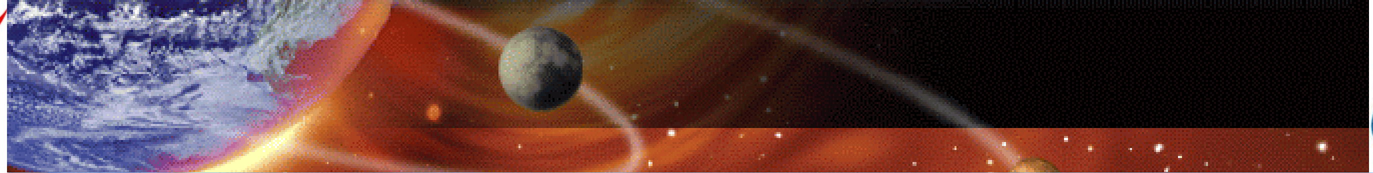

Summary of JPSS-1 VIIRS Pre-Launch Radiometric Performance

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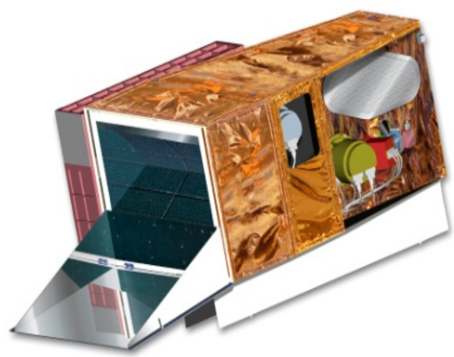
[3]NASA VIIRS Characterization & Support Team/Fibertek Inc., VA, 20171

Courtesy of NASA SNPP Land SIPS – S. Devadiga & P. Ma



Courtesy of NASA SNPP Land SIPS – S. Devadiga & P. Ma

MODIS/VIIRS Calibration Workshop

June 6th, 2016

Acknowledgements:

Government Data Analysis Working Group (DAWG), NASA VIIRS On-site Instrument Team

Content

- Background of VIIRS Sensor
- J1 VIIRS Pre-launch Testing
- J1 VIIRS Performance Assessment
- Status of J2 VIIRS Ambient Testing
- Summary/Conclusion

VIIRS Bands and Products

VIIRS 22 Bands:
16 M-Band, 5 I-Band and 1 DNB

	Band	λc(nm)	$\Delta\lambda$(nm)	Spatial Resolution (m)	MODIS Equivalent Band
VisNIR	DNB	700	400	750	
VisNIR	**M1**	**412**	**20**	**750**	B8
VisNIR	**M2**	**445**	**18**	**750**	B9
VisNIR	**M3**	**488**	**20**	**750**	B3-B10
VisNIR	**M4**	**555**	**20**	**750**	B4-B12
VisNIR	**M5**	**672**	**20**	**750**	B1
VisNIR	I1	640	80	375	B1
VisNIR	M6	746	15	750	B15
VisNIR	**M7**	**865**	**39**	**750**	B2
VisNIR	I2	865	39	375	B2
SMWIR	M8	1240	20	750	B5
SMWIR	M9	1378	15	750	B26
SMWIR	M10	1610	60	750	B6
SMWIR	I3	1610	60	375	B6
SMWIR	M11	2250	50	750	B7
SMWIR	I4	3740	380	375	B20
SMWIR	M12	3760	180	750	B20
SMWIR	**M13**	**4050**	**155**	**750**	B21-B22-B23
LWIR	M14	8550	300	750	B29
LWIR	M15	10763	1000	750	B31
LWIR	I5	11450	1900	375	B31-B32
LWIR	M16	12013	950	750	B32

Dual Gains

VIIRS 22 Environmental Data Products (EDRs)

Land

1- Active Fires
2- Snow Cover
3- Land Surface Albedo
4- Vegetation Index
5- Land Surface Temperature
6- Surface Type
7- Ice Surface Temperature
8- Net Heat Flux
9- Snow Ice Characterization

Ocean

1- Sea Surface Temperature
2- Ocean Color/Chlorophyll

Imagery and Clouds

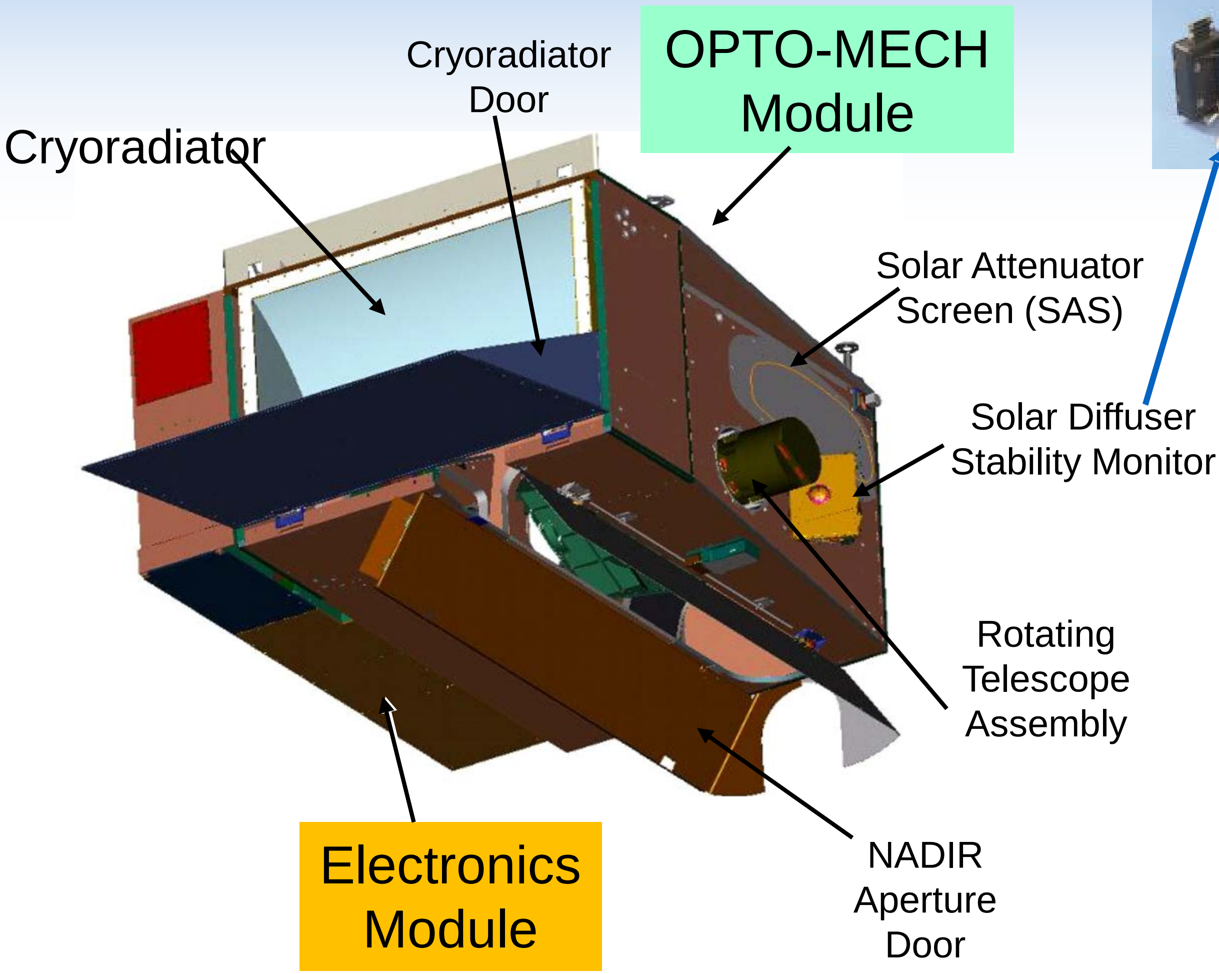
1- Imagery and low light imaging
2- Cloud Top Height
3- Cloud Optical Thickness
4- Cloud Top Temperature
5- Cloud Effective Particle Size
6- Cloud Base Height
7- Cloud Top Pressure
8- Cloud Cover/Layers

Aerosol

1- Aerosol Optical Thickness
2- Aerosol Particle Size
3- Suspended Matter

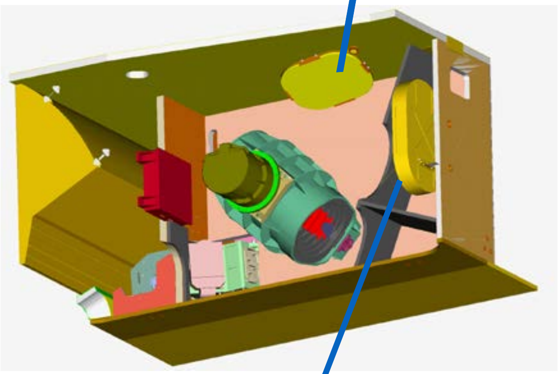
- 14 reflective solar bands (RSB): 0.4-2.2 μm and 1 day night band (DNB)
- 7 thermal emissive bands (TEB): 3.7-12.0 μm
- Dual gain bands: M1-M5, M7, and M13

VIIRS Sensor & On-board Calibrators



SDSM

Solar Diffuser



Blackbody (BB)

- ***Proven design through SNPP mission***
- ***Comprehensive pre-launch testing, and on-orbit predictions***

Pre-Launch Testing Objectives

- **Radiometric, Spectral and Spatial testing**
  - Ambient, TV (cold, nominal, hot), HAM sides, E-sides, detectors, etc.
- **Ensure sensor performance meets design requirements**
  - Compliance, Waivers
- **Capability to generate sensor performance parameters for on-orbit operation and calibration**
- **Support modeling and predictions to ensure overall science objectives are met**
- **Development and implementation of potential mitigation strategies to address artifacts and noncompliance issues**

Overview of J1 Pre-launch Testing

Performance Testing:

- Radiometric (SNR/NEdT, detector calibration, dynamic range)
- Spectral (IB and OOB RSR)
- Spatial and geometric (BBR, MTF, and pointing)
- Others
  - Polarization sensitivity
  - Response versus scan-angle
  - Stray light and Near-field response
  - BB/SD/SDSM characterization
- Thermal testing
- Vibration testing
- Electromagnetic interference
- Special testing (ETPs)

Testing Phases:

- **Component/Sub-system Testing**
- **Sensor Level Testing**
  - ✓ Ambient: *08/24/2013 - 01/19/2014*
  - ✓ TVAC: *07/16/2014 - 10/30/2014*
  - ✓ Sensor Delivery: *02/06/2015*
- **Observatory Level Testing:**
  - ✓ Sensor Integrated to J1: *02/20/2015*
  - ✓ Environmental Testing: *April-September 2016*
- **JPSS-1 Launch:**
  - ✓ January 20, 2017

Testing & Performance Teams

- **Test data independently analyzed and reviewed by**
  - Sensor Vendor (Raytheon)
  - Government Team
    - NASA
    - NOAA
    - Aerospace
    - U. of Wisconsin
- **Test results reviewed by**
  - Data Review Board (DRB): results primarily from sensor team
  - Data Analysis Working Group (DAWG): results primarily from gov. team
  - Technical Interchange Meetings (TIMs)
  - Regular briefings at NOAA-led VIIRS SDR meetings

