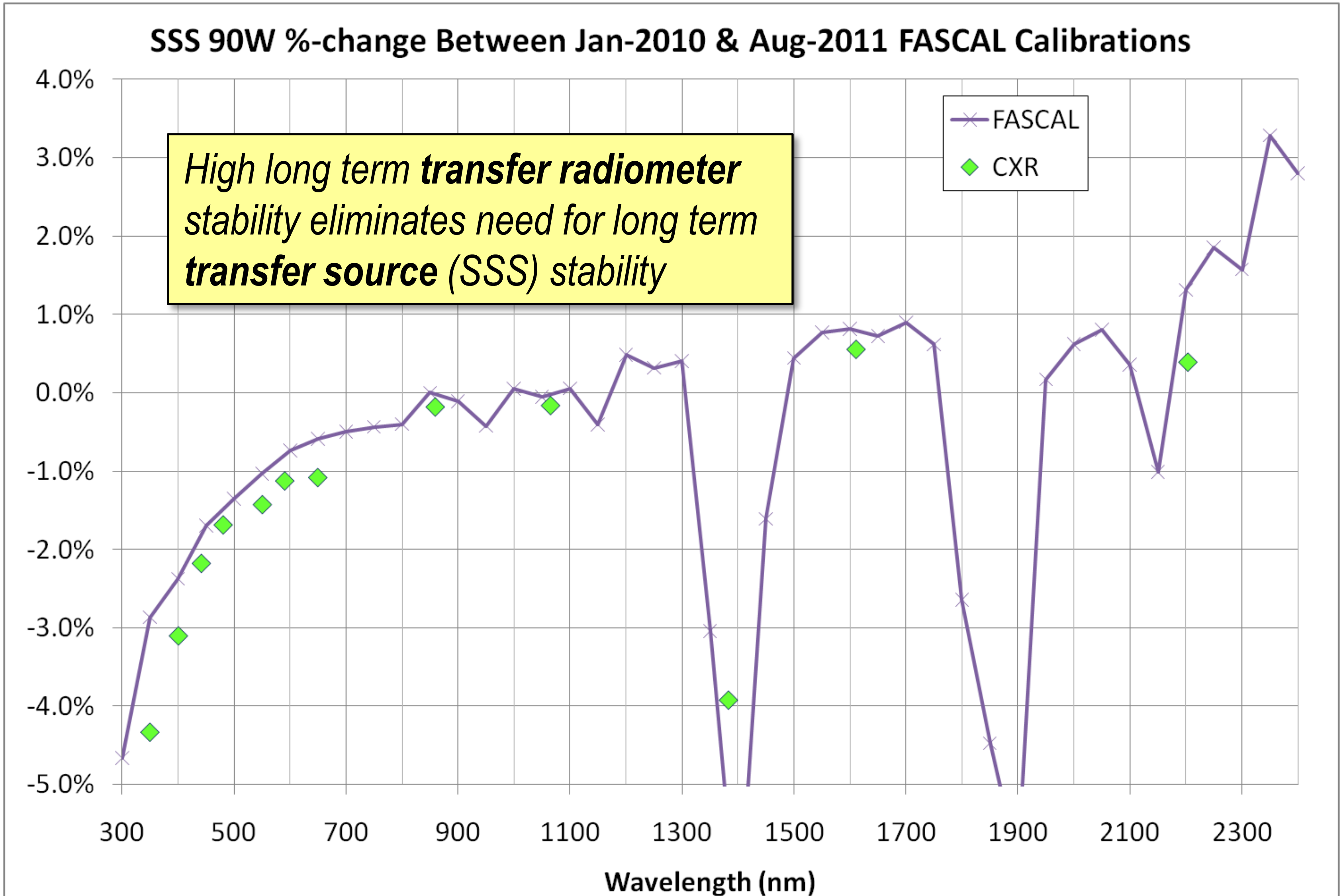
#1	Objective	Demonstrate stability of participating radiometers
	Verification Methodology	Compare observed trends in SSS output from 6 measurement campaigns (Jan. 2009 – Aug. 2011) & evaluate consistency amongst the radiometers
#2	Objective	Validate CXR responsivity scale uncertainty
	Verification Methodology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

