GOES-R Calibration Working Group Progress Update

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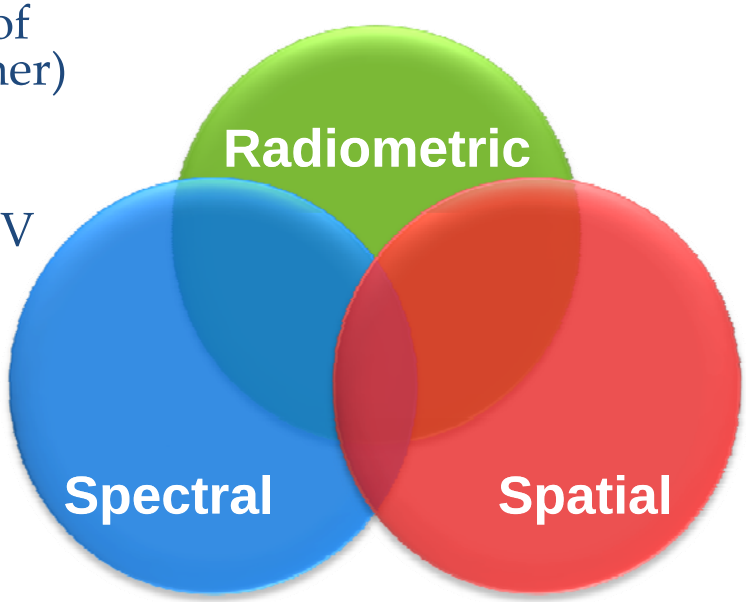
With contributions from the STAR, NIST, MIT/LL, MSFC teams
NOAA/NESDIS/STAR
GOES-R Calibration Working Group

January 2012

GOES-R Calibration Working Group (CWG)

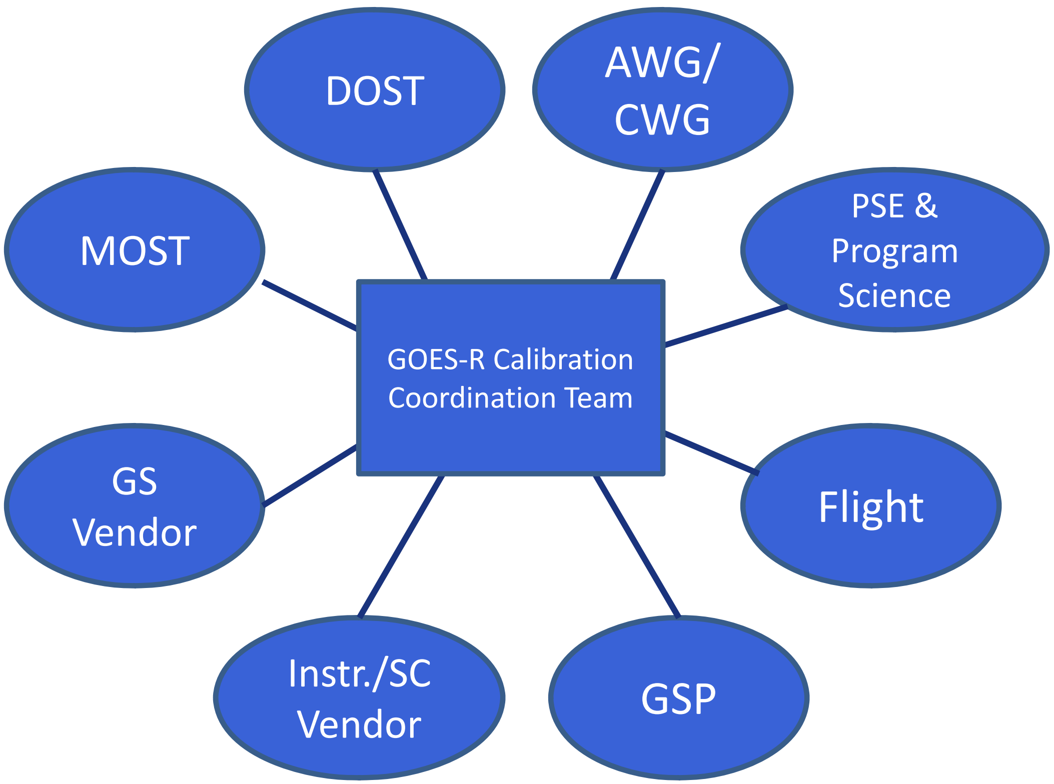
- Verify and ensure well-calibrated, & well-navigated GOES-R L1b data for the life time of the instruments (ABI, GLM, and Space Weather)
- Ensure Level 1B data quality and science integrity. Provide technical oversight and V&V for:
  - Radiometric calibration
  - Spectral calibration
  - Spatial calibration/navigation
  - Verification of L1B data
  - Instrument performance issues



- Provide technical support to the Flight and Ground through Program System Engineering (PSE)
- Members include scientists and engineers from NOAA, NASA, NIST, MIT/LL, and all segments of GOES-R program

Calibration Coordination Team (CCT) Formed Under PSE

Scope – ***A coordinating body to ensure efficient implementation of calibration activities throughout the GOES-R Program during all mission phases.***



GOES-R Calibration Coordination Team membership diagram

CCT members - Representatives of any group with responsibility to ensure L1b Product integrity, *e.g.,*

- PSE & Program Science (Cal/Val Working Group Reps)
- Flight (Deputy Project Manager, Instrument Managers)
- GSP (Ground System Project)
- Vendors (Instrument, Spacecraft and Ground)
- AWG (Algorithm Working Group)
- MOST (Mission Operations Support Team)
- DOST (Data Operations Support Team)

