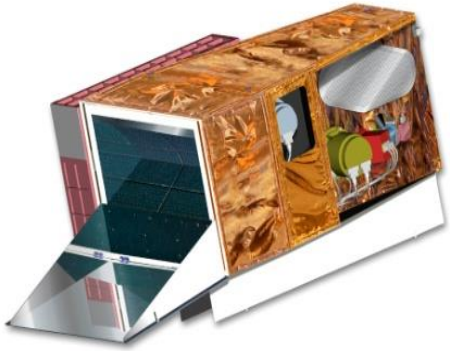
JPSS-3 VIIRS Pre-Launch Radiometric Performance

VIIRS Characterization Support Team, NASA GSFC
Presented by Jeff McIntire

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



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

Calibration Workshop: February 25, 2021

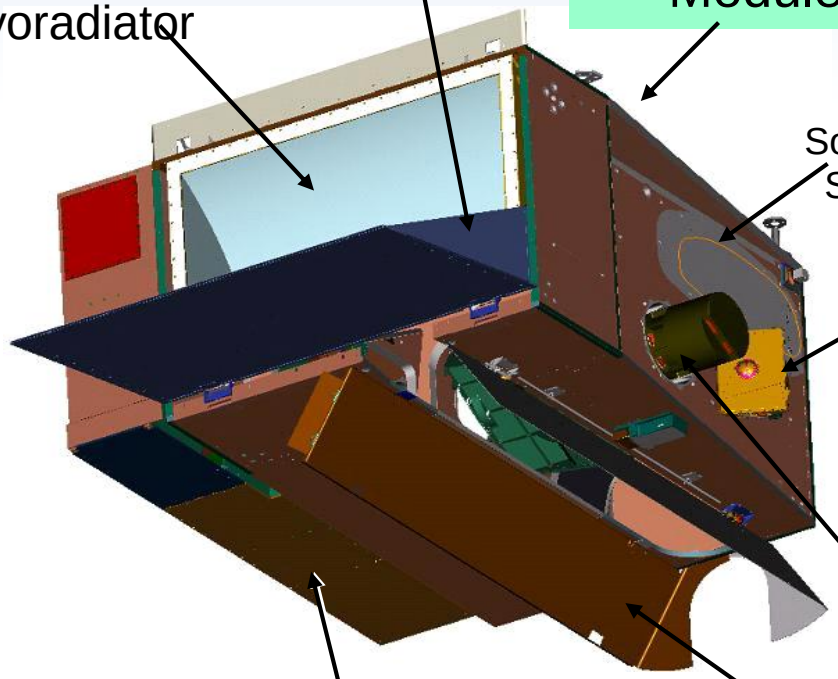
Acknowledgements:

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

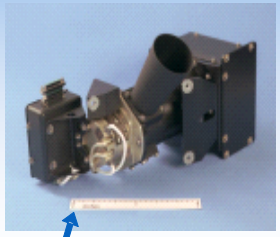
Content

- JPSS-3 VIIRS Pre-launch Testing
- JPSS-3 VIIRS Improvements
- JPSS-3 Performance Waivers
- Status of JPSS-3 VIIRS Performance Assessment
- Conclusion

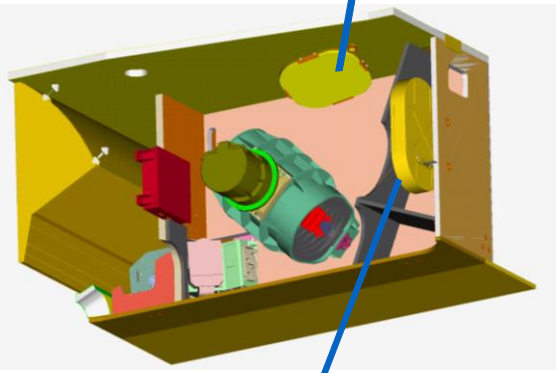
VIIRS Sensor & On-board Calibrators



SDSM



Solar Diffuser



Blackbody (BB)

- ***Proven design through SNPP and JPSS-1 missions on-orbit***
- ***Comprehensive pre-launch testing, and on-orbit predictions***

Overview of JPSS Pre-launch Testing

	JPSS-1	JPSS-2	JPSS-3	Key Testing
Ambient	8/2013 - 1/2014	4/2016 – 8/2016	10/2019 – 1/2020	SNR/NEdT, dynamic range, polarization, RVS, stray light, BB/SD/SDSM characterization, RSR (GLAMR), spatial (LSF/MTF/BBR)
TVAC	7/2014 - 10/2104	4/2017 – 12/2017	9/2020 – 2/2021	SNR/NEdT, dynamic range, calibration, RSR (SpMA), spatial (LSF/MTF/BBR)
SC TVAC	4/2016 – 9/2016 4/2017	10/2021	TBD	SNR/NEdT, calibration (FPI and OBC BB)
Launch	10/2017	10/2022	2026	

- **Radiometric, Spectral and Spatial testing**
  - Ambient, TVAC (cold, nominal, hot), HAM sides, E-sides, detectors, etc.
- **Ensure sensor performance meets design requirements**
  - Compliance, waivers
- **Generate performance parameters for on-orbit operation**
  - SDR LUTs, etc.
- **Modeling and predictions for science data quality**
  - Unexpected changes on-orbit, etc.
- **Develop mitigation strategies for performance issues**

Test program developed with lessons from S-NPP and JPSS-1/2 VIIRS
Test data independently analyzed and results extensively reviewed

J1/J2/J3 Sensor Improvements

JPSS-1

- RTA Mirrors Changed from Ni coated to VQ to improve spatial stability with temperature
- Dichroic 2 Coatings Redesigned to improve spatial performance between SMWIR and LWIR
- Eliminated Throughput Degradation due to Tungsten as seen on SNPP to improve radiometric sensitivity
- Enhanced VisNIR integrated Filter coating change to reduce crosstalk and OOB. Higher polarization sensitivity resulted in bands M1 – M4
- BAE SBC replaced Honeywell SBC (for single event anomaly on-orbit)
- Improved interface between HAM and RTA motor to prevent scan-sync loss on-orbit
- Spacewire replaced IEEE 1394 as the spacecraft BUS

JPSS-2

- VisNIR FPA detectors redesigned to eliminate dynamic crosstalk
- VisNIR FPA ROIC circuit reworked to address rollover after Lsat
- Integrated filter assemblies (IFAs) for all focal planes (except DNB) redesigned to improve dynamic range and reduce VisNIR polarization sensitivity
- Dichroic beamsplitter mounting fixed to improve BBR between VisNIR and cold FPAs
- SDSM spectral filters redesigned to reduce out-of-band signal.
- Additional baffling and closeouts to reduce stray light for the DNB.

JPSS-3

- Dichroic beamsplitter #1 redesigned to decrease polarization splitting in M1
- Additional baffling and closeouts to reduce stray light for the DNB.