General Agreement on the good quality of J1 VIIRS test data, and instrument performance

J1 Instrument Improvements

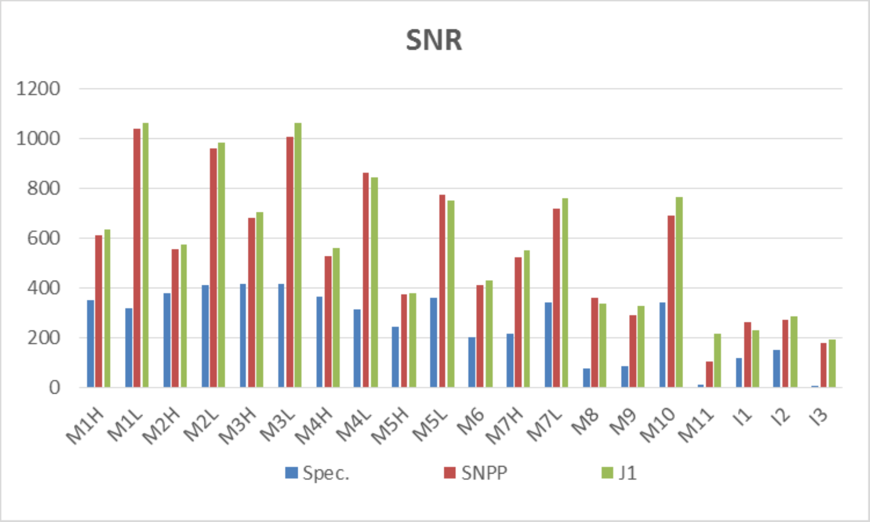
- RTA Mirrors Changed from Ni coated to VQ
  - Improved spatial stability with temperature
- Dichroic 2 Coatings Redesigned
  - Improved spatial performance between SMWIR & LWIR
- Eliminated Throughput Degradation Due to Tungsten
  - Improved radiometric sensitivity
- Enhanced VisNIR Integrated Filter Coating Change
  - Improved crosstalk, OOB, and RSR performances
  - Higher polarization sensitivity: Bands M1 – M4

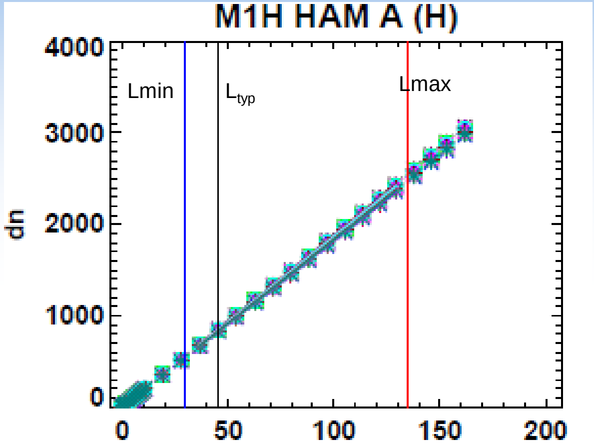
Other changes were also included but not expected to make substantial change in the sensor performance

RSB Radiometric Performance

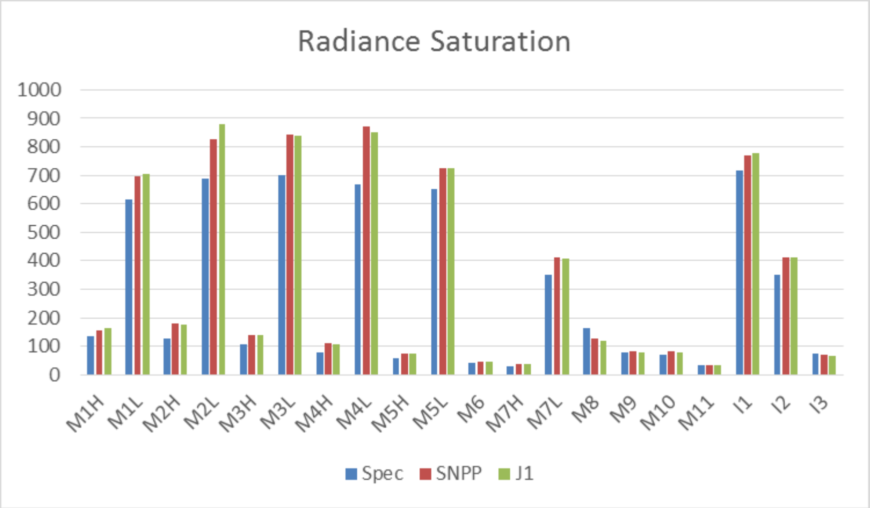
J1 SNR compliant with margin

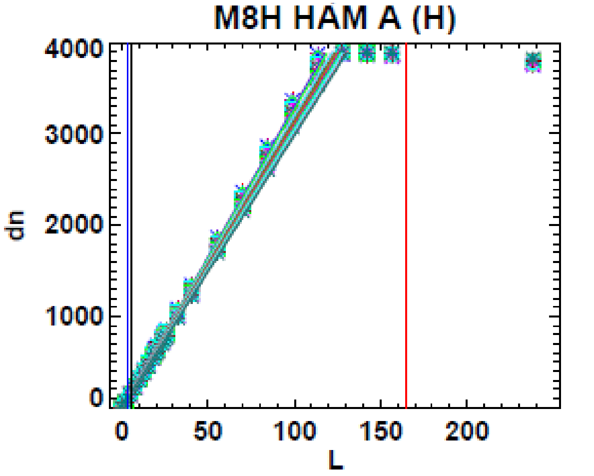
I3 Det4 noisy





Minor Dynamic range non-compliance (M8, I3)

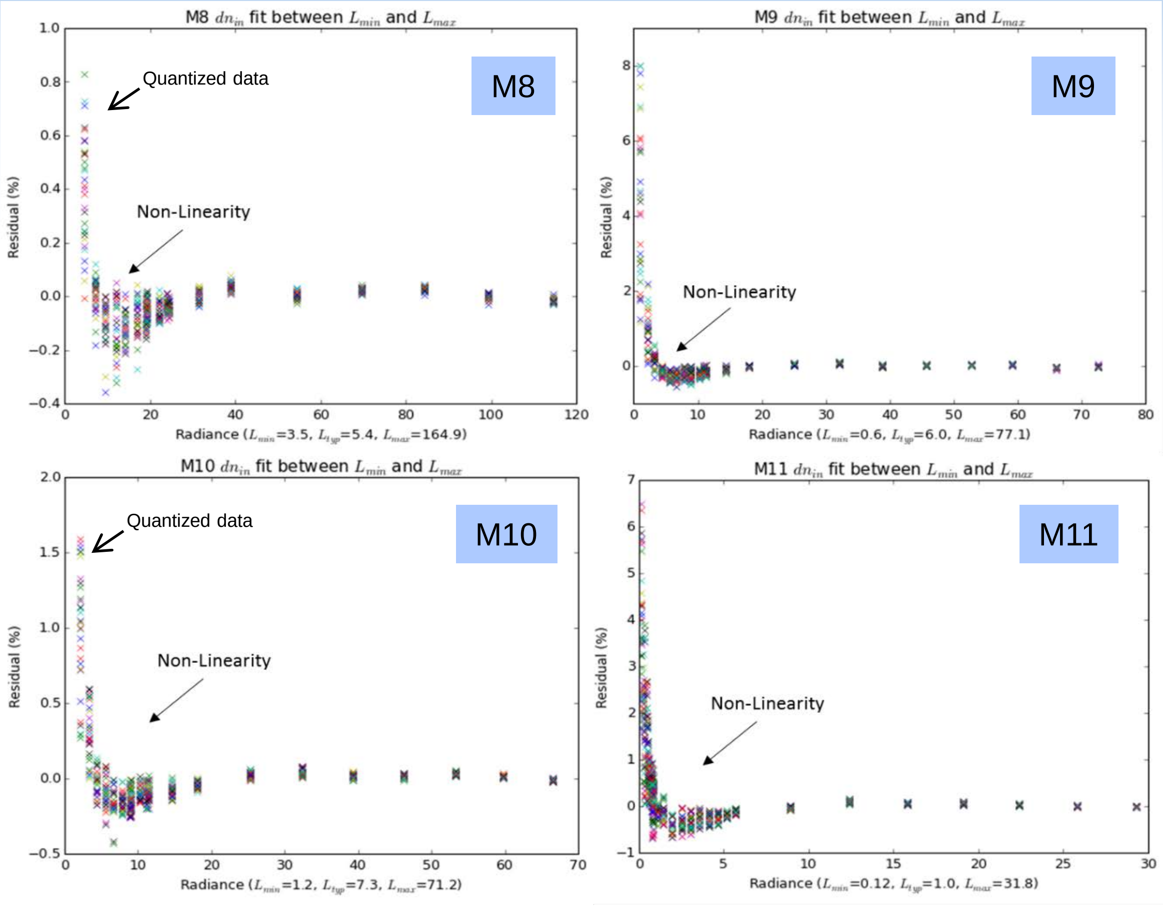




- J1 Radiometric performance is quite similar to SNPP
- Higher than expected non-linearity seen in SWIR bands and DNB

SWIR Radiometric Performance

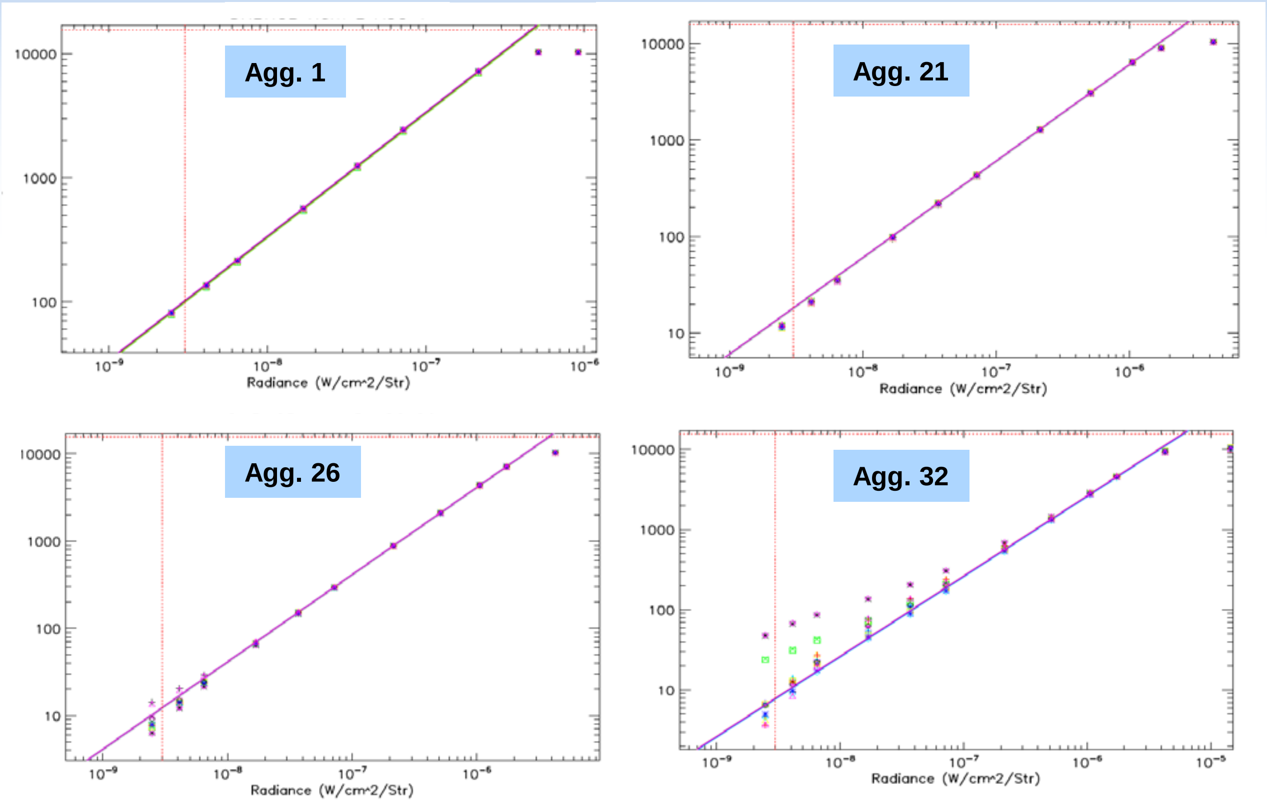
SWIR Non-Linearity Issue (Low Radiance)