Four Phases of Calibration/Validation

1. Pre-Launch (development and I&T)
- CDRL (Contractor Delivery Requirement List) peer review, PDR /CDR (Preliminary/Critical Design Review)
- Algorithm & calibration database development & verification
- Data format/content/quality flags
- Bench/TVAC (Thermal Vacuum) tests and analysis
- Trade studies and waivers
- Validation capability development and preparation
- Prelaunch SI traceability

2. Postlaunch check-out
- Engineering tests to ensure specification compliance
- Calibration processing
- Anomaly analysis

3. On-orbit verification (Environmental cal. initialization)
- Instrument characterization
- Sensor artifact study and correction
- Algorithm adjustment
- Inter-comparison between satellites, and with NWP models
- Both L1b and L2Validation

4. Long-Term Monitoring (Mission operational life)
- Routine monitoring of instrument performance
- Inter-satellite comparison and NWP (Numerical Weather Prediction)models

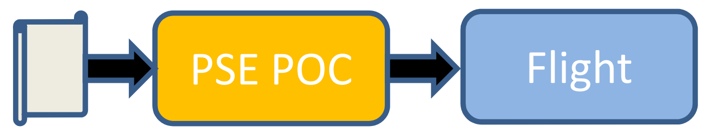
Prelaunch Test Data Analysis and Verification

Objective

- To ensure that the pre-launch data are evaluated consistently and accurately with respect to requirements and well understood for operational use as well as on-orbit anomaly resolution

Process

- Review test plans and technical reports
- Analyze test data delivered by vendors
- Develop and deliver reports documenting findings



CWG Report Process

Progress:

1. <u>ABI PTM (Proto-type Model) Reports Completed</u>
   - ➢Irradiance Calibration Test for Reflective Bands
   - ➢Emissive Band Calibration Test

2. <u>ABI PTM Reports Pending</u>
   - ➢ Coherent Noise Test
   - ➢ Reflective Band Calibration Test

NIST Participation in Prelaunch Testing

NIST participation in prelaunch tests ensures quality of the level 1b data products by establishing traceability to SI units

Deployments and Tests:

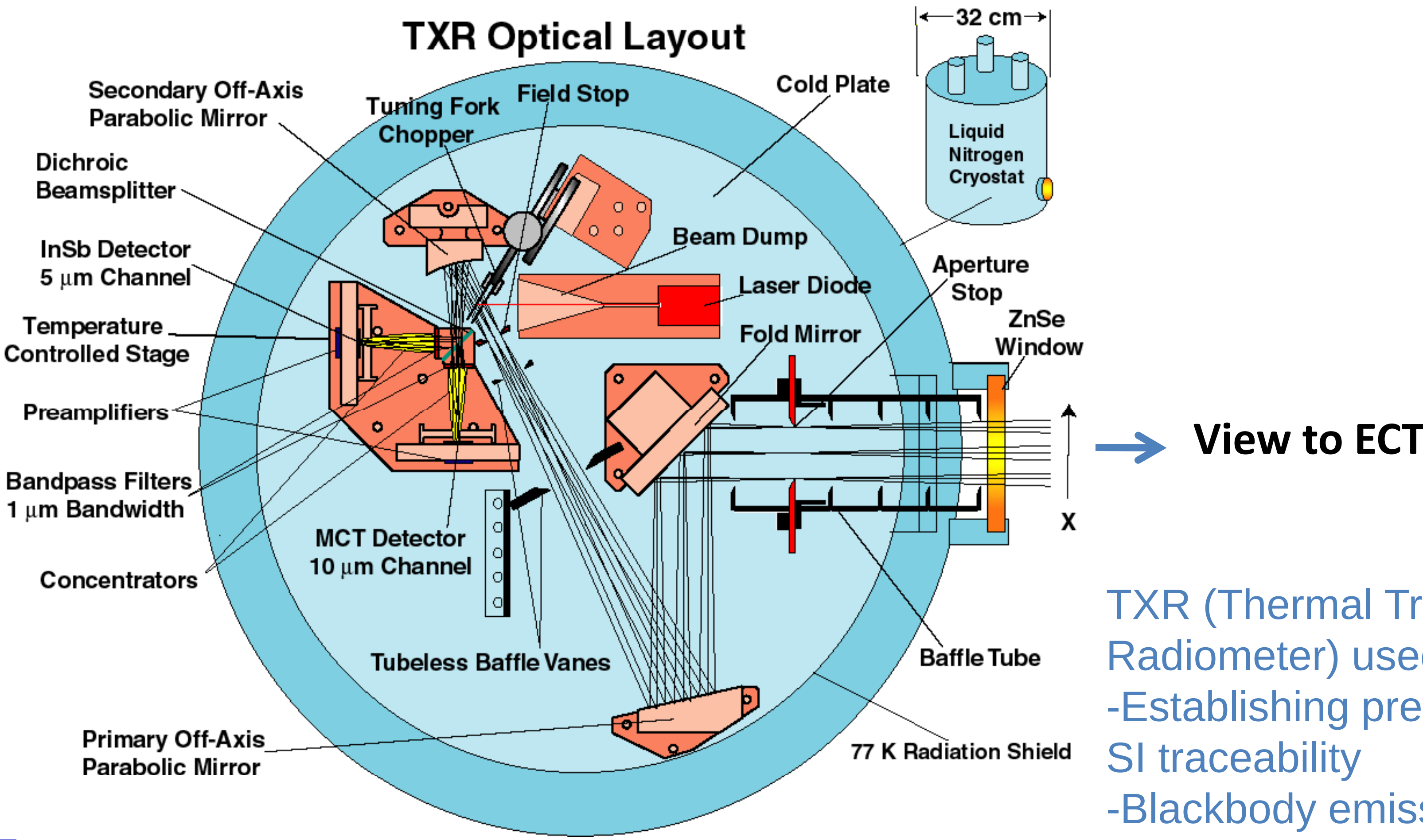
ABI

- Measurements related to Irradiance Calibration Test:
  - Validation of vendor FEL lamp calibration process
  - Uniformity Test associated with Irradiance Calibration Test ✓Completed
- Thermal Infrared Transfer Radiometer (TXR) Deployment ✓Completed
- Spectral Irradiance and Radiance Responsivity Calibration with Uniform Sources (SIRCUS) Deployment ✓Completed ✓Completed for PTM
- Filters for 16 ABI bands safely arrived at NIST and are being characterized — In progress
- Transfer sphere calibration, Visible Transfer Radiometer (VXR) Deployment, ✓Completed

EXIS/ SUVI

- SURF calibration tests for XRS instruments ✓Completed
- EXIS grating measurements ✓Completed

External Calibration Target (ECT) Characterization using NIST TXR



TXR (Thermal Transfer Radiometer) used for
-Establishing prelaunch SI traceability
-Blackbody emissivity characterization

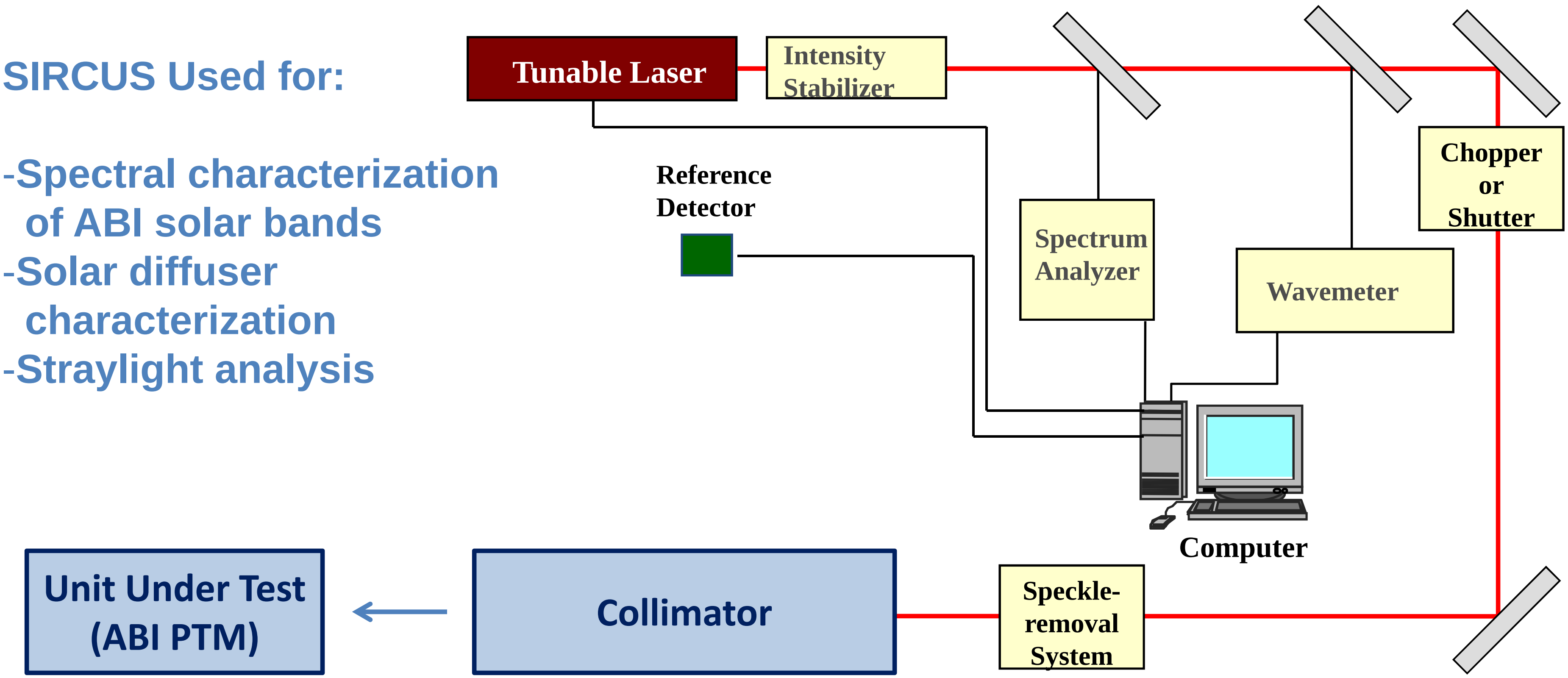
NIST
National Institute of Standards and Technology

NIST Travelling SIRCUS

Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources (SIRCUS)

SIRCUS Used for:

- Spectral characterization of ABI solar bands
- Solar diffuser characterization
- Straylight analysis