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

JPSS-3 VIIRS Performance Waivers

JPSS-3 Performance Waivers		
JPSS-3 Wavier	**Title**	**SNPP / JPSS-1**
W181	DNB stray light in certain viewing geometries	W053D / RDW150B
W182 / W182A	Relief from relative spectral response	W116 / W161 W049A / W161
W183	M1 predicted sensor polarization sensitivity	W166
W184 / W184A	Near field response relief	W112A / W168
W186 / W186A	DNB uniformity	W126 / W173
W187	Band to band registration for Imaging band	W024B / W173
W188 / W188B	Emissive relative radiometric response characterization uncertainty	W070B / W171
W190	Reflective band uniformity	W113 / W172
W191 / W191A	M and I band crosstalk	W054A / W153
W192	Reflective relative radiometric response	W113 / W172
W193	DNB crosstalk	W054A / W153
W214	DNB spatial performance (HSI)	
W215	M12 near field response	
	VisNIR band MTF and HSR	
	M12 emissive response uniformity	

- **Some waivers still pending NASA / NOAA approval (TVAC just finished)**
- Compliance is against end-of-life (EOL) performance
- All non-compliances have mitigation plans, or expected to lead to acceptable impact.

JPSS-3 Performance Summary

Results derived from Pre-TVAC and TVAC testing are preliminary

JPSS-3 VIIRS Performance

- **JPSS-3 RSB Radiometric Performance:**
  - JPSS-3 VIIRS meets all requirements for SNR, Dynamic Range, Gain Transition
    - Successful JPSS-3 RSB radiometric calibration in TVAC. Overall, as good as JPSS-2.
    - Minor non-compliances for uniformity (consistent with earlier VIIRS builds).
  - Other JPSS-3 RSB performance characteristics of note
    - M1 polarization factor less than 2.7 % (JPSS-2 had 4.7 % and JPSS-1 had 6.4 %).
- **JPSS-3 DNB Radiometric performance:**
  - JPSS-3 VIIRS meets all requirements for SNR, Dynamic Range
    - Successful JPSS-3 DNB radiometric calibration in TVAC. Overall, as good as JPSS-2.
    - Minor non-compliances for uniformity (consistent with earlier VIIRS builds).
    - Select aggregation zones show slight nonlinearity near solar tie point, which could affect gain ratios.

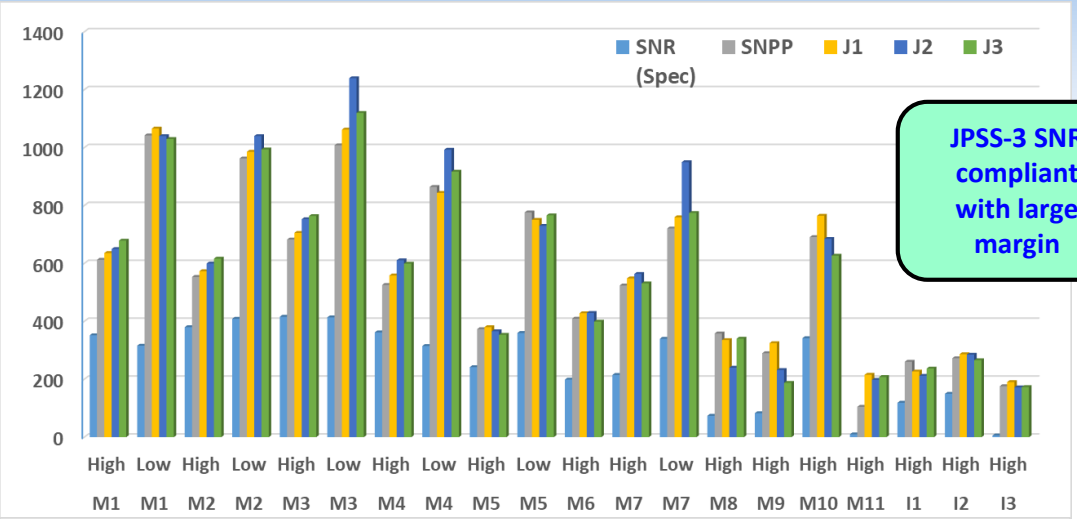
JPSS-3 results derived from Pre-TVAC and TVAC testing are preliminary

JPSS-3 VIIRS Performance

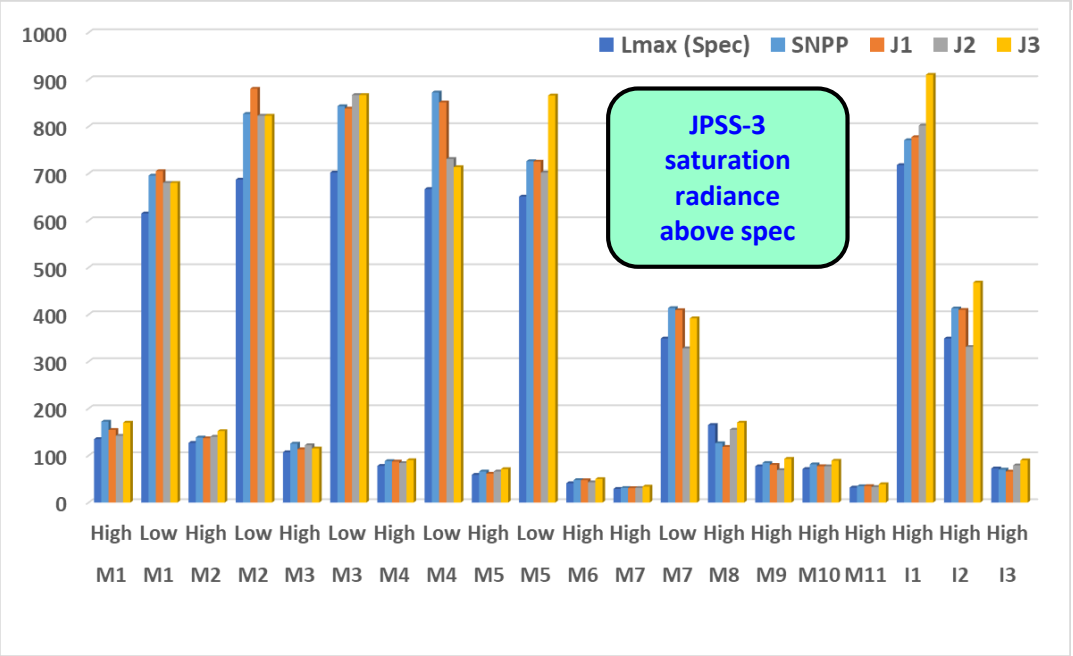
- **JPSS-3 TEB Radiometric Performance**
  - JPSS-3 VIIRS meets all requirements for Noise (NEdT), Dynamic Range, Uncertainty and Uniformity.
    - TEB showed excellent calibration performance based on the TVAC testing; comparable to JPSS-1 or JPSS-2 performance.
    - Non-compliance of OBC-BB non-uniformity was observed during TVAC (up to ~40mK vs. 30mK Spec). Not observed on JPSS-1; JPSS-2 showed worse non-uniformity (up to ~50 mK).
    - FPAs set to 80K. Slightly better than JPSS-2, which was set to 82 K.
- **JPSS-3 Spectral Performance**
    - Successful spectral testing based on NASA GLAMR (VisNIR and SWIR) and Raytheon SpMA. JPSS-3 performance in general as good as JPSS-1 or JPSS-2.
      - Minor non-compliances for M1 and M15 center, M14 and M16 bandwidth.
      - Merger of SpMA and GLAMR data sets ongoing.