Most measurements (>90%) complete, analysis & documentation still ongoing

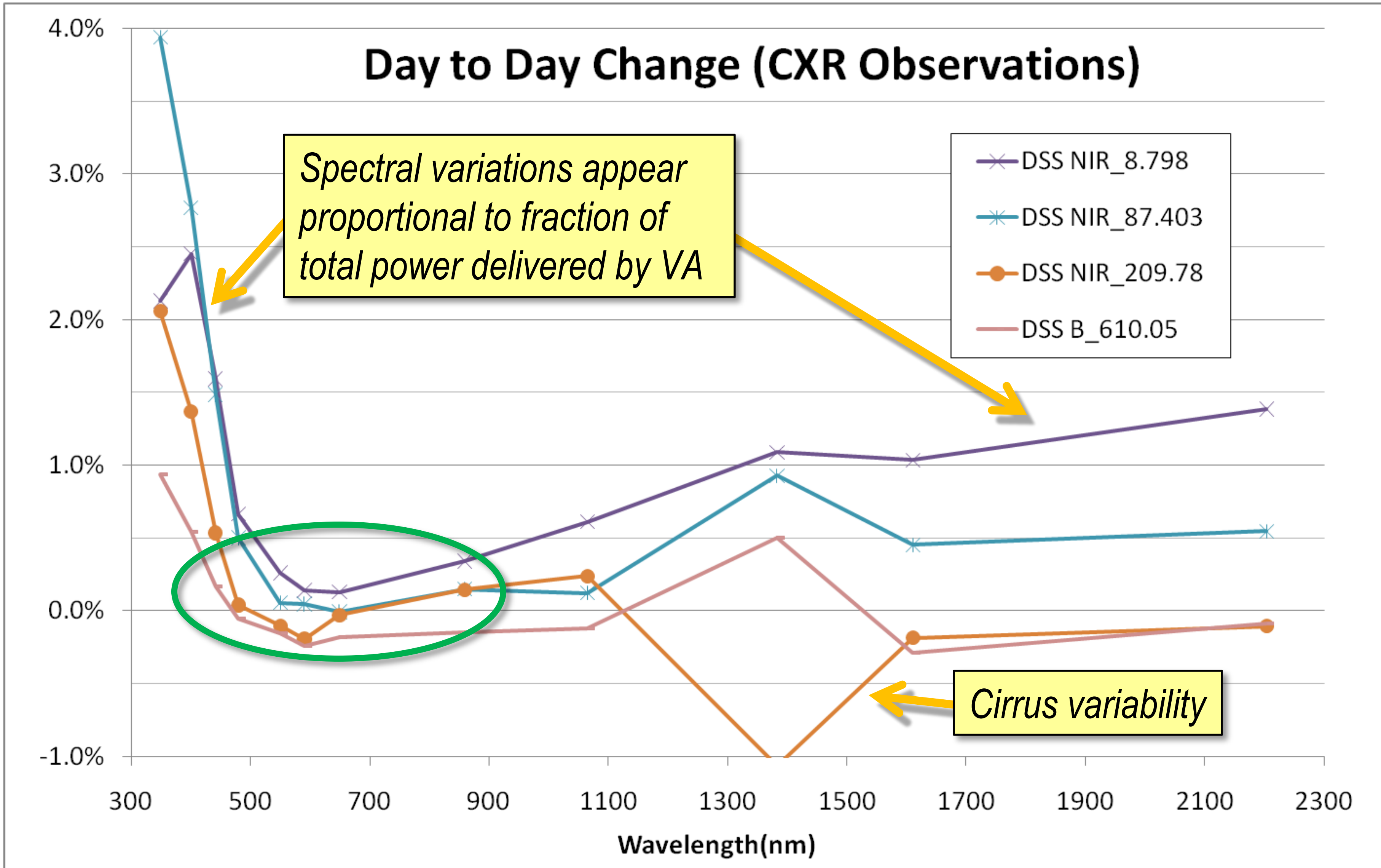
CXR/SSS Stability Measurements Illustrate Challenges in Using Spheres as Artifacts