- **Issue characterized and root cause identified (electronics Voltage)**
- **Plan to mitigate in the SDR software (3rd degree equation, or other options)**

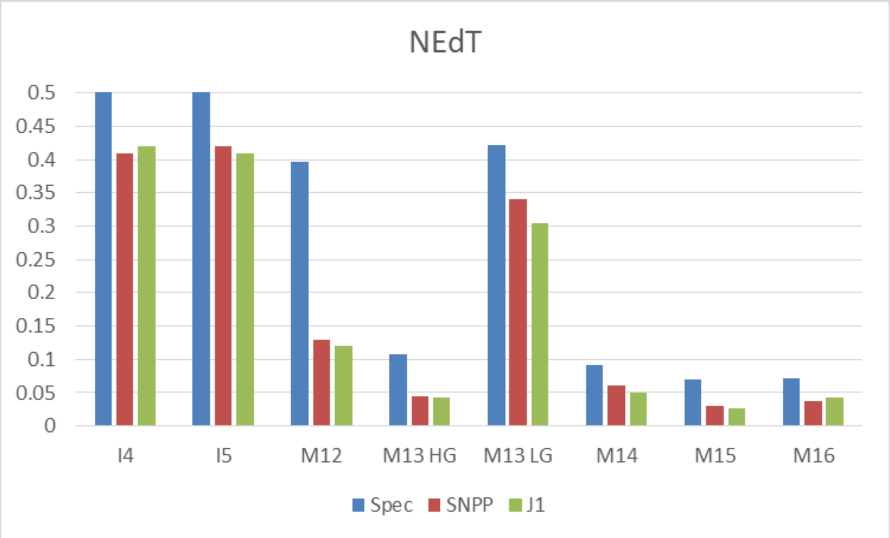
DNB Radiometric Performance

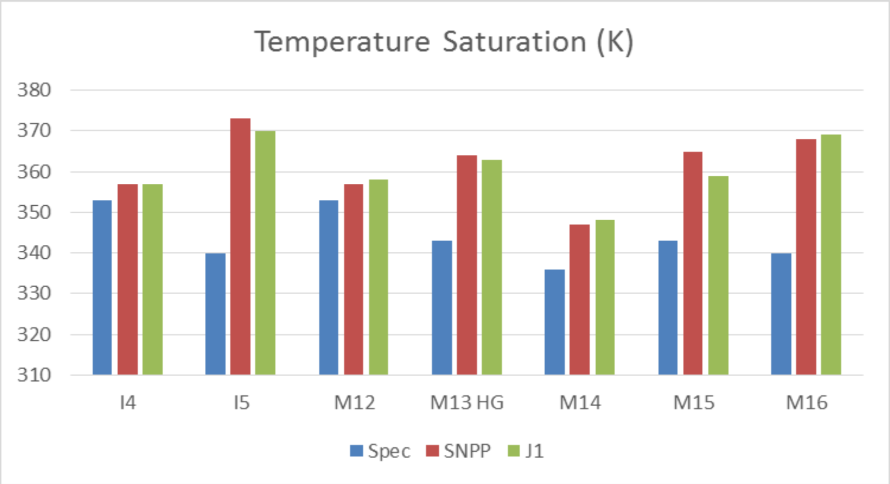
DNB Non-Linearity Issue (Low Radiance)

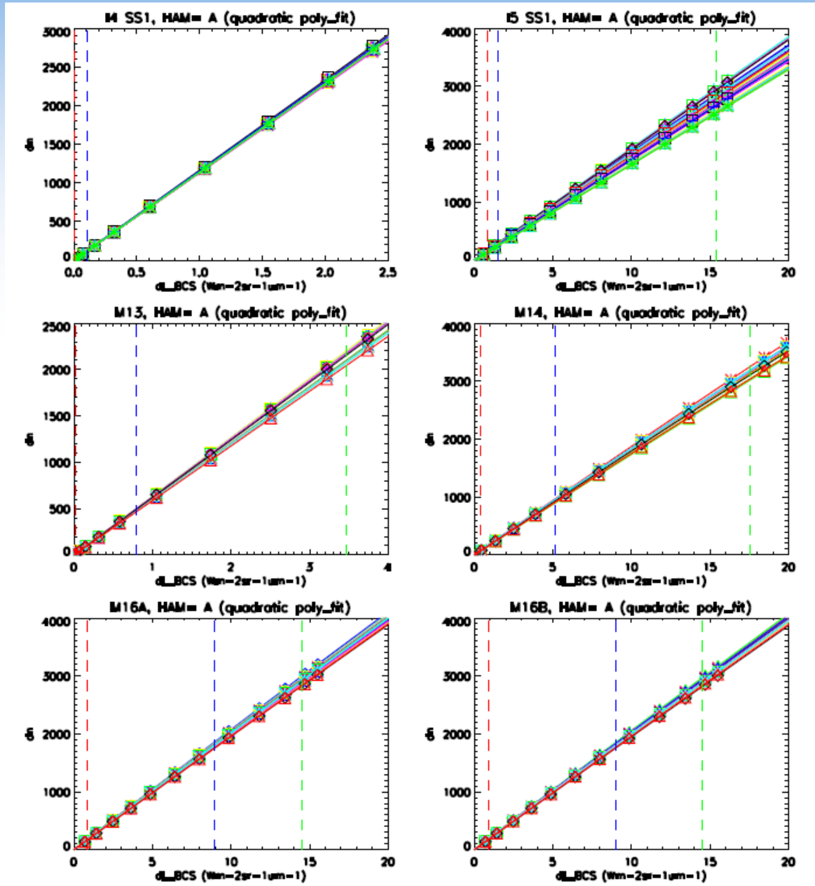


- Limited to agg. modes at the end of scan (22-32)
- Issue characterized and root cause identified (timing card setting)
- Mitigation plan is in place at the expense of spatial resolution

TEB Radiometric Performance





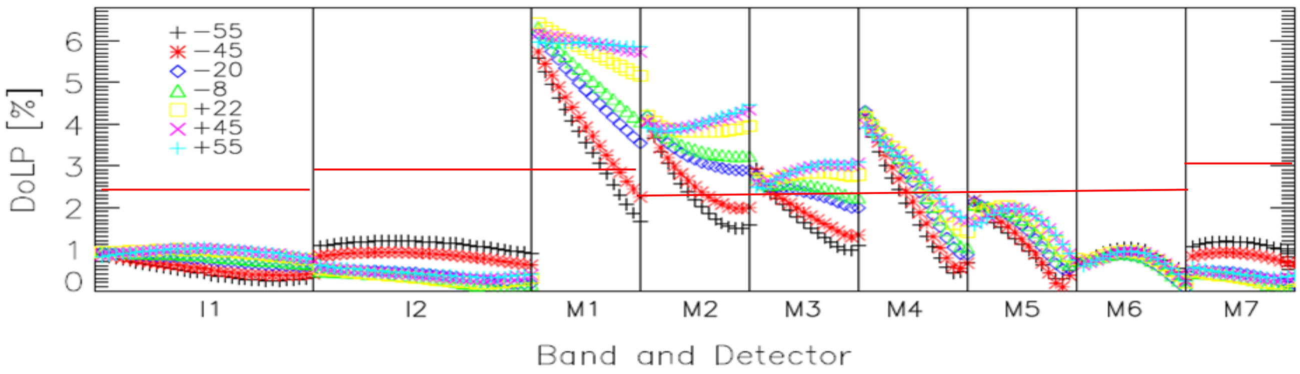


Radiance

- J1 TEB calibration performance is very good, similar to SNPP performance.
- Minor non-compliances observed: T_{MIN} for I4 and M14; M13 gain transition radiance.
    - Impact to science is expected to be small.

VisNIR Polarization Sensitivity

- **Bands M1–M4 were non-compliant with the polarization sensitivity requirements**
- **A series of telecons were held with NASA/NOAA SMEs**
  - Provided impact assessments for Ocean, Land , and Atmosphere disciplines
  - Correction methodologies available to enhance EDR products
- **Additional testing was requested after TVAC**
  - Additional scan angles were measured using a broadband source
  - Limited measurements performed with a laser source for model validation