JPSS-3 results derived from Pre-TVAC and TVAC testing are preliminary

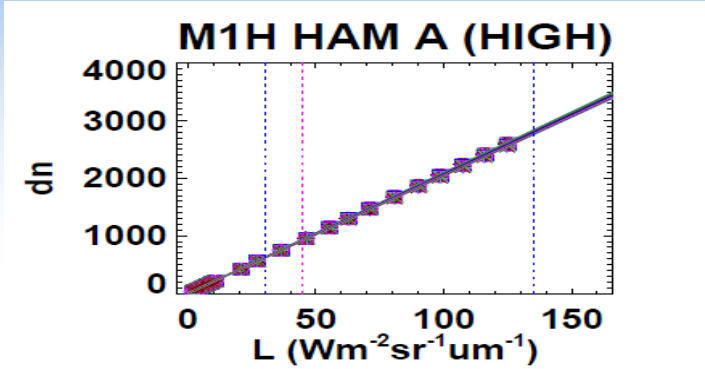
RSB Radiometric Performance

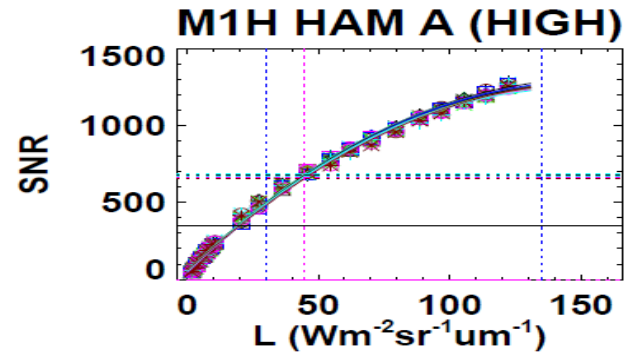


JPSS-3 SNR compliant with large margin



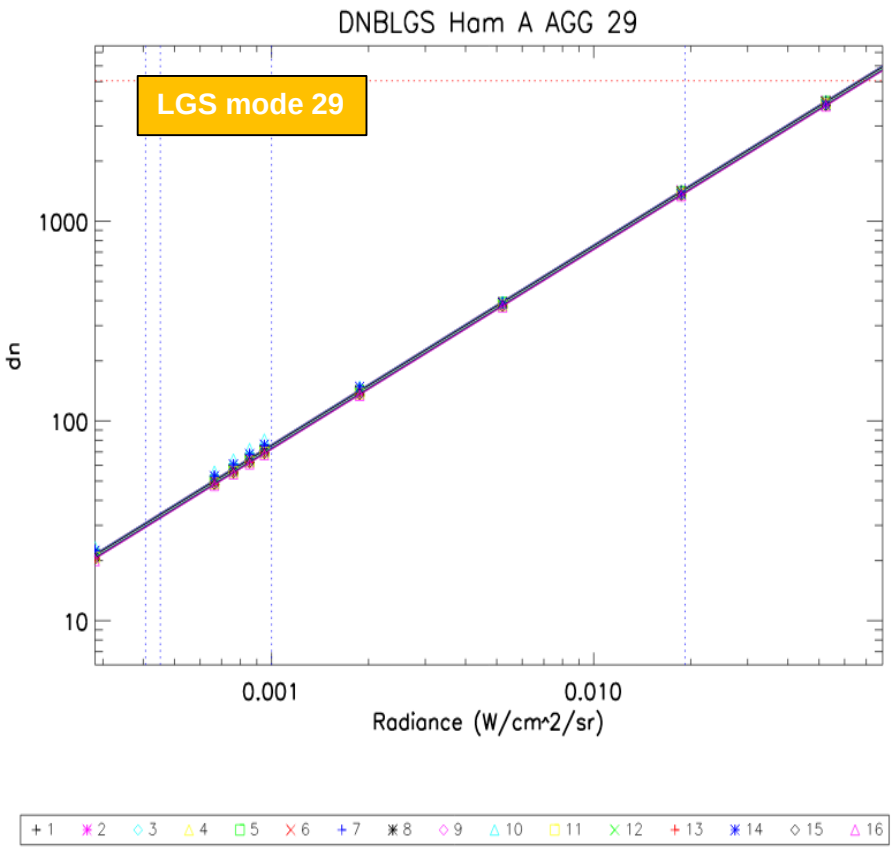
JPSS-3 saturation radiance above spec

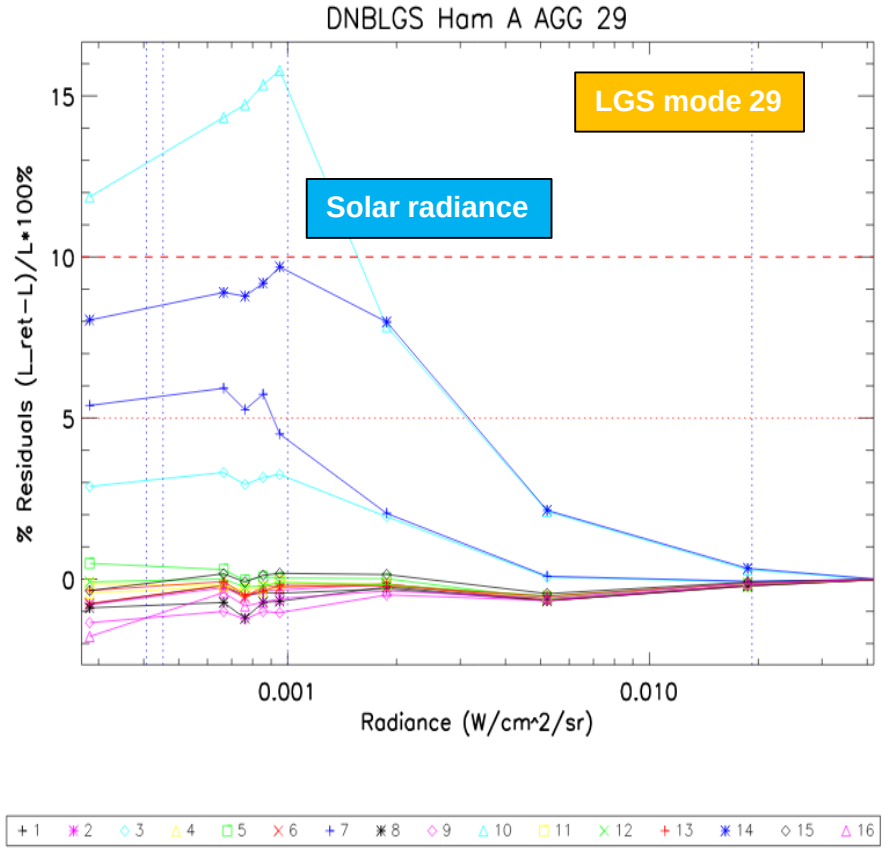




JPSS-3 RSB calibration performance is very good, similar to SNPP / JPSS-1 / JPSS-2.
Minor non-compliances: uniformity.