CXR Stability Verified by NIST FASCAL Measurements

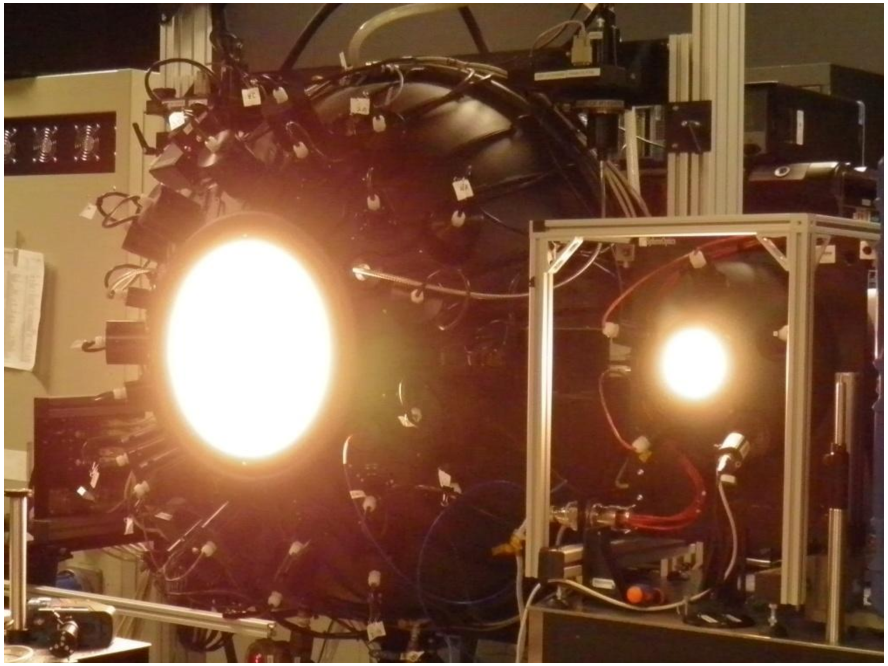


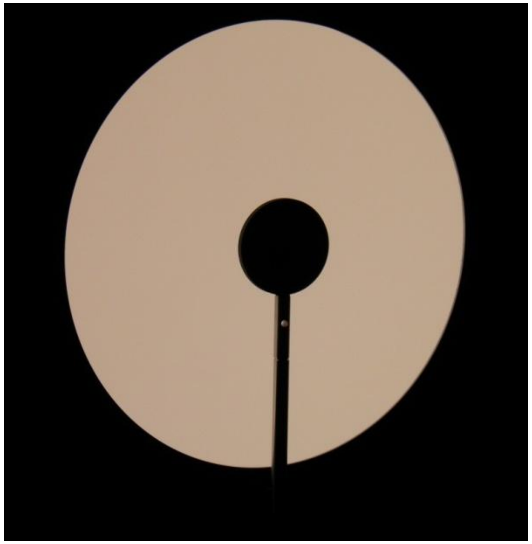
Closed Loop Radiance Control Helps at Control Wavelength, May Hurt Elsewhere



Disparate Apertures Require Size of Source Effect Measurements and Corrections

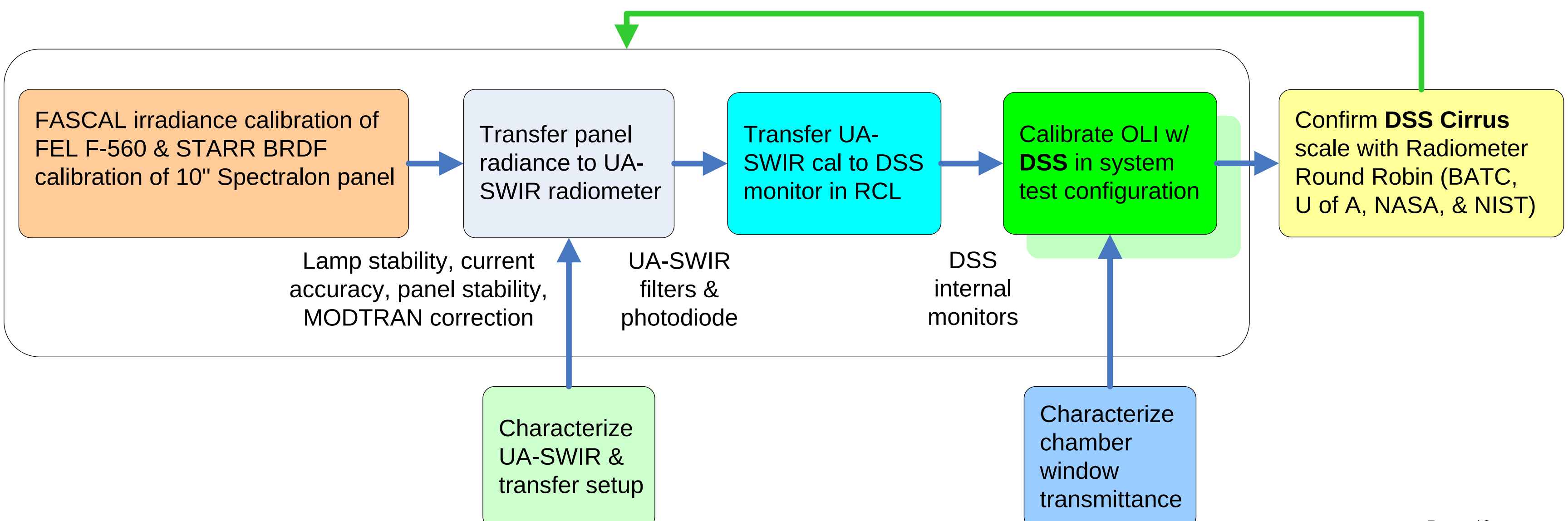
- Process requires calibration transfer from a 3” aperture source to a 14” aperture source
- Observations of a 3” black “lollipop” used to quantify out-of-field (OOF) contribution & evaluate important radiometer spatial response characteristics
- The OOF was independent of sphere level (as expected)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