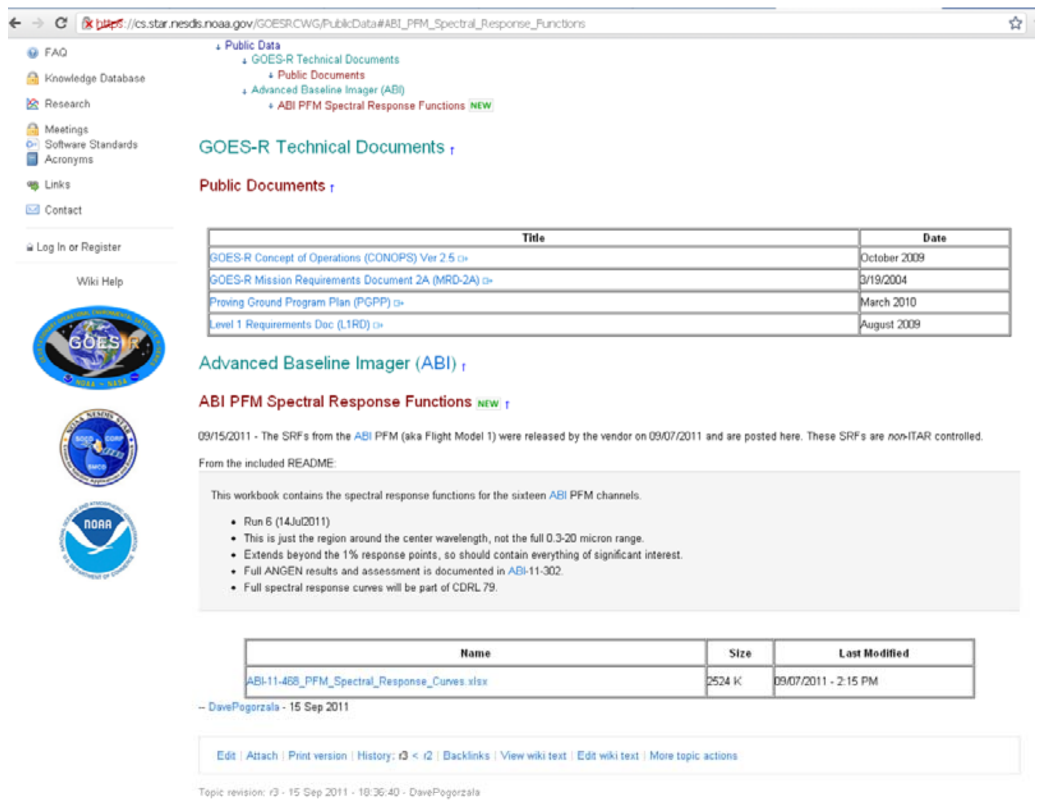
ABI PFM Spectral Response Functions

- ABI PFM (Proto-flight Model) =flight model

- Public version of ABI PFM Spectral Response Functions (SRFs) are made available

- SRFs were analytically Generated (ANGEN)

- Witness sample filters will be tested at NIST



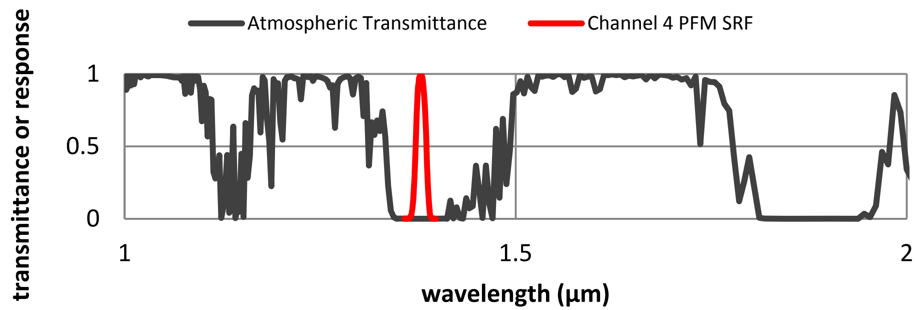
ABI PFM SRF available at : https://cs.star.nesdis.noaa.gov/GOESRCWG/PublicData

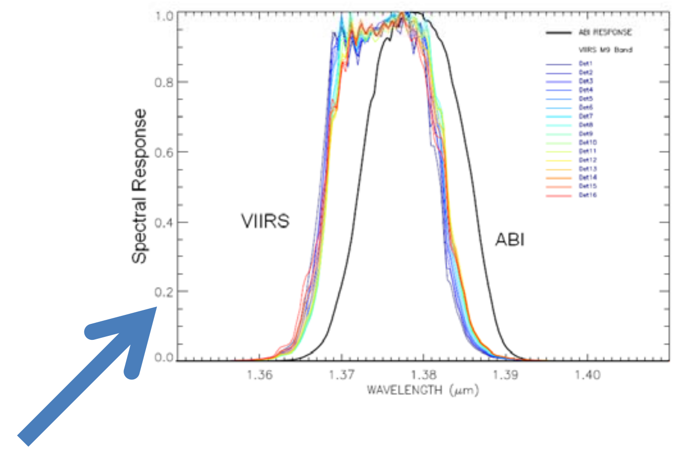
Spectral Response Function Uncertainties for the 1.38 um band