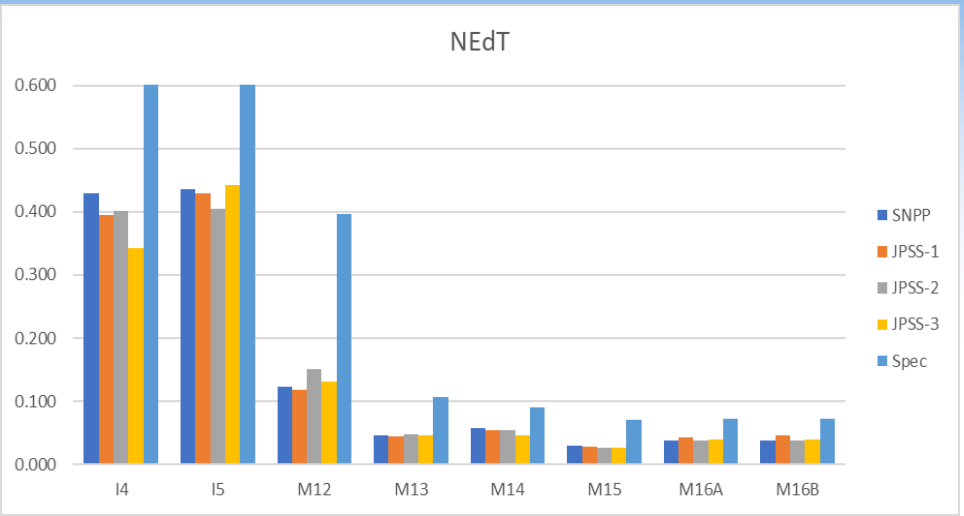
DNB Radiometric Performance

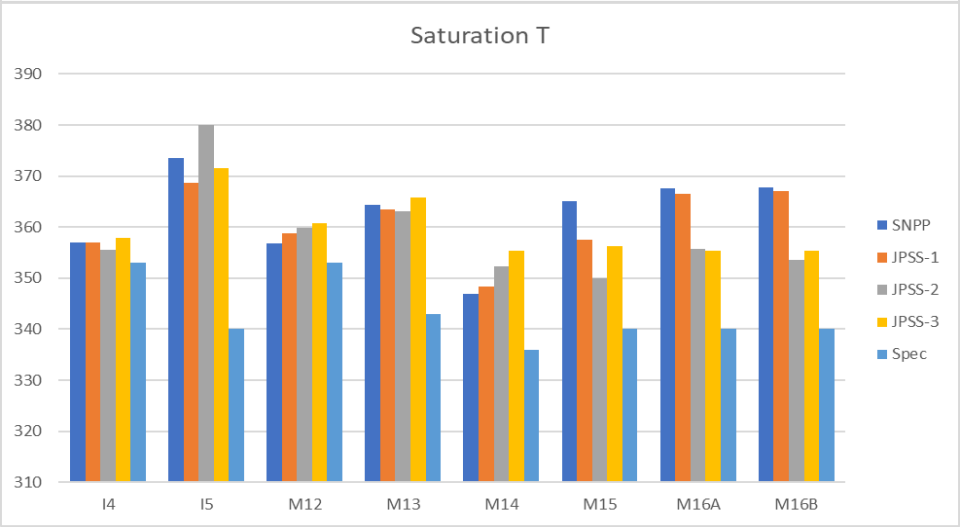


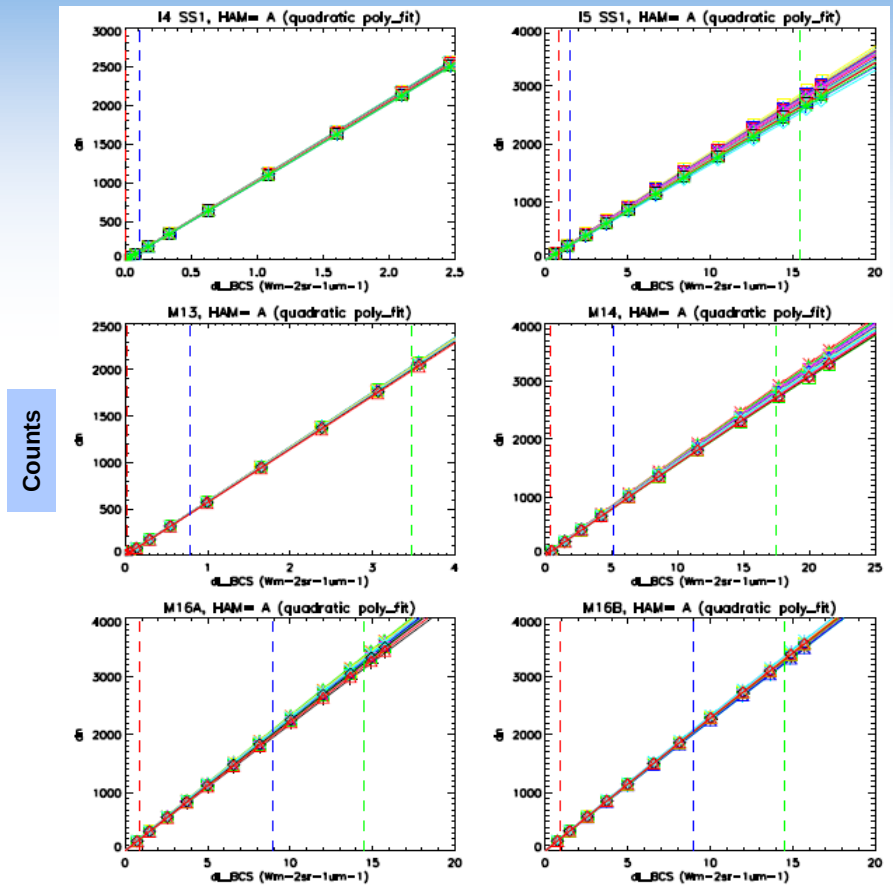


- **JPSS-3 VIIRS DNB performance good overall.**
  - **Some nonlinearity observed near solar tie point in LGS for select aggregation modes. Could influence gain transfer to MGS and HGS.**
  - **Uniformity issues similar to previous builds.**