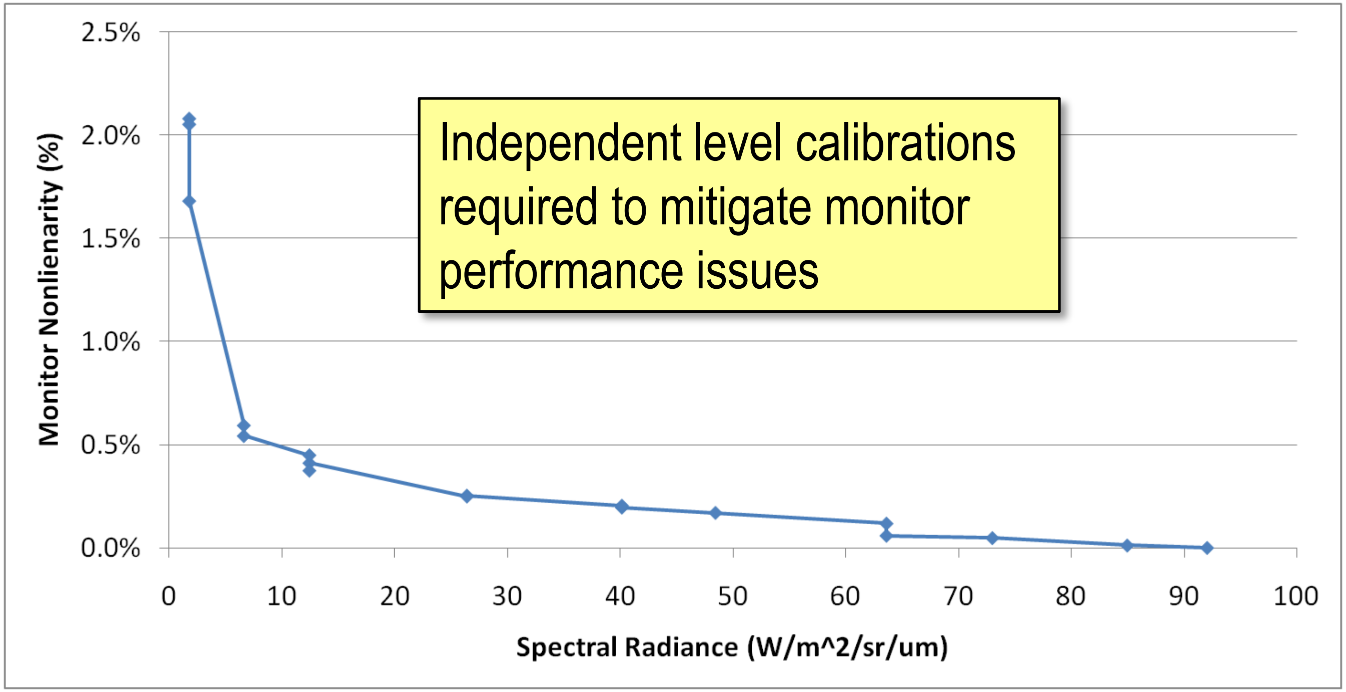
UA-SWIR Radiometer Utilized for Cirrus Band Calibration

- 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



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



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?