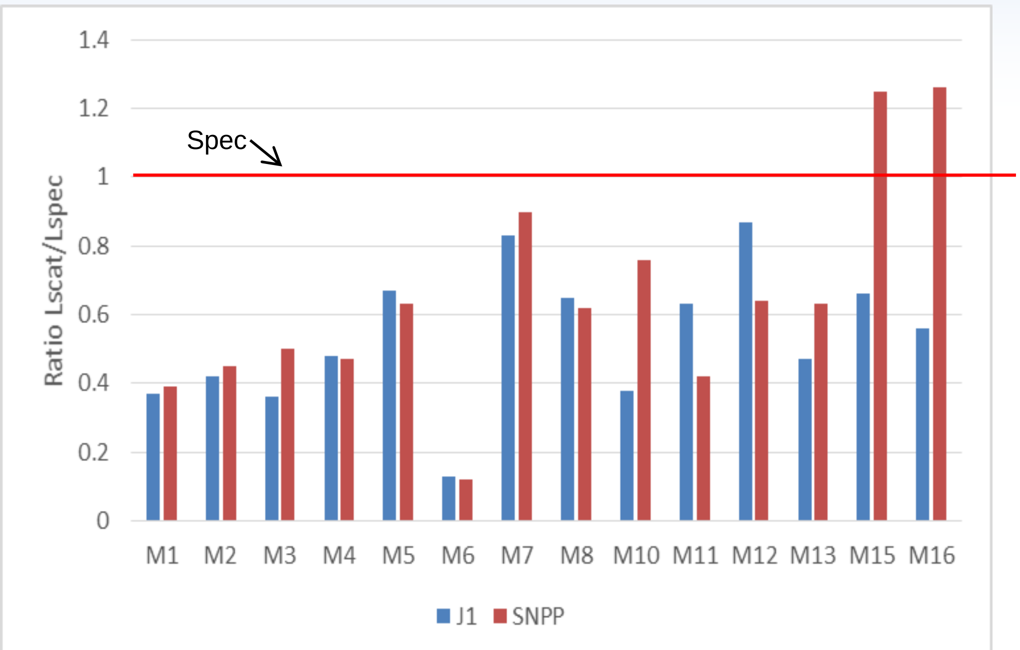


Successful and comprehensive J1 polarization testing was completed

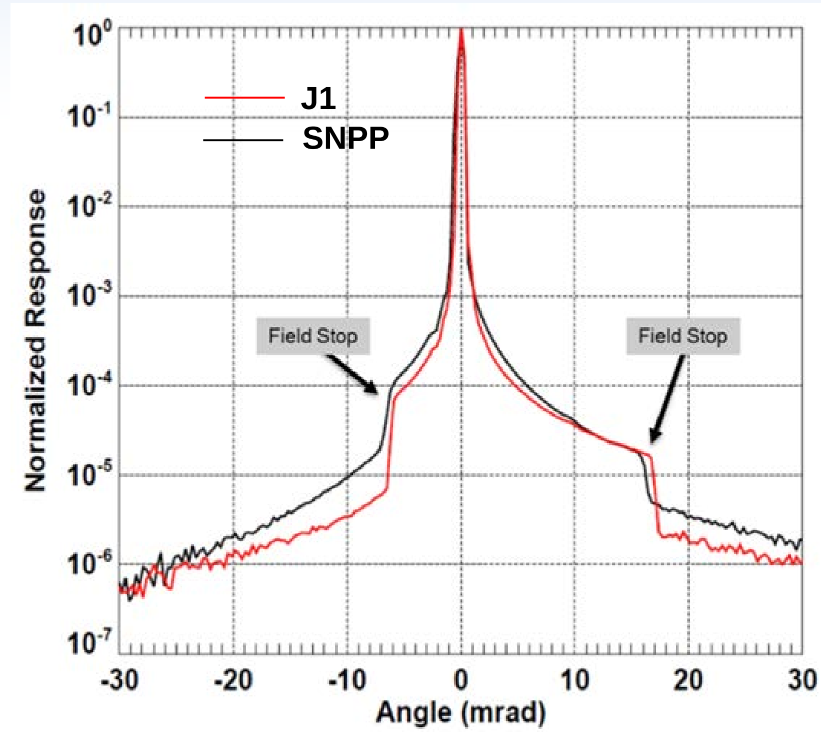
- Uncertainty less than (0.4%), Repeatability within 0.13%

Near-Field Response (NFR) Performance

J1 NFR Performance at Beginning of Life (BOL)



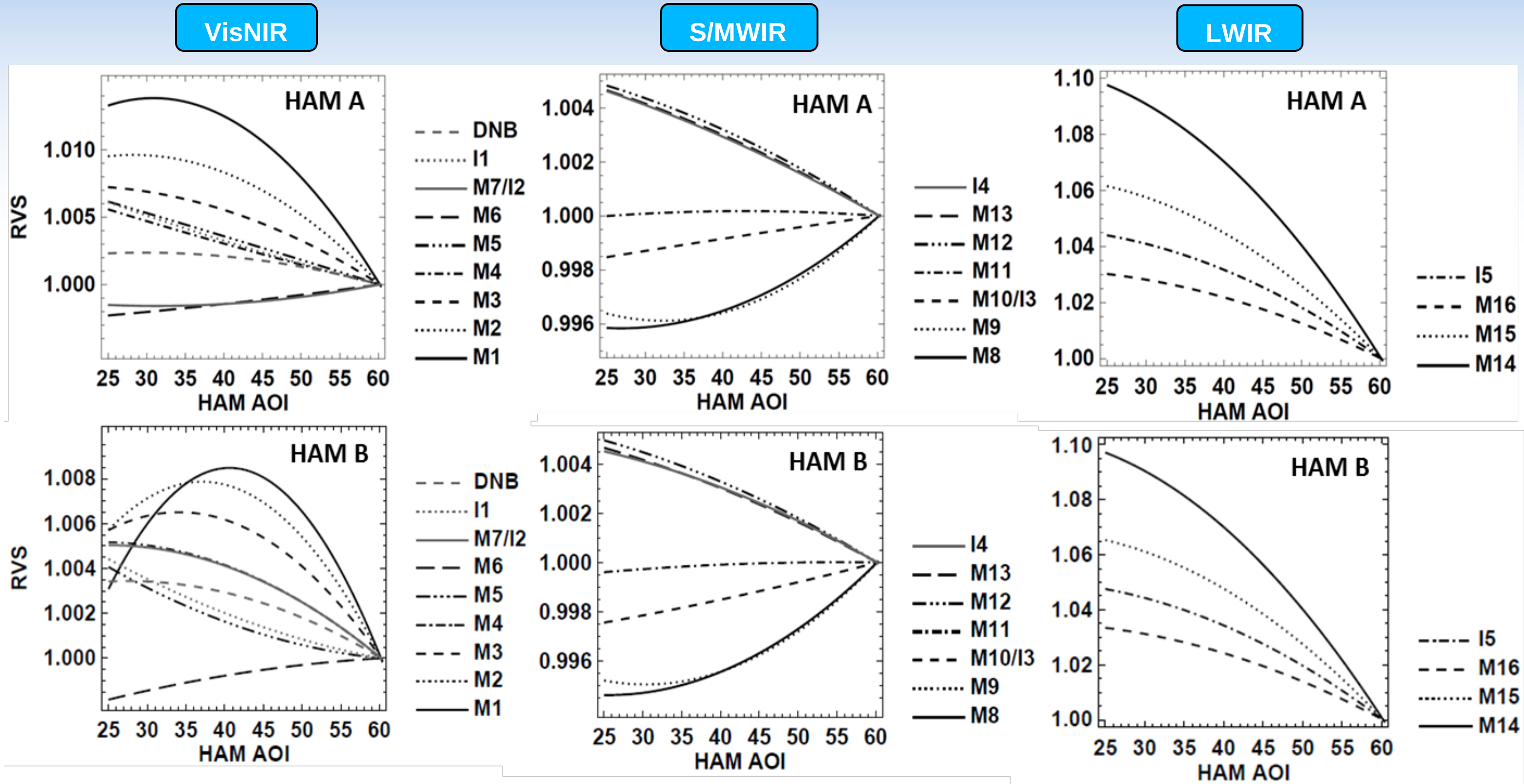
Band M5 (672 nm) detector 8



J1 NFR requirements are met for all bands

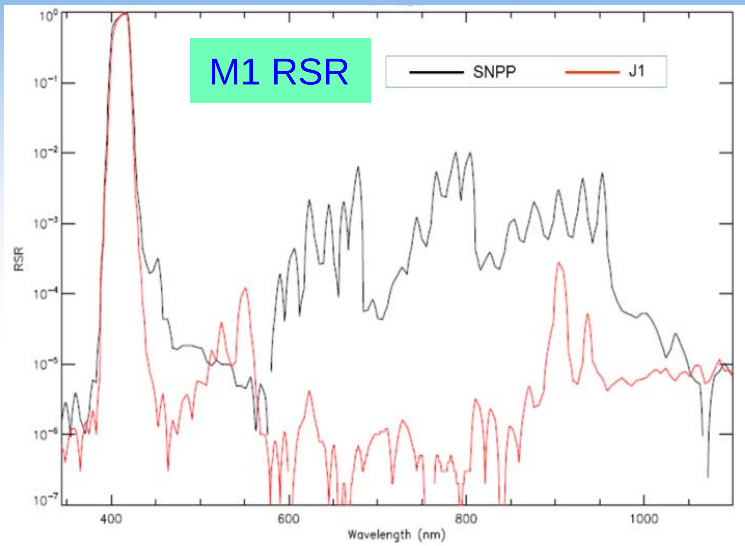
Response vs. Scan (RVS)

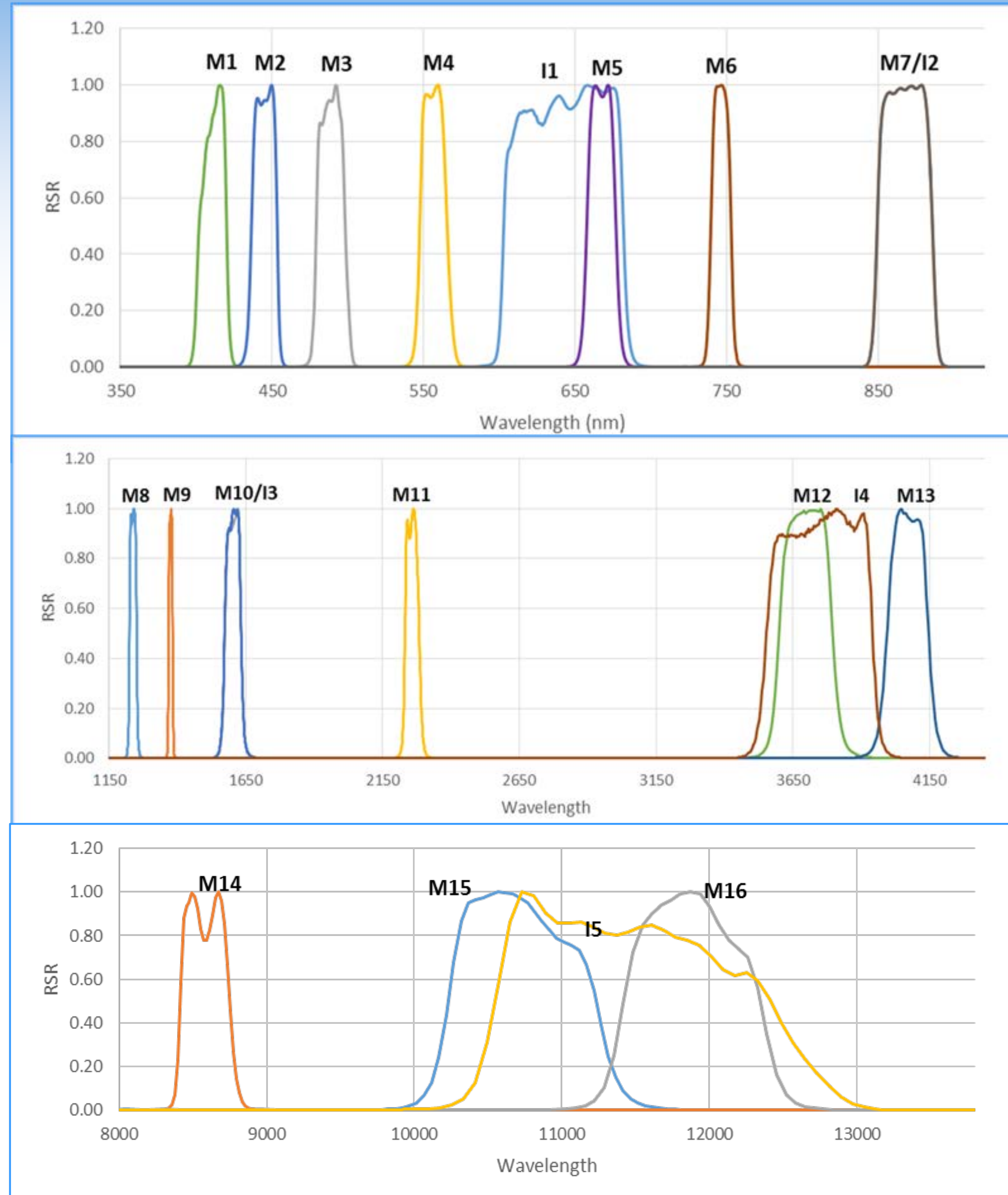
RVS is the HAM reflectance as a function of HAM Angle of incidence (AOI)