TEB Radiometric Performance

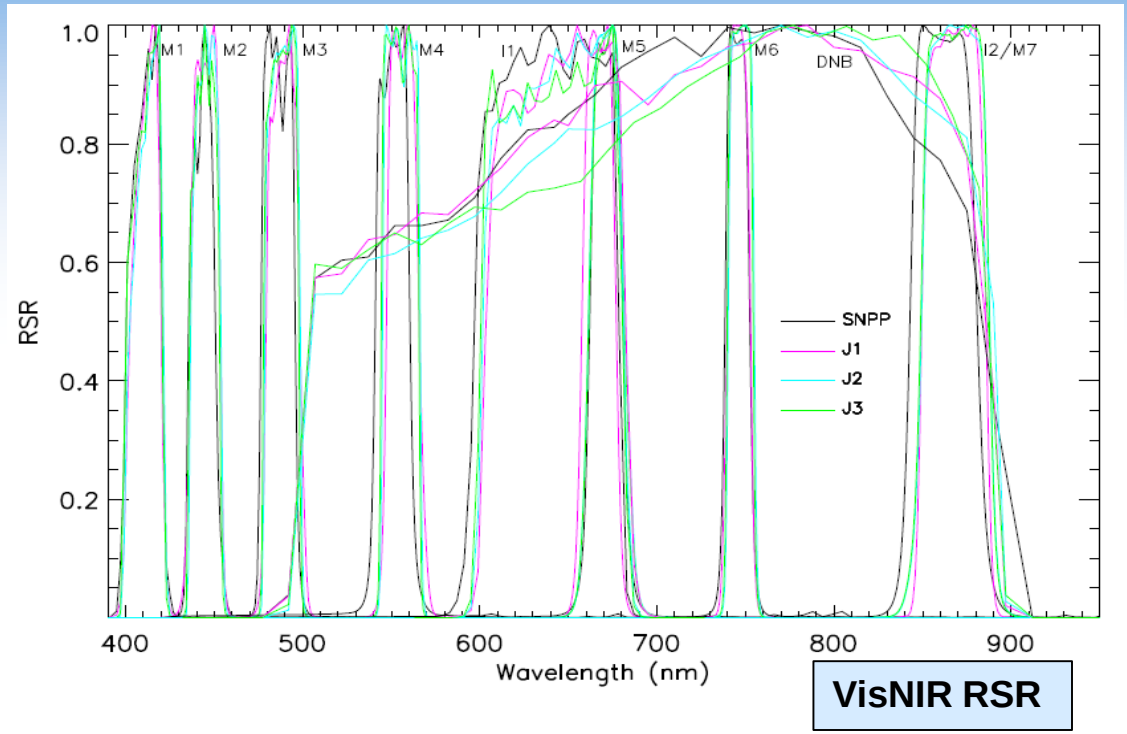


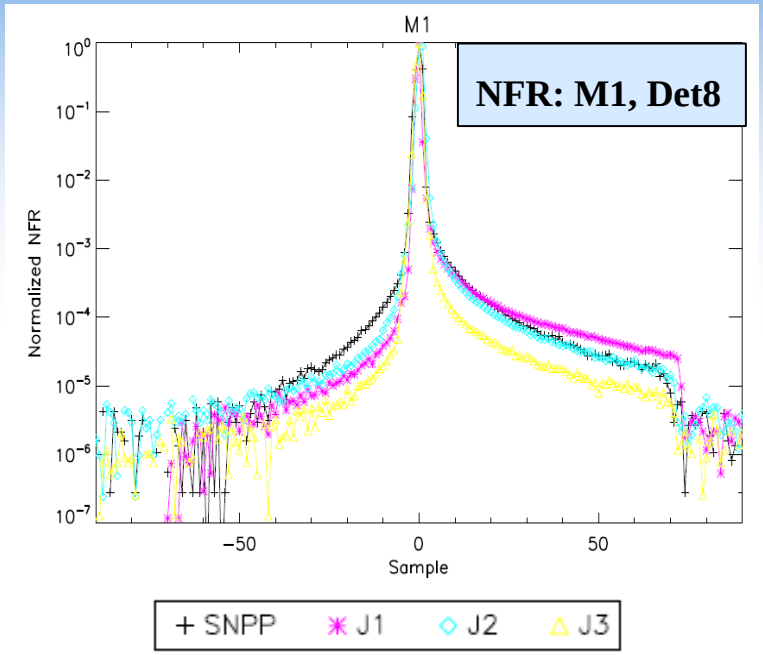




- **JPSS-3 TEB calibration performance is very good, similar to SNPP / JPSS-1 / JPSS-2.**
- **Minor non-compliances observed: OBC BB uniformity, characterization uncertainty, detector uniformity**