- Comparison with VIIRS

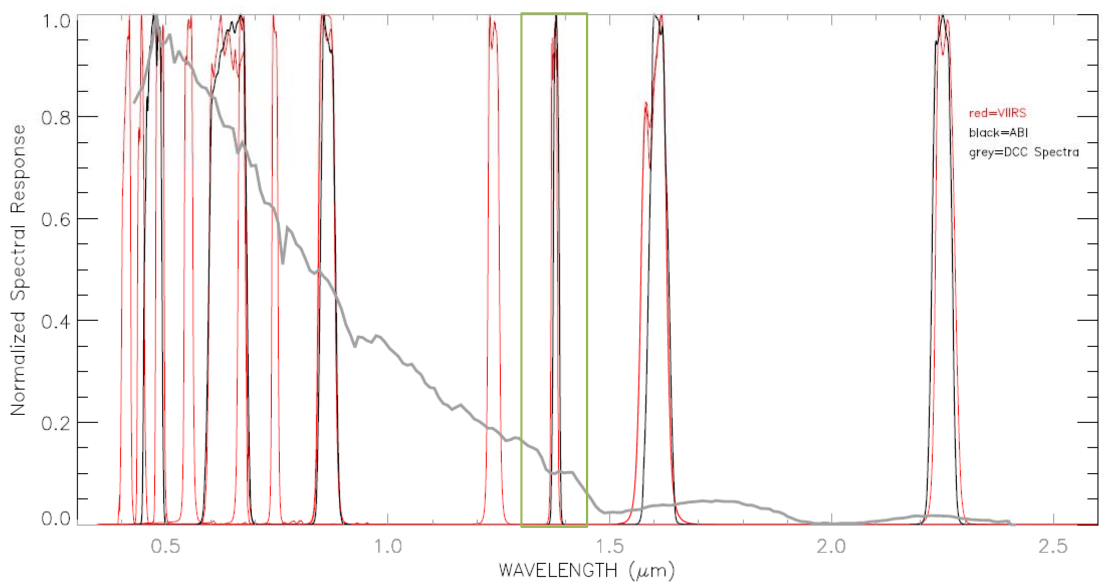
Proto Flight Model(PFM)-1

Total Atmospheric Transmittance from Sea Level to 100km Altitude and Relative Response of the ABI 1.38µm Channel





- ABI and VIIRS have several similar solar bands
- Both use NIST SIRCUS to reduce spectral uncertainties
- The 1.38 um band still has large uncertainties due to atmospheric effects which require additional studies (vacuum vs. ambient, etc.)



Mitigation for ABI SRF Uncertainties

NIST SIRCUS Test and Data Analysis

- Analyze SIRCUS data to verify ANGEN for PTM.
- Compare SIRCUS results of ABI vs VIIRS

PFM Witness Filter Measurements

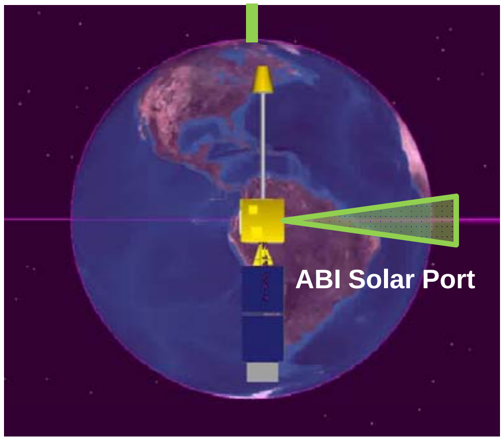
- NIST to measure witness filters for the ABI PFM for all bands to
  - Reproduce vendor results
  - Examine dependence on temperature and angle of incidence
  - Measure filters in flight conditions
- Analyze NIST witness filter measurements and recreate ANGEN for PFM to evaluate uncertainties.

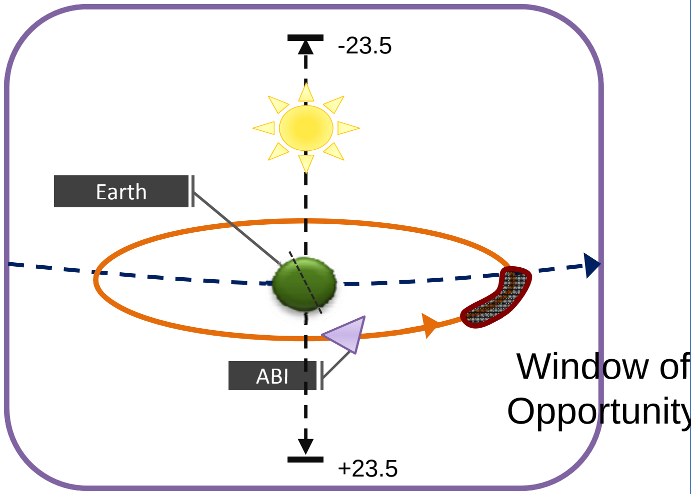
MODTRAN Simulations

- Perform simulations to understand potential impacts of SRF differences.

Solar Diffuser (SD) Calibration Support

- SD is critical for evaluating solar band performance, including stability, degradation, signal to noise, and anomaly analysis (as demonstrated in NPP VIIRS)
- ABI SD calibration is more challenging due to partial aperture, and the alternative approach used in prelaunch testing
- CWG completed analysis of PTM irradiance test results with important findings and provided feedback to the program
- CWG is developing analytical capabilities to support on-orbit solar diffuser calibration, including solar and lunar geometry analysis using orbital perturbation models, leveraging experience with NPP/VIIRS SD calibration



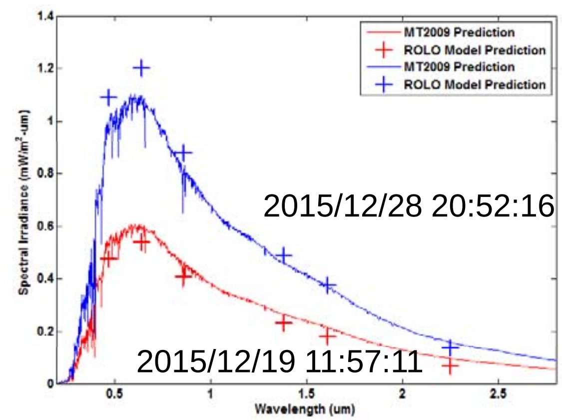


1 Day

Calibration of GOES-R ABI using Lunar Irradiation Models

- Lunar calibration: Photometric stability of the lunar surface < 10^{-8} /year.
- In collaboration with T. Stone from USGS to predict
  - Opportunities to view the Moon from the hypothetical GOES–R positions in geostationary orbit
  - Lunar irradiance with ROLO model in the six ABI solar reflective channels
- Acquired Miller-Turner (MT2009) lunar irradiance prediction model
- Compared moon irradiance predictions between MT2009 model and ROLO model.