- **Excellent J1 RVS performance characterization, Similar to SNPP**
  - **RSB uncertainty under 0.06% (Spec 0.3)**
  - **TEB uncertainty under 0.15 % (Spec 0.2)**

Spectral Performance



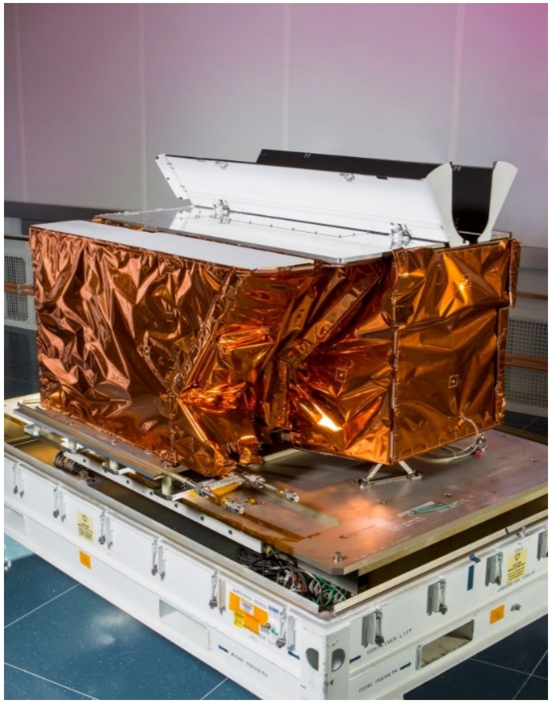


- J1 spectral performance testing was completed successfully for all bands
- Combination of best quality data from monochromator and laser is used for J1
- Overall spectral performance is expected to be better than SNPP.

JPSS VIIRS Future Enhancements

- **DNB On-orbit Stray light Issue Investigation**
  - **Observed in SNPP on-orbit, but root-cause still to be identified.**
- **Implement enhanced calibration to eliminate SWIR non-linearity at low radiance**
- **Algorithm changes to reduce stripping effect due to sensor calibration artifacts (M15-M16, I3 Det4)**
- **Finalize List of J1 lessons learned, and Hardware/Software Improvements to be implemented for future builds (JPSS-2,3,4)**
  - **Testing enhancements, adding a water vapor band, electronics noise, radiance roll-over, etc.**

JPSS-2 VIIRS:
Initial Radiometric Performance



JPSS-2 VIIRS Status

- JPSS-2 VIIRS is the 3rd unit of VIIRS sensors, also built and tested by Raytheon El Segundo (CA), with support from the Government team.
  - Ambient Phase: April-October 2016
  - Thermal Vacuum: June-August 2017
  - Expected launch date: January, 2021

- JPSS-2 VIIRS is similar to its two predecessors, with multiple performance enhancements, including:
  - The redesign of the VisNIR IFA filter to reduce polarization sensitivity, and changes to the AOA fold mirror #2.
  - SWIR and DNB non-linearity issues seen in J1 were eliminated
  - JPSS-2 test program included numerous lessons-learned:
    - Better efficiency and cost reduction (e.g. enhanced stray light testing, shorter crosstalk testing, etc.)

J2 VIIRS Performance Testing

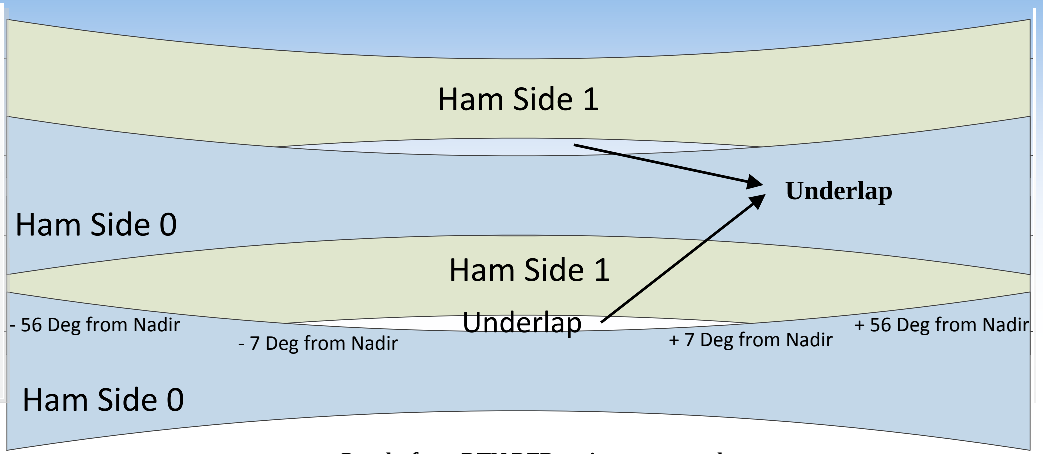
- **J2 VIIRS Ambient phased is planned for April to June 2016**
  - ➢ Radiometric: SNR, NEdT, Lmax
  - ➢ Spatial: LSF/MTF, BBR, pointing
  - ➢ Spectral: RSRs using GLAMR (NASA)
  - ➢ Special testing: polarization, RVS, NFR, Xtalk.

Tests in Green means completed

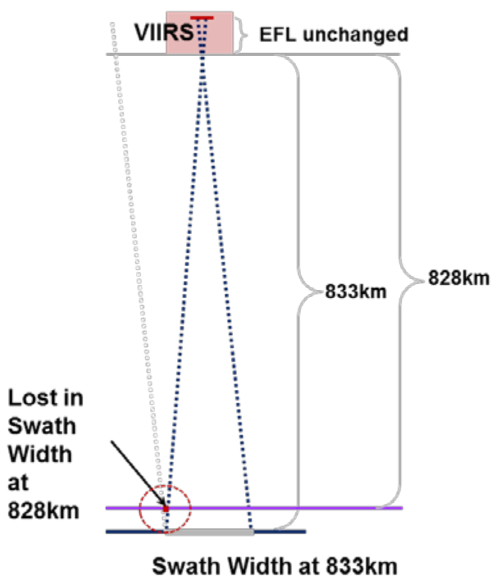
- **J2 Ambient testing was halted (05/16) because of the an issue with HAM alignment**
  - ➢ HAM repair will take about 10 wks to complete this task.

J2 Scan Underlap Issue

- Underlap is defined as non-overlapping VIIRS swath projections on the ground in track extent
- Underlap will be seen on every other swath pair with current J2 as built tolerances
- **Combination of facts led to this Issue,**
  - **1) Requirement change from 833 to 828km,**
  - **2) HAM misalignment exceeded tolerance.**



Graphs from RTN RFB review, not to scale

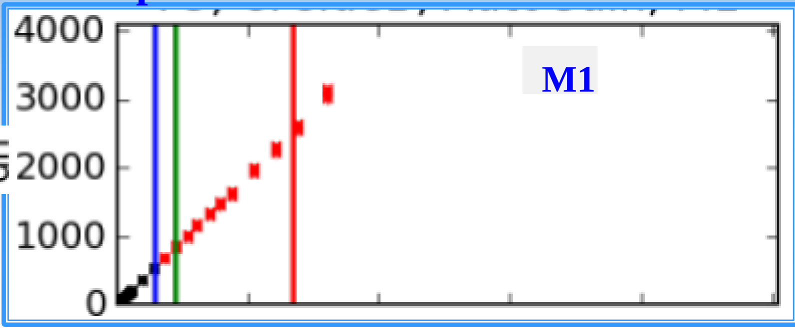


- Scan Overlap is driven by the following parameters:
  - **Altitude** – as altitude gets lower, projection on the ground gets smaller
  - **HAM Alignment** – alignment between A & B drives spacing between successive scans on the ground
  - **Scan Rate** – matched to EFL for BBR purposes, but drives the number of scans we get in one orbit
  - **Orbital velocity** – drives the number of scans we get in one orbit
  - **System EFL** – as EFL gets longer, projection on the ground gets smaller
  - **Spacecraft Jitter** – moves the LOS randomly between scans

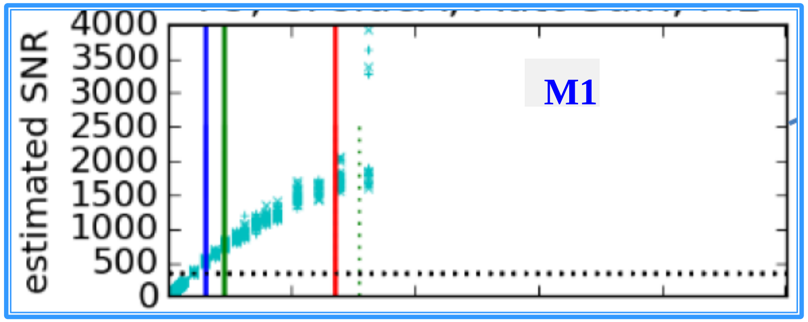
The ongoing effort to adjust J2 HAM alignment is expected to eliminate this issue

J2 Radiometric Performance

Example of J2 Radiometric Performance

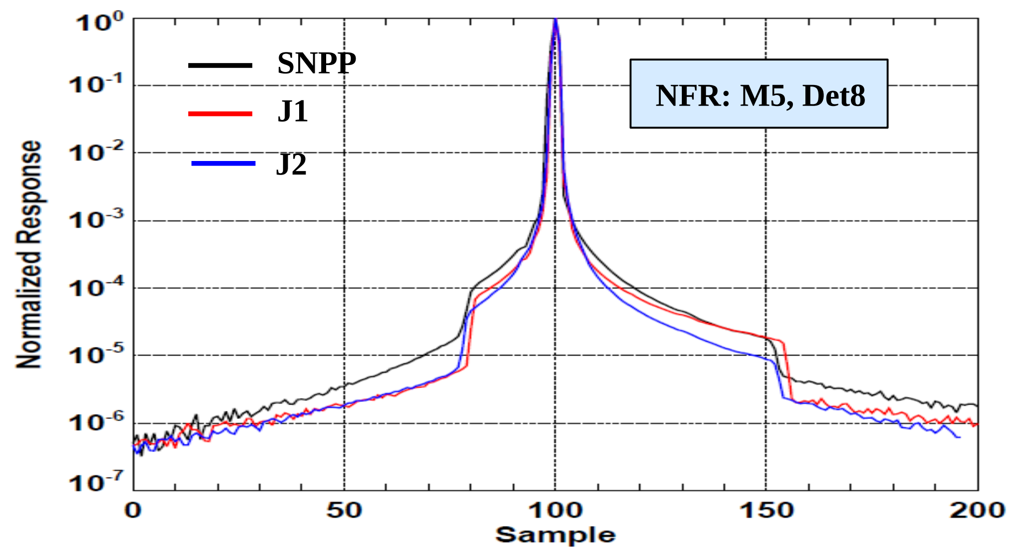


Radiance (Wm²st⁻¹μm⁻¹)