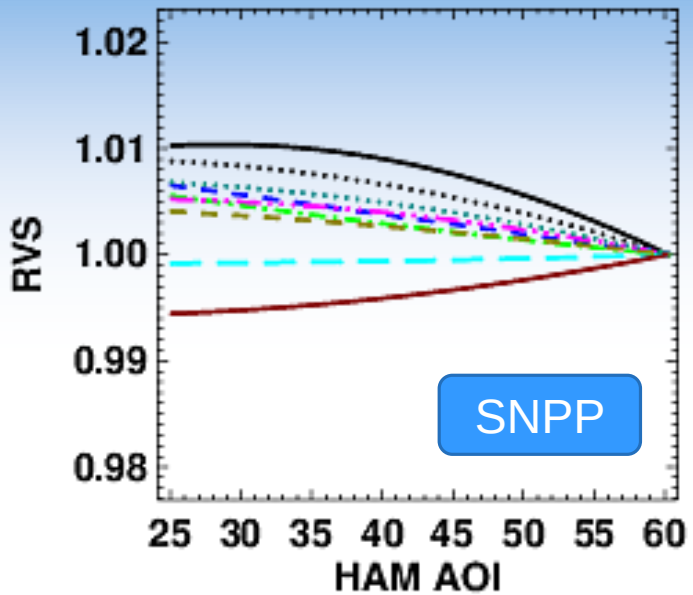
RSR and Scattered Light

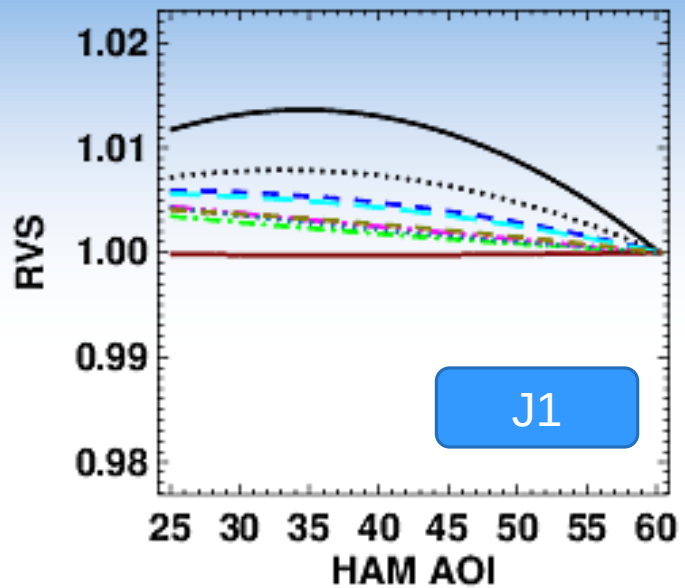


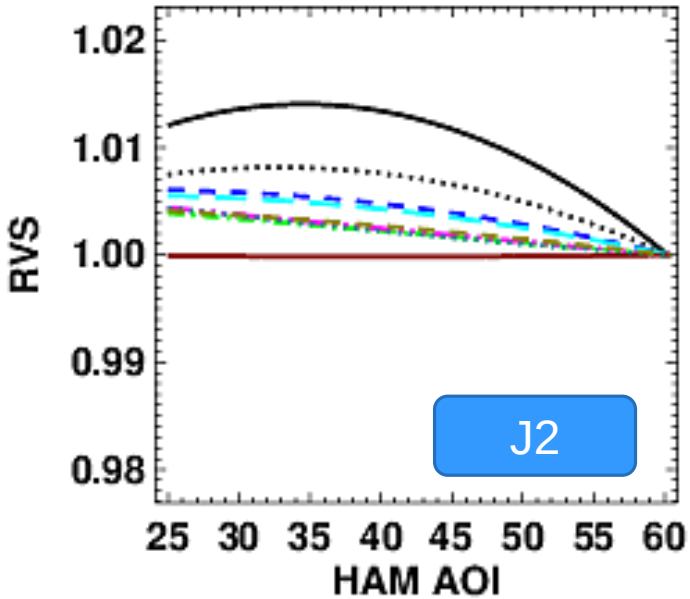


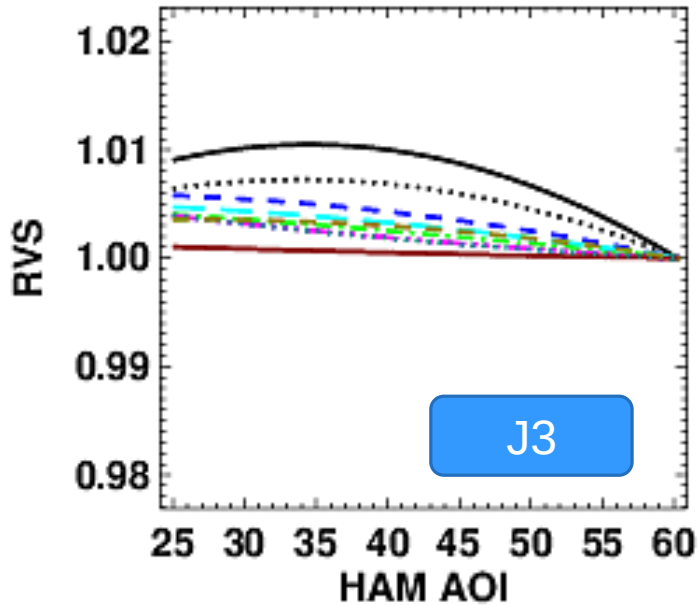
- **Successful JPSS-3 spectral testing based on NASA GLAMR (VisNIR and SWIR) and Raytheon SpMA.**
  - **Limited non-compliances: M1 and M15 band centers; M14 and M16 bandwidths.**
- **JPSS-3 NFR test data quality is very good.**
  - **All band meet the requirements.**
- **JPSS-3 stray light performance also very good.**
  - **All bands meet the requirements. DNB investigation ongoing.**
- **Results are comparable to JPSS-1 / JPSS-2.**

Response Versus Scan (RVS)







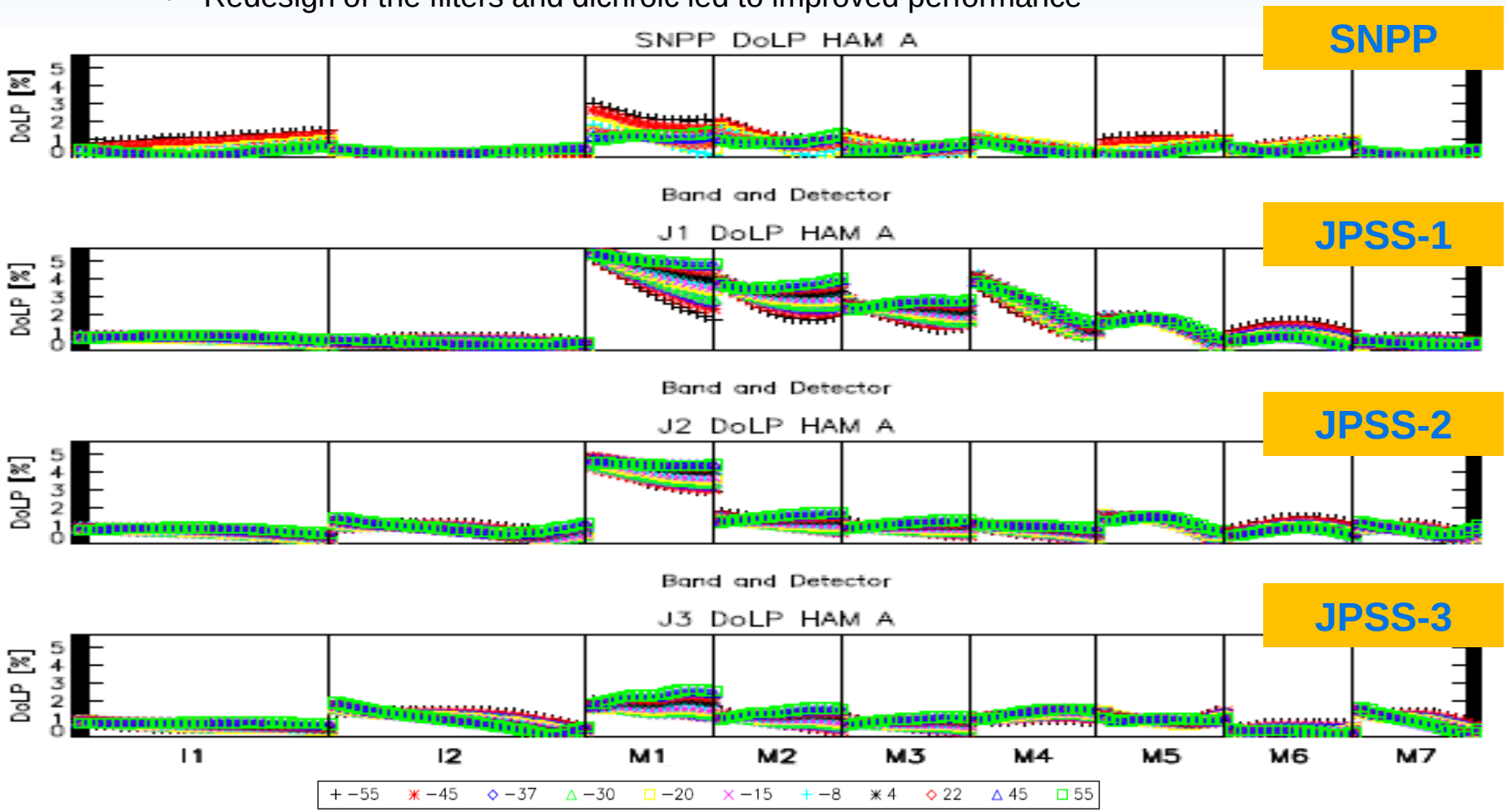


- JPSS-3 RVS performance comparable to SNPP, JPSS-1, and JPSS-2.
- Similar RVS between HAM sides (differences were present on JPSS-1)
- Uncertainties were within tolerances.