Sample lunar image (GOES10)



Aircraft Campaign to Characterize Vicarious Target BRDF

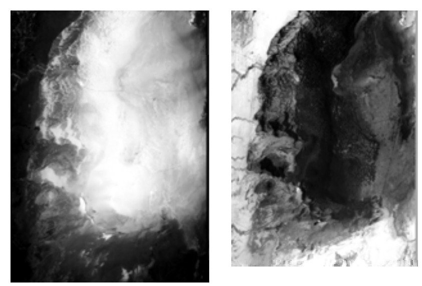
- **Background:**
  - » Characterization of WSMR, NM and Sonora Desert, Mexico BRDF with airborne radiometers to support long-term GOES-R V&V efforts.
- **Accomplishments:**
  - » Completed NASA ER-2 Flights with an AVIRIS (JPL) and MASTER (UC Santa Cruz) payload.
  - » WSMR flight support gained from NASA's AERONET facility at WSMR and Forecast and weather data support from El Paso, Texas NWS Line Office
  - » Sonoran Desert supported by aerosol and water vapor estimated from Microtops sunphotometer measurements taken near the Mexican border south of Yuma, AZ.
  - » WSMR and Sonoran Desert sand is being processed for lab measurement of BRDF.

May 24, 2011 post-flight calibration of the AVIRIS performed in Palmdale, CA.

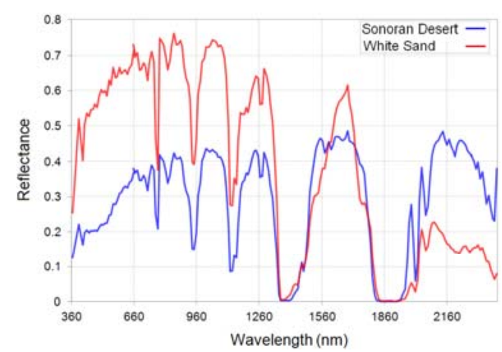
	White Sands Missile Range, NM (32.988,-106.30)	
DATE	EOS Aqua (2020 UTC or 14:20 MDT)	Metop-A (1700 UTC or 11:00 MDT)
5/23/2011	199	139

	Sonora Desert Mexico (32.0,-114.39)			
DATE	EOS Terra (1830 UTC or 11:30 MST)	EOS Aqua (2055 UTC or 13:55 MST)	Metop-A (1735 UTC or 10:35 MST)	N19 (2055 UTC or 13:55 MST)
6/10/2011	275W		60W	92E

Flight day satellite overpasses of WSMR (upper) and Sonoran Desert (lower)

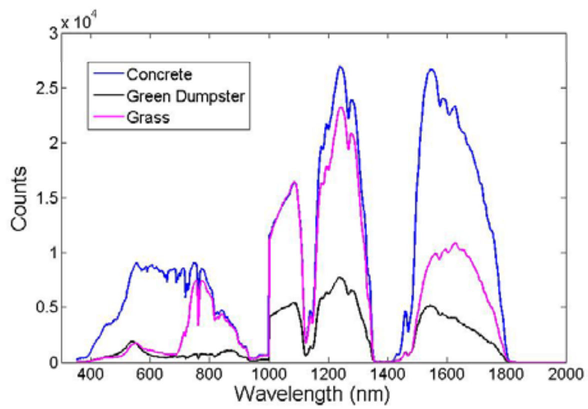


MASTER images at 540 nm (left), 1981 nm (right) for 1030 MDT May 23, 2011. Courtesy of MASTER Instrument Team.



Ground Instruments for ABI Cal/Val

- Support spectral and radiometric calibration for underflights
- New ground instruments for vicarious cal/val
  - Sun photometer [540 Microtops II (Solar Light)]
    - Measuring total incoming and reflected radiance for ABI VNIR channel
  - Spectroradiometer [ASD FieldSpec Hi-Res]
    - Spectral characterization of surface (covers all ABI VNIR channels)
    - Validation for GOES-R/ABI
  - Thermal Imager – [FLIR T400]
    - Broadband radiance in all emissive channels
- Currently developing capability to deploy these instruments.



ASD

Summary

GOES-R Cal/Val Working Group:

- Fully engaged in all segments of the GOES-R program to provide V&V and Cal/Val support
- Made definitive progress in prelaunch test data analysis and post launch capability development
- Strengthening collaboration with different segments of the GOES-R program and member organizations
- Leveraging vast experiences and expertise with other programs such as NPP VIIRS
- Will collaborate internationally with JMA (Japanese Meteorological Agency) on AHI (Advanced Himawari Imager)

- Backup slides

Cross Calibration between POES, JPSS, and GOES-R

- Enhanced orbital prediction capabilities for simultaneous nadir observations between polar-orbiting and geostationary satellites

- Leveraging existing cross-calibration efforts such as GSICS

- Expanding the prediction to include lunar and solar diffuser calibration

Simultaneous Nadir Overpass (SNO) Predictions for POES and GOES Satellite

Satellite	NPP	AQUA	METOP-A	NOAA-19	TERRA
GOES-15	GOES-15 vs. NPP	AQUA vs. GOES-15	GOES-15 vs. METOP-A	GOES-15 vs. NOAA-19	GOES-15 vs. TERRA