Radiance (Wm²st⁻¹μm⁻¹)

Electronics	Gain	Band	SNR spec	SNR		Lmax spec	Maximum radiance		Gain factor	
				HAM A	HAM B		HAM A	HAM B	HAM A	HAM B
A-Side Elec.	HG	M1	352	732	752	135	164.8	164.8	18.5	18.6
		M2	380	702	701	127	169.5	169.1	21.9	21.9
		M3	416	861	851	107	126.1	126.0	29.3	29.4
		M4	362	683	672	78	98.9	98.9	37.6	37.6
		M5	242	359	359	59	81.0	81.0	45.8	45.8
		M6	199	567	571	41	53.4	53.4	73.0	73.0
		M7	215	654	658	29	37.5	37.4	99.5	99.6
		M8	74	302	292	164.9	158.2	158.1	24.6	24.6
		M9	83	177	176	77.1	131.9	131.8	29.6	29.6
		M10	342	767	749	71.2	98.1	98.0	39.7	39.8
		M11	90	237	235	31.8	33.1	33.0	117.8	117.9
		I1	119	208	204	718	969.2	969.1	4.0	4.0
		I2	150	372	372	349	455.6	455.1	8.6	8.6
		I3	6	200	199	72.5	100.7	100.7	38.6	38.7
	LG	M1	316	1090	1099	615	508.7	508.7	3.8	3.8
		M2	409	1124	1128	687	844.3	841.9	4.4	4.4
		M3	414	1064	1065	702	894.4	894.7	4.1	4.1
		M4	315	819	851	667	775.2	774.7	4.8	4.8
		M5	360	665	660	651	949.5	949.4	3.9	3.9
		M7	340	1427	909	349	411.1	410.7	9.0	9.0



J2 radiometry is very good

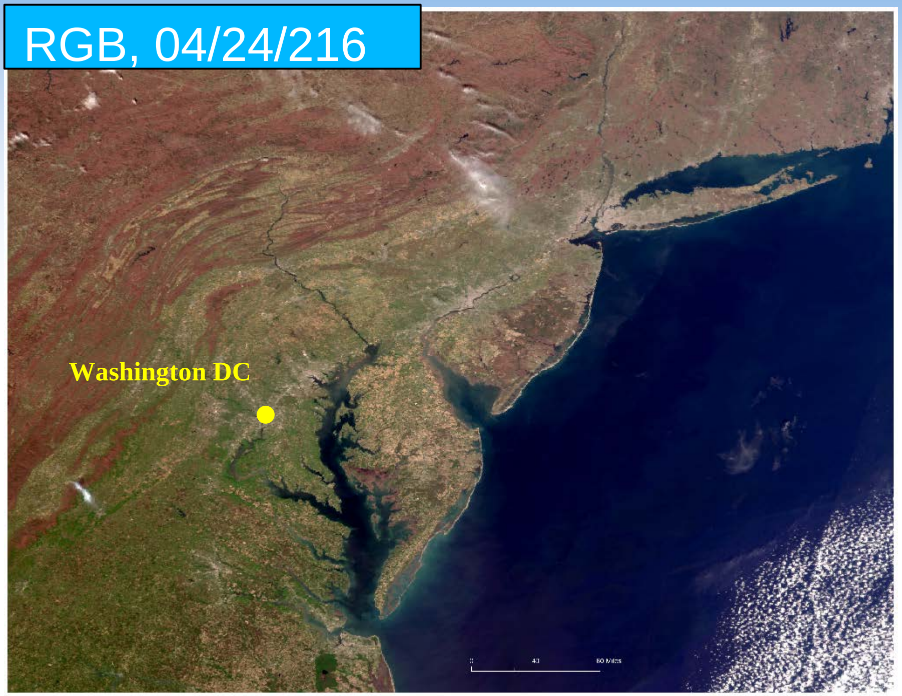
SNR compliance with significant margin
Lmax compliant except for M8 (95%)
Near Field Response comparable to J1

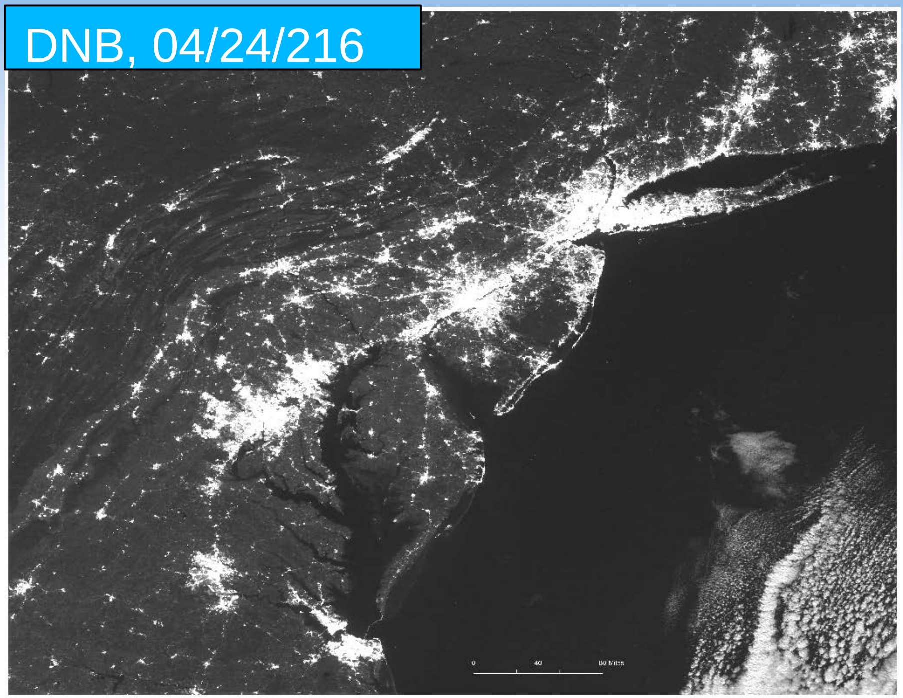
Summary & Conclusion

- **J1 VIIRS test program was completed successfully**
- **Provided an extensive amount of high quality data to assess sensor performance**
- **VIIRS performance exceeds requirements with few non-compliances**
  - Non-compliances have been reviewed, impacts have been assessed, and mitigation plans are being prepared for on-orbit processing
  - J1 VIIRS spacecraft testing is expected to be completed by September 2016
  - J1 LUTs needed for on-orbit calibration are being finalized.
  - J1 SDR code change is ongoing to mitigate performance issues (e.g. DNB non linearity, polarization).
- **J2 VIIRS partial testing has shown good performance**
  - Good radiometric and spatial performance (i.e. SNR, Dynamic range, NFR, spatial)
  - **OMM repair is ongoing to adjust HAM alignment (to correct the underlap between scans)**
  - Ambient testing to resume in August, and expected to be complete in October.
- **J3/J4 VIIRS contract almost complete, and sensor parts are being selected from spares or in development,**
  - Taking advantage of lessons learned from previous sensors (i.e. S-NPP, J1 and J2)

SNPP VIIRS Imagery

Eastern Seaboard





Courtesy of NASA SNPP Land SIPS – S. Devadiga & P. Ma

J1 VIIRS is also expected to deliver high quality radiance and environmental data products

Thanks!

Backup

J1 Spectral Performance

SNPP

Band	Band center	Bandpass (FWHM)	Lower 1% point	Upper 1% point	MIOOB
'M1'	pass	pass	pass	pass	FAIL
'M2'	pass	FAIL	pass	pass	pass
'M3'	pass	pass	pass	pass	FAIL
'M4'	FAIL	pass	pass	pass	FAIL
'I1'	pass	pass	pass	pass	pass
'M5'	pass	pass	pass	pass	FAIL
'M6'	pass	pass	pass	pass	FAIL
'I2'	pass	pass	pass	pass	FAIL
'M7'	pass	pass	pass	pass	pass
'M8'	pass	FAIL	pass	pass	pass
'M9'	pass	pass	pass	pass	pass
'I3'	pass	pass	pass	pass	pass
'M10'	pass	pass	pass	pass	pass
'M11'	pass	pass	pass	pass	pass
'I4'	pass	pass	pass	pass	pass
'M12'	pass	pass	pass	pass	pass
'M13'	pass	pass	pass	pass	pass
'M14'	pass	FAIL	pass	pass	FAIL*
'M15'	pass	pass	pass	pass	FAIL*
'I5'	pass	pass	pass	FAIL	FAIL*
'M16A'	FAIL	pass	pass	pass	FAIL*
'M16B'	FAIL	pass	pass	pass	FAIL*
DNBLGS	pass	pass	pass	pass	pass

J1

Band	Band center	Bandpass (FWHM)	Lower 1% point	Upper 1% point	MIOOB
'M1'	pass	FAIL	pass	pass	pass
'M2'	pass	pass	pass	pass	pass
'M3'	pass	pass	pass	pass	pass
'M4'	pass	pass	pass	pass	pass
'I1'	pass	pass	Pass	pass	pass
'M5'	pass	pass	pass	pass	pass
'M6'	pass	pass	pass	pass	pass
'I2'	pass	pass	pass	pass	pass
'M7'	pass	pass	pass	pass	pass
'M8'	pass	FAIL	pass	pass	pass
'M9'	pass	pass	pass	pass	pass
'I3'	pass	pass	pass	pass	pass
'M10'	pass	pass	pass	pass	pass
'M11'	pass	pass	pass	pass	pass
'I4'	pass	pass	pass	pass	pass
'M12'	pass	pass	pass	pass	pass
'M13'	pass	pass	pass	pass	pass
'M14'	pass	FAIL	pass	pass	pass
'M15'	pass	pass	pass	pass	pass
'I5'	pass	pass	pass	FAIL	pass
'M16A'	FAIL	pass	pass	pass	pass
'M16B'	FAIL	pass	pass	pass	pass
DNBLGS	pass	pass	pass	pass	pass

- **J1 RSR showing good performance as expected. Minor non-compliances are small risk**
- **J1 RSR version 2 (V2) was released to the science community in February, 2016**