DNB
I1
M7/I2
M6
M5
M4
M3
M2
M1

Polarization Performance

- **JPSS-3 VIIRS has shown compliance for all bands**
  - Largest DoLP was for band M1 (2.7 %)
  - JPSS-3 comparable to SNPP; better than JPSS-1 and JPSS-2
    - JPSS-1 had non-compliances for bands M1-M4 due to filter and dichroic issues
    - JPSS-2 had non-compliance for band M1 due to a dichroic issue
    - Redesign of the filters and dichroic led to improved performance



Summary of VIIRS Key Issues

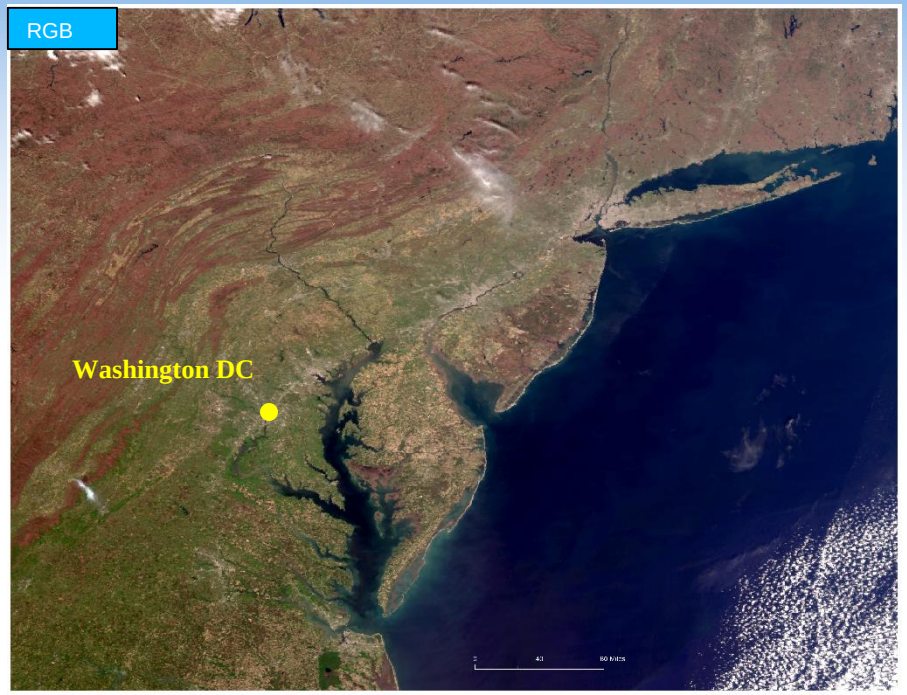
- **JPSS-3 Key Issues**
  - **OBC BB non-uniformity to be monitored, better than JPSS-2 but worse than SNPP / JPSS-1.**
  - **DNB nonlinearity observed in some aggregation zones near the solar tie point; could affect the gain transfer from LGS to MGS and HGS.**
- **Other Issues/topics:**
  - **Low cryo-cooler margins observed late in TVAC for JPSS-3. Currently under investigation by Raytheon (possible cryo target configuration issue).**
  - **JPSS-3 TEB characterization added source levels at high temperature to help characterize band I4 rollover. Band I4 may be used for fire detection due to higher spatial resolution.**
  - **Differences in RSRs between all VIIRS units, but very good spectral characterization.**
  - **DNB stray light on-orbit near the terminator orbit could still be seen. Closeouts for stray light on JPSS-2 and JPSS-3 have not been tested on-orbit yet.**
  - **Improved SDSM filters for JPSS-3 / JPSS-4.**

Summary & Conclusion

- **JPSS-3 VIIRS sensor level test program (ambient and TVAC) was completed successfully**
  - Some minor testing post-TVAC (checking the cryo target; stray light, FPI)
  - EMI upcoming (deferred to after TVAC)
  - Sensor to be shipped to AZ for SC integration.
- **Provided an extensive amount of high quality data to assess sensor performance**
- **VIIRS performance exceeds requirements with a few non-compliances**
  - Non-compliances have been reviewed or are being reviewed, impacts are being assessed, and mitigation plans are being prepared for on-orbit processing.
  - JPSS-3 LUTs neccesary for on-orbit calibration need to be created.
- **JPSS-4 VIIRS ambient testing to begin summer 2021**

SNPP VIIRS Imagery

Eastern Seaboard, 04/24/2016



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

JPSS-2 and JPSS-3 VIIRS are also expected to deliver high quality radiance and environmental data products

Backup

VIIRS Bands and Products

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

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

SNPP VIIRS Performance Waivers

SNPP Performance Waivers				
SNPP Waiver #	J1 Equivalent	J2-J4 Equivalent	Title	Status
W053D	RDW_150B_V5	RDW_W181	DNB Stray Light	Approved
W047C	RDW_175	--	DFOV, MTF, I-Band HSR, DNB HSR, DNB HSI, DNB HRI	Approved
W114	RDW_175	--		Approved
W051A	RDW_151	--	M8 Dynamic Range	Approved
W120	--	--	Swath Width	Approved
W043B	--	--	Gain Transition	Approved
W116	RDW_161	RDW_W181	In-Band Spectral	Approved
W024B	RDW_173	RDW_W187	Band to Band Registration	Approved
W049A	RDW_161	RDW_W181	Integrated OOB Response	Approved
W112A	RDW_168	RDW_W184	M-Band & DNB Near Field Response	Approved
W054A	RDW_153	RDW_W191	Crosstalk	Approved
W128	--	--	Effective Focal Length	Approved
W113	RDW_172	RDW_W190	M-Band Uniformity	Approved
W126	RDW_173	RDW_W186	DNB Uniformity	Approved
W070B	RDW_171	RDW_W188	Emissive Band Radiometric Characterization	Approved
W113	RDW_172	RDW_W192	Reflective Band Characterization Uncertainty	Approved
W113	RDW_149	--	M11 Absolute Radiometric Calibration Uncertainty	Approved
W080A	--	--	One-Day Pointing	Approved

- **All 16 waivers were approved by NASA/NOAA review board**
- Compliance is against end-of-life (EOL) performance
- All non-compliances have mitigation plans, or expected to lead to acceptable impact.

J1 VIIRS Performance Waivers

J1 Performance Waivers

J1 Waiver #	SNPP Equivalent	J2-J4 Equivalent	Title	Status
RDW_148	--	--	J1 Relief against reflective band absolute radiometric calibration uncertainty requirements for bands M1-M3	Approved
RDW_149	W113	RDW_W181	J1 Relief against reflective band absolute radiometric calibration uncertainty requirements for band M11	Approved
RDW_150B_V5	W053D	--	J1 Relief for DNB stray light in certain viewing geometries and related impacts on sensitivity and radiometric calibration	Approved
RDW_151A_v1	W051A	--	J1 relief against maximum radiance requirement for bands M8, I1 and possibly M1LG and I3.	Approved
RDW_166	--	RDW_W183	J1 relief agains maximum polarization sensitivity requirement for bands M1 to M4.	Approved
RDW_153_v1	W054A	RDW_W191	J1 relief against electrical and optical crosstalk. Stringent requirements and testing artefacts are leading to non-compliances	Approved
RDW_154_v4	W047C-W114		J1 relief against the sensor modulated transfer function (MTF)	Approved
RDW_161	W116- W049A	RDW_W182	J1 relief against the relative spectral response (RSR) requirements. Band center (M5, M16), Band width (M1,M8,M14,DNB), 1% limit (I5,DNB), IOOB (M16)	Approved
RDW_168	W112A	RDW_W184	J1 relief against near field response (NFR). Non-compliance for (M7, M13, M16A and I3)	Approved
RDW_171	W113-W070B	RDW_W188	J1 relief from emissive relative radiometric reponse calibration uniformity (M12-M14 at high temp) and characterization uncertainty (I5 and M12).	Approved
RDW_172	W113	RDW_W190-W192	J1 relief from reflective band characterization uncertainty (all bands non-compliant except M4HG and M5HG, and M7HG), and uniformity characterization (all bands non-compliant except M1-M7	Approved
RDW_173	W024B	RDW_W187	J1 relief from band-to-band registration for I bands (non-compliance for I1-I3, I2-I3, I1-I4, I2-I4, I1-I5, I2-I5, I3-I5, I4-I5)	Approved
RDW_174	W126	RDW_W186	J1 relief from DNB SNR, uniformity and RCU.	Approved
RDW_175	W047C-W114	--	J1 relief from spatial dynamic field of view (DFOV). All M bands and I5 not compliant	Approved
RDW_177	--	--	J1 DNB relief from dynamic range (LGS)	Approved