(Powered by SGP4 V2008)

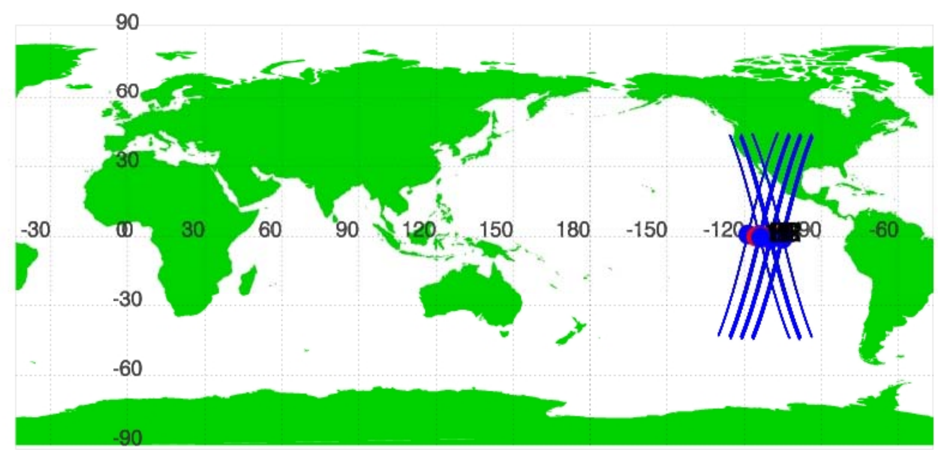
GOES-15 vs NPP

Prediction of SNOs between GOES-15 and NPP Satellite Orbit:

Table of predicted SNOs for the next 14.0 days since TLE Epoch: 11/5/2011

Index	Date	Time (GOES-15)	GOES-15 Lat,Lon	NPP Lat,Lon	Distance(km)	Time Diff (sec)
1	11/06/2011	08:28:57	0.07,-105.04	0.20,-105.51	54.40	80
2	11/07/2011	20:48:10	-0.05,-106.50	-0.91,-110.20	423.13	80
3	11/08/2011	20:24:59	-0.07,-107.29	0.37,-105.27	230.59	80
4	11/10/2011	08:46:42	0.05,-108.28	0.44,-109.91	186.02	80
5	11/11/2011	08:23:31	0.08,-109.07	-0.83,-104.97	467.31	80
6	11/12/2011	20:42:44	-0.06,-110.53	0.14,-109.67	98.19	80
7	11/14/2011	09:04:27	0.04,-111.51	0.68,-114.31	318.78	80
8	11/15/2011	08:41:16	0.06,-112.30	-0.59,-109.37	334.09	80
9	11/16/2011	21:03:09	-0.03,-113.75	-0.09,-114.07	35.52	80
10	11/18/2011	09:22:13	0.01,-114.74	0.93,-118.70	452.50	80
11	11/19/2011	08:59:01	0.03,-115.53	-0.33,-113.76	200.10	80

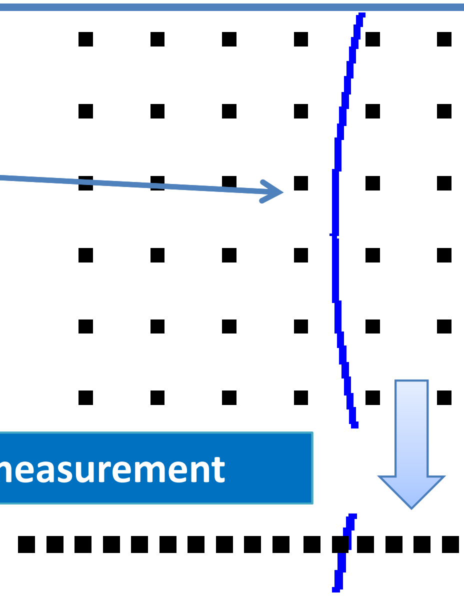
Figure of GOES-15 and NPP satellite orbits during SNOs since TLE Epoch: 11/5/2011



Red line: GOES-15 Blue line: NPP TLE Epoch: 2011/11/5

On-Orbit Modulation Transfer Function (MTF) Evaluation

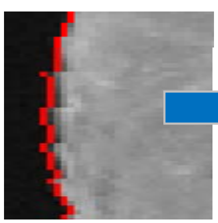
Lunar edge (curvature exaggerated)

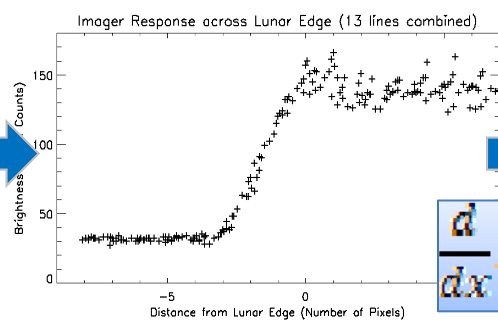


Sub-pixel measurement

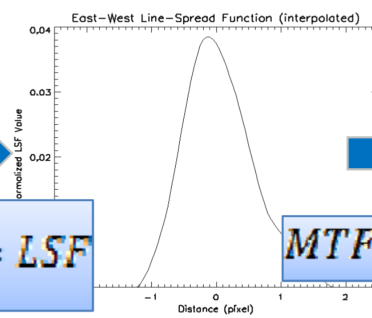
The **lunar edge near the equator** is **approximately vertically aligned**, and its position at each line changes, allowing a **sub-pixel measurement** by combining the lines.