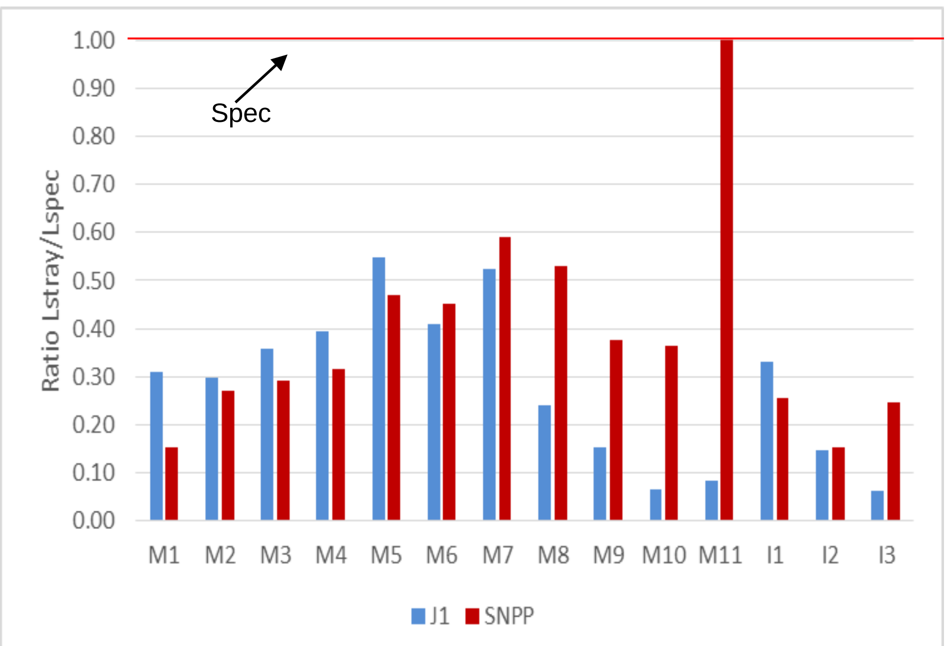
*High noise floor in LWIR out-of-band response test

Stray Light Response (SLR) Performance

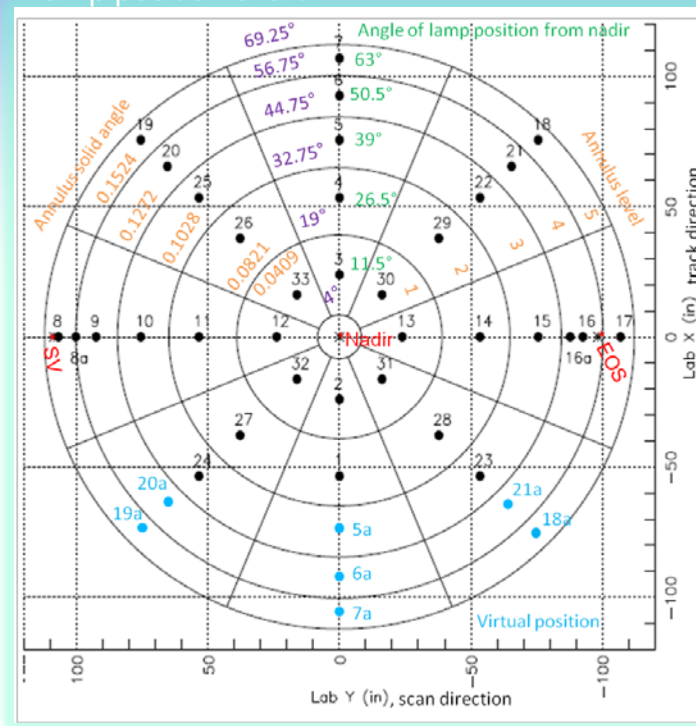
J1 SLR performance is comparable to SNPP. The right hand side shows a couple of examples (out of 336) of simulated views from detectors.

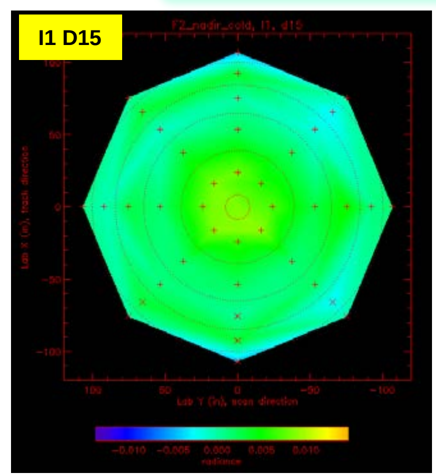
All RSB detectors meet SLR specification at Beginning of Life (BOL) (plot below).

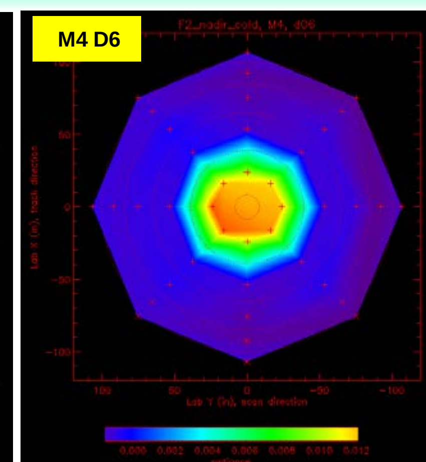
Bands M5 and M7 are predicted to fail Spec at the End of Life (EOL), while M6 will become marginal.



Lamp position chart







VIIRS Operation & Data Flow

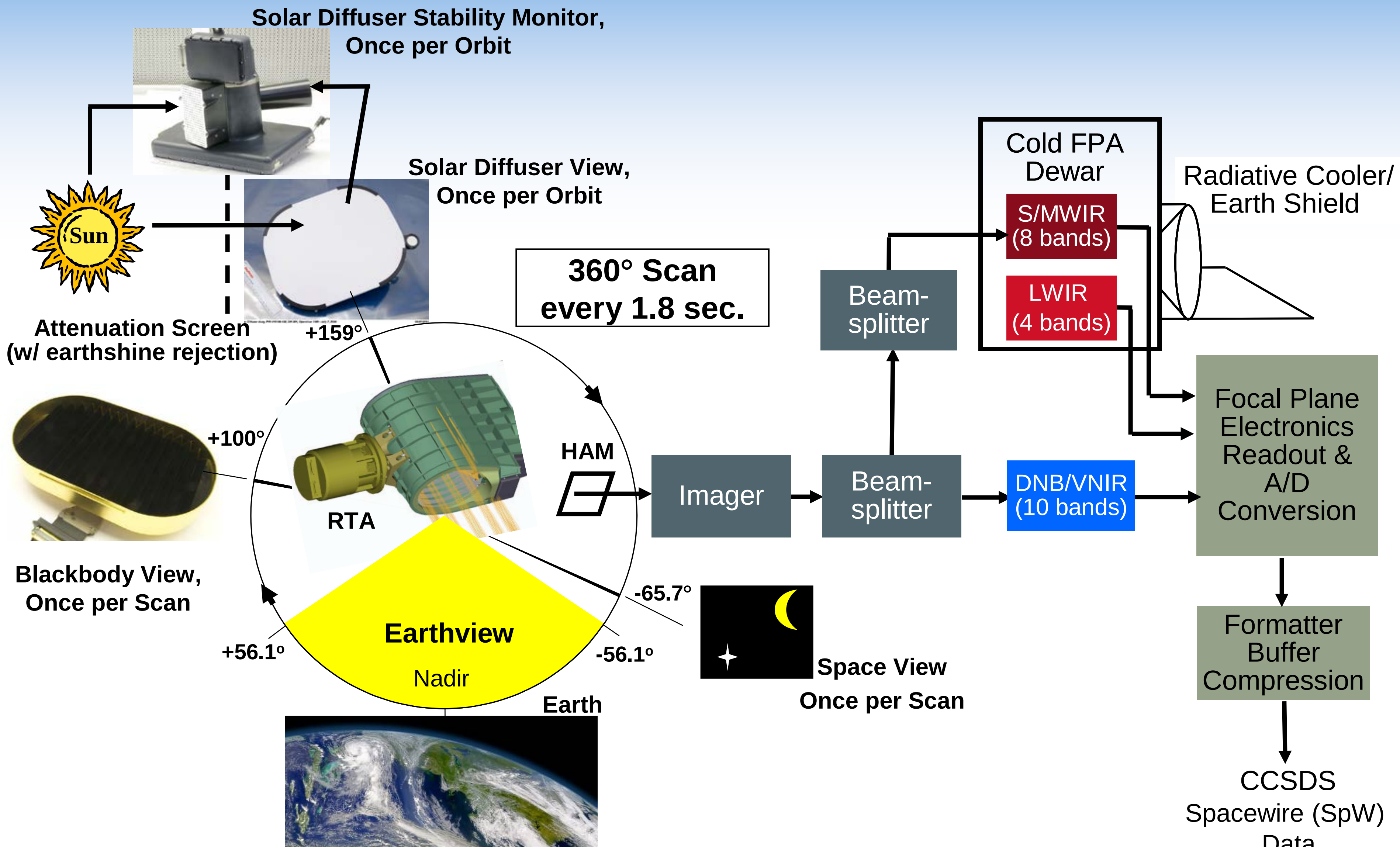
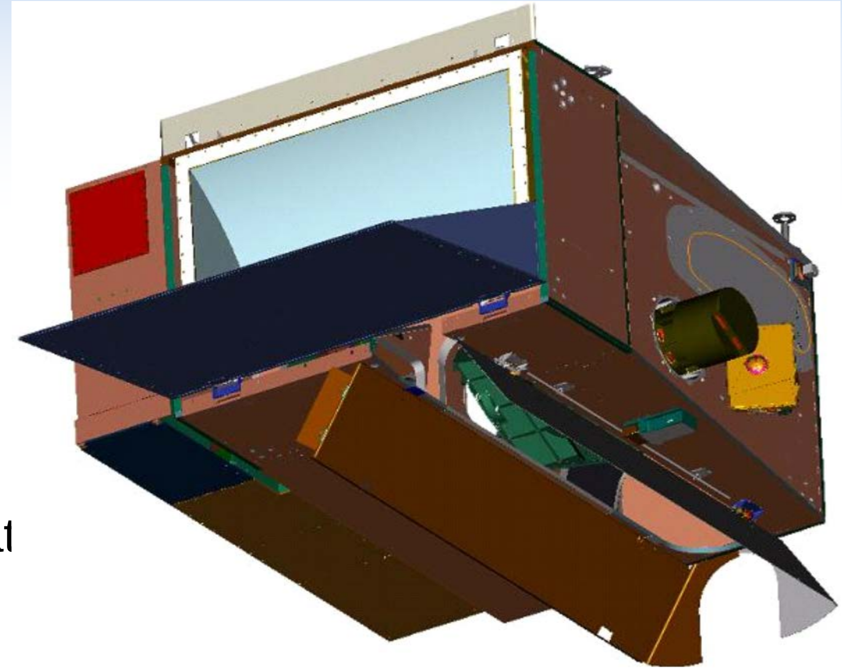


Image provided courtesy of NASA GSFC

VIIRS Flight Units

- 1st Flight Unit (S-NPP) – On-Orbit
  - Integrated onto BATC Spacecraft
  - Sumoi NPP (S-NPP) Satellite Mission
  - Launched October 2011
  - Delta-2 Rocket from Vandenburg AFB
- 2nd Flight Unit (J1) – Integrated to Bus
  - JPSS-1 Satellite Mission
  - Launch Date January 2017
  - Delta-2 Rocket from Vandenburg AFB
- 3rd Flight Unit (J2) – Subassembly Integrat
  - Currently at Component/Sub-System build
  - JPSS-2 Satellite Mission
  - Spacecraft built by Orbital
  - Launch Vehicle TBD