- **All 15 waivers were approved by NASA/NOAA review board**
- Completed a series of telecons (half-dozen) with NASA and NOAA SMEs to review each waiver
- Compliance is against end-of-life (EOL) performance
- All of non-compliances have mitigation plans, or expected to lead to acceptable impact.

J2 VIIRS Performance Waivers

J2 Performance Waivers

J2-J4 Waiver #	SNPP Equivalent	J1 Equivalent	Title	Starus
RDW_VIIRS-W183	--	RDW_166	Relief for M1 Predicted Sensor Polarization Sensitivity 11/09/2015	Open
RDW_VIIRS-W184	W112A	RDW_168	Relief on Near Field Response Performance 11/09/2015	Open
RDW_VIIRS-W181	W053D	RDW_150B_V5	Relief for DNB Stray Light in Certain Viewing Geometries 11/09/2015	Open
RDW_VIIRS-W188	W113-W070B	RDW_171	Relief from Emissive elative Radiometric Response Characterization Uncertainty	Open
RDW_VIIRS-W186	W126	RDW_174	Relief from DNB Uniformity	Open
RDW_VIIRS-W182	W116-W049A	RDW_161	Relief from Relative Spectral Response 11/09/2015	Open
RDW_VIIRS-W187	W024B	RDW_173	Relief from Band to Band Registration for I Bands 11/09/2015	Open
RDW_VIIRS-W191	W054A	RDW_153	Relief on M and I Band Crosstalk Performance	Open
RDW_VIIRS-W192	W113	RDW_172	Relief from Reflective Radiometric Response Characterization Uncertainty (RRCU)	Open
RDW_VIIRS-W190	W113	RDW_172	Relief from Reflective Relative Response Uniformity (RRU)	Open
RDW_VIIRS-W193	W054A	RDW_153	Relief on DNB Crosstalk Performance	Open

- There are 11 waivers (Status as of early last year)
- Most of the waivers are still being prepared, and are still in the NASA/NOAA approval process
- Waiting for TV testing results to support some waivers
- Compliance is against end-of-life (EOL) performance
- All of non-compliances will have mitigation plans, or will lead to acceptable impact.

Status as of last year

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 government team
  - Technical Interchange Meetings (TIMs)
  - Regular briefings at NOAA-led VIIRS SDR meetings

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

VIIRS Operation & Data Flow

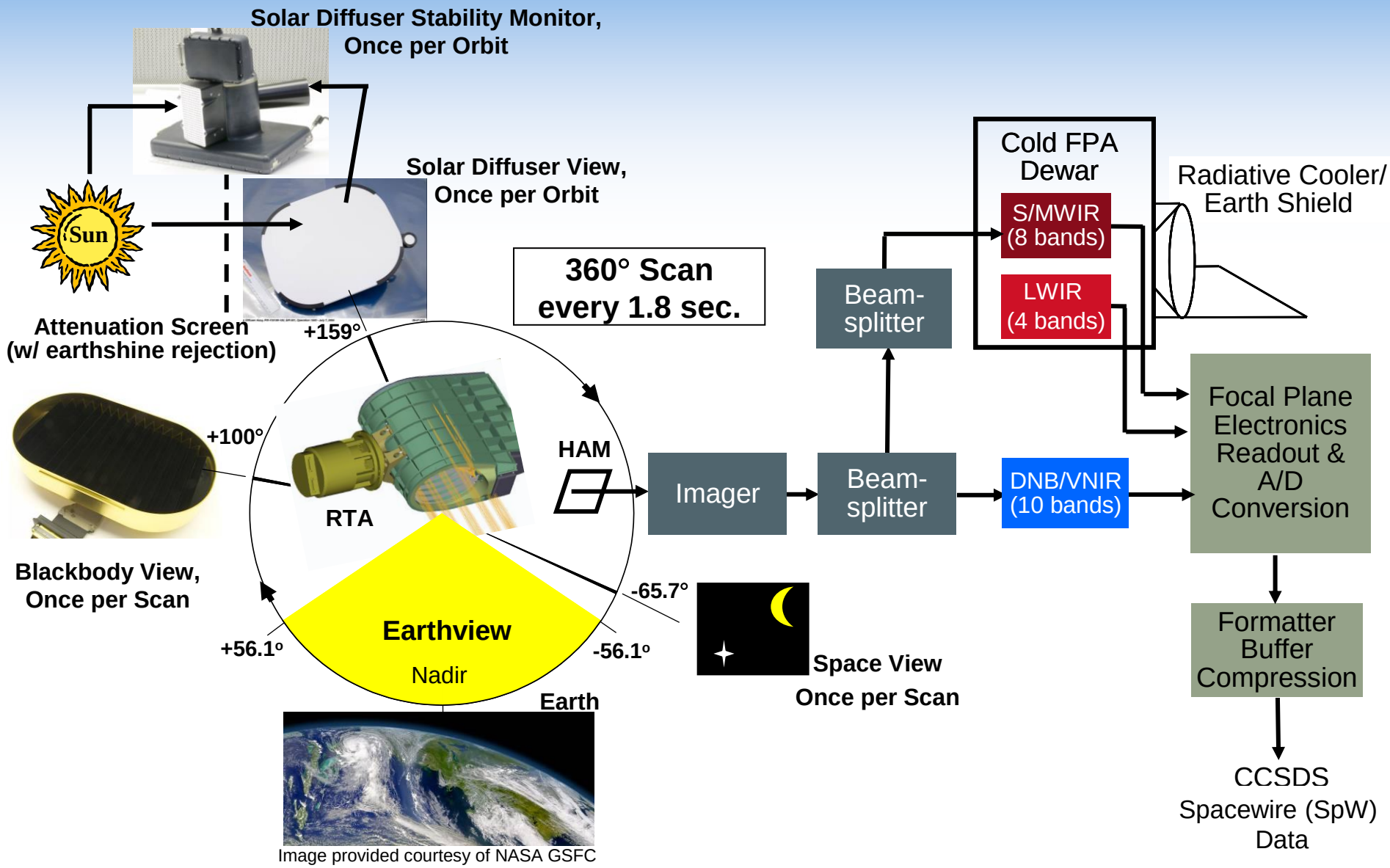


Image provided courtesy of NASA GSFC