Efforts based on previous study: Shea, J. J., 1999: Lunar limb Knife-edge optical transfer function measurements, *Journal of Electronic Imaging*, ***8(2)***, *196-208.*

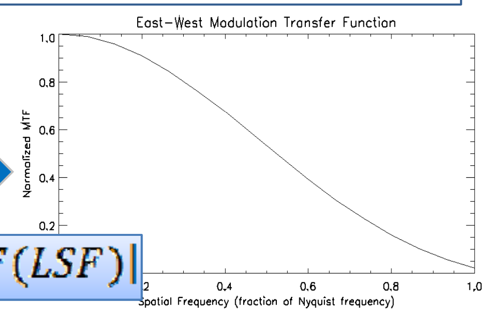




$$\frac{d}{dx} ESF = LSF$$



$$MTF = |\mathcal{F}(LSF)|$$



The lunar edge is tracked at the sub-pixel level.

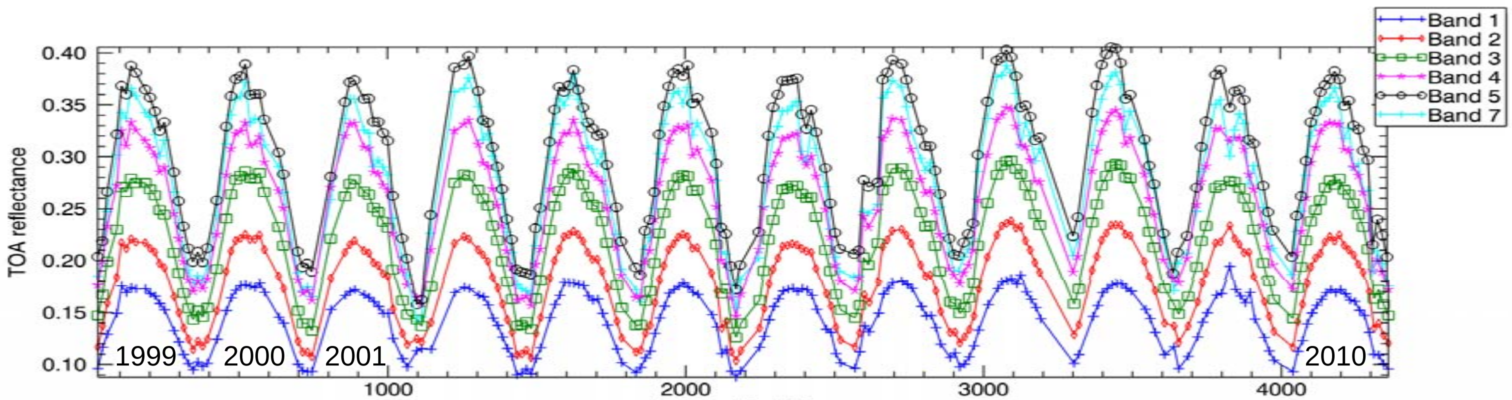
Lines of data assembled from a lunar image creates an Edge-Spread Function (ESF). Combining lines relative to lunar edge creates a sub-pixel measurement.

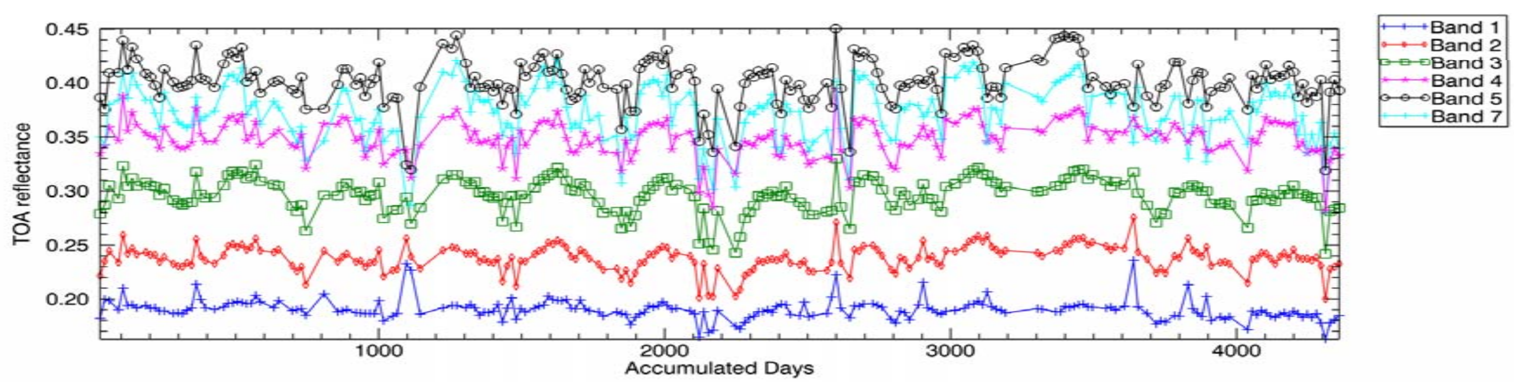
The spatial derivative of an Edge-Spread Function is a Line-Spread Function.

The modulus of the Fourier Transform of the Line-Spread Function is the Modulation Transfer Function (MTF).

Sonoran Desert Target Stability

TOA Reflectance Time Series





BRDF Model - Simple linear assumption

Dividing TOA reflectance by cosine of solar zenith angle

- Excluded the scenes that has cloud cover > 1%

Courtesy of Liang & Kim, UMD