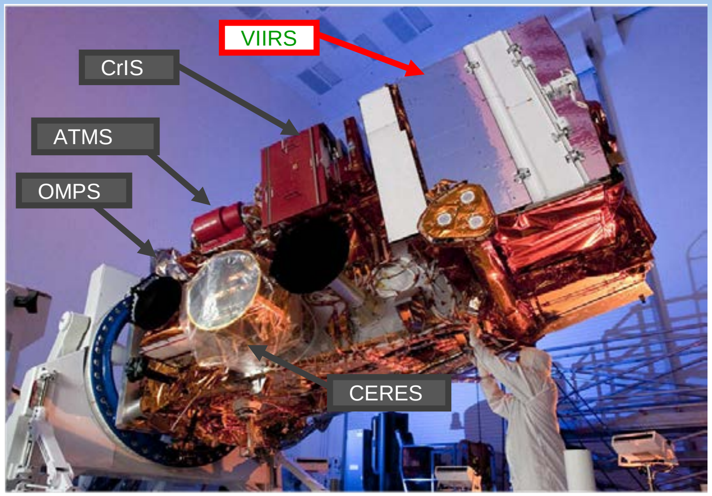


VisNIR Polarization Factor (%)

Band	Sensor	Scan Angle												
		-55	-45	-37	-30	-22	-15	-8	4	20	45	55	Max Pol.	Spec
I1	SNPP	1.5	1.24	~	~	0.93	~	0.85	~	0.7	0.64	0.62	**1.24**	2.5
	J1	0.81	0.74	0.75	0.73	0.73	0.79	0.76	0.8	0.82	0.85	0.85	**0.85**	2.5
I2	SNPP	0.29	0.27	~	~	0.34	~	0.37	~	0.47	0.51	0.51	**0.51**	3
	J1	0.73	0.62	0.54	0.47	0.36	0.37	0.37	0.43	0.5	0.61	0.66	**0.62**	3
M1	SNPP	2.99	2.63	~	~	1.95	~	1.79	~	1.42	1.21	1.4	**2.63**	3
	J1	5.13	5.26	5.35	5.52	5.54	5.56	5.65	5.7	5.66	5.51	5.37	**5.7**	3
M2	SNPP	2.11	1.97	~	~	1.63	~	1.53	~	1.28	1.17	1.29	**1.97**	2.5
	J1	3.72	3.79	3.85	3.95	3.9	3.89	3.94	3.95	3.9	3.99	4.04	**3.99**	2.5
M3	SNPP	1.2	1.14	~	~	0.9	~	0.82	~	0.61	0.7	0.8	**1.14**	2.5
	J1	2.89	2.85	2.83	2.85	2.73	2.69	2.68	2.63	2.62	2.8	2.84	**2.85**	2.5
M4	SNPP	1.05	1.1	~	~	1.19	~	1.16	~	1	0.88	0.84	**1.19**	2.5
	J1	3.61	3.9	4.08	4.16	4.17	4.22	4.18	4.18	4.04	3.89	3.8	**4.22**	2.5
M5	SNPP	1.19	1.02	~	~	0.85	~	0.84	~	0.76	0.73	0.69	**1.02**	2.5
	J1	1.9	1.86	1.9	1.86	1.82	1.85	1.79	1.83	1.81	1.8	1.8	**1.9**	2.5
M6	SNPP	0.99	0.96	~	~	0.94	~	0.94	~	0.88	0.82	0.76	**0.96**	2.5
	J1	1.62	1.32	1.13	0.99	0.86	0.85	0.79	0.75	0.73	0.75	0.76	**1.32**	2.5
M7	SNPP	0.17	0.19	~	~	0.25	~	0.28	~	0.38	0.42	0.41	**0.42**	3
	J1	0.73	0.62	0.54	0.46	0.36	0.36	0.32	0.39	0.45	0.55	0.6	**0.62**	3

- **Polarization using Broadband source was of high quality**
  - Uncertainty less than (0.4%), Repeatability within 0.13%
- **Polarization using Spectral source (T-SIRCUS): M1 and M4**
  - Agreement between Broadband and Spectral to within ~0.3 %
- **General agreement for high quality polarization testing**

VIIRS Integrate on J1 Spacecraft



- ✓ J1 VIIRS is the follow on sensor after SNPP VIIRS
- ✓ J1 VIIRS completed successfully its sensor level testing program
- ✓ Sensor Shipped from Raytheon to Ball (spacecraft) on 2/6/15
- ✓ Sensor installed on spacecraft on 2/20/15
- ✓ J1 VIIRS completed its initial ambient testing on 03/17/2015.
- J1 VIIRS TV testing (as-you-fly), expected June 2016.
- J1 VIIRS Launch Janaury 2017

J1 VIIRS Sensor Integration to Spacecraft and Initial Performance Trending were Completed Successfully

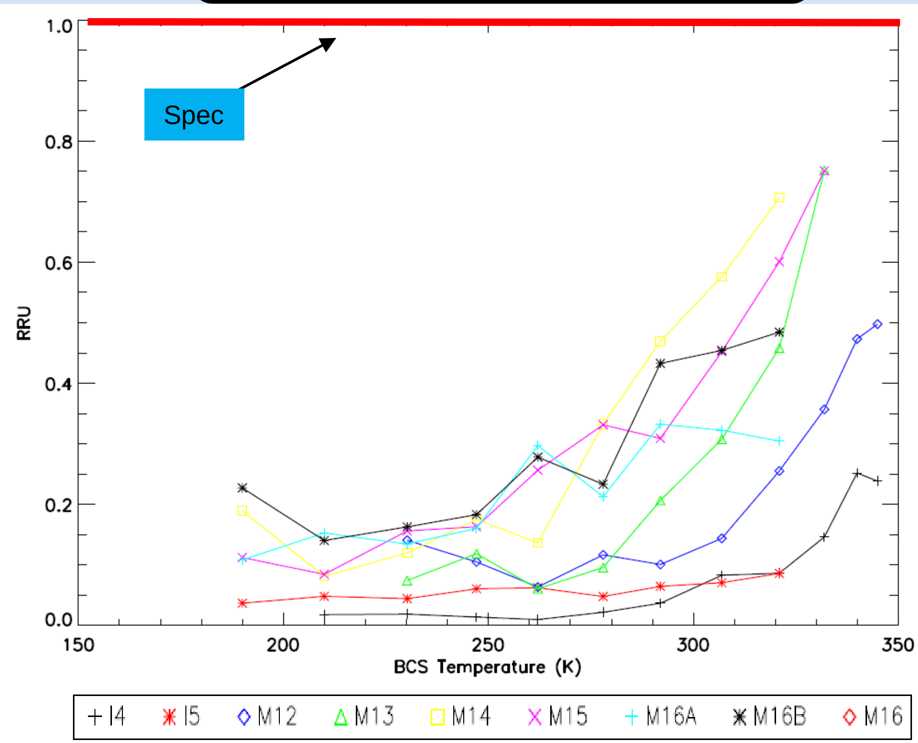
TEB Radiometric Performance

Absolute Radiometric Uncertainty (ARD): Nominal

Uniformity – Det. Striping Nominal

ARD Performance (%)								
Temp (K)	**I4**	**I5**	**M12**	**M13**	**M14**	**M15**	**M16A**	**M16B**
190	~	~	~	~	0.68	0.29	0.17	0.25
230	~	~	7.60	2.95	0.11	0.07	0.08	0.04
267	0.48	0.10	~	~	~	~	~	~
270	~	~	0.24	0.15	0.08	0.05	0.04	0.04
310	~	~	0.25	0.17	0.11	0.06	0.03	0.04
340	~	~	0.27	0.18	0.09	0.05	0.03	0.03
ARD Specification (%)								
Temp (K)	**I4**	**I5**	**M12**	**M13**	**M14**	**M15**	**M16A**	**M16B**
190	~	~	~	~	12.30	2.10	1.60	1.60
230	~	~	7.00	5.70	2.40	0.60	0.60	0.60
267	5.00	2.50	~	~	~	~	~	~
270	~	~	0.70	0.70	0.60	0.40	0.40	0.40
310	~	~	0.70	0.70	0.40	0.40	0.40	0.40
340	~	~	0.70	0.70	0.50	0.40	0.40	0.40

J1 ARD requirements met with margins



- **J1 TEB calibration shows very good performance for ARD and uniformity (striping).**
  - **ARD is below ~0.3 % except at low temperatures for the MWIR (as expected).**
  - **Detector-to-detector uniformity shows some small potential for striping at high temperatures in bands M12 – M14 (similar to SNPP).**

T-SIRCUS Polarization Measurements

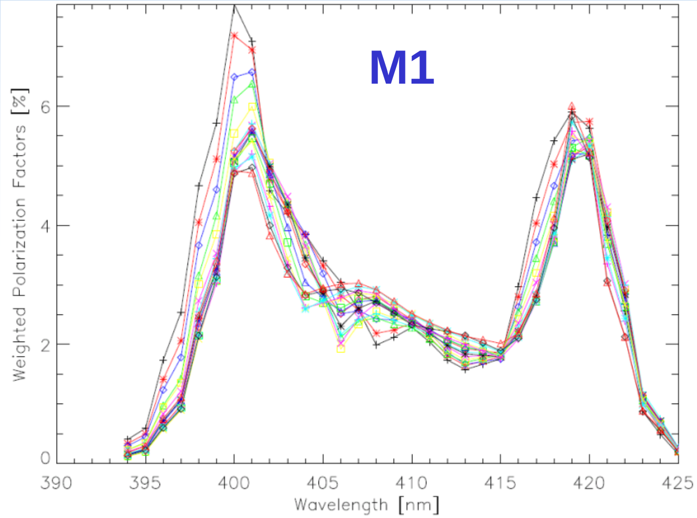
T-SIRCUS polarization measurements were performed in December 2014.

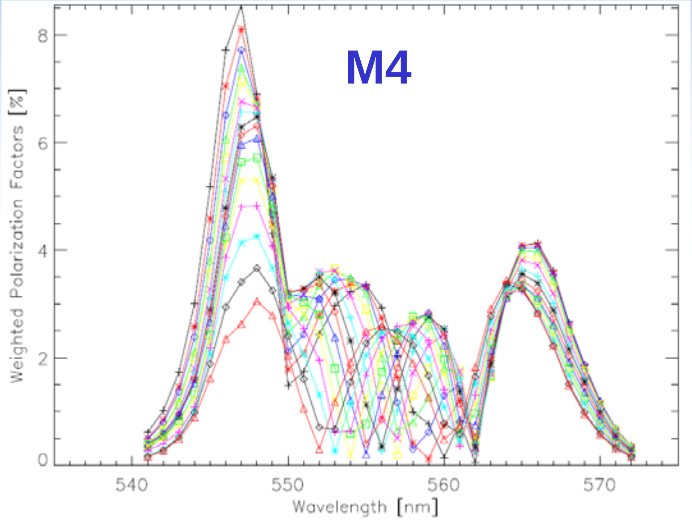
Limited number of measurements made in terms of scan angle, HAM side, and wavelength.

FRED model data compared to measurement results:

1) Good agreement on general shape of wavelength dependence
2) Largest contributor to the polarization sensitivity comes from the edges of the bandpass
3) Some phase shifts in the center of M4 bandpass unexplained by model

Measurement





FRED model