VALIDATED MATURITY SCIENCE REVIEW FOR NOAA-20 VIIRS SDR

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With contributions from NOAA STAR, NASA/VCST, The Aerospace Corp., and U. of Wisconsin

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Outline

- Algorithm Cal/Val Team Members
- Product Requirements
- Evaluation of instrument performance in meeting specifications and requirements
  - Accuracy, Precision, Stability, Uncertainty
  - Anomalies
- User Feedback
- Downstream Product Feedback
- Documentations (Science Maturity Check List)
- Conclusion
- Path Forward

NOAA-20 VIIRS SDR Cal/Val Team

PI	Organization	Team Members	Roles and Responsibilities
C. Cao	STAR		Team lead, calibration/validation, SDR science, coordination, oversight
S. Blonski / W. Wang	STAR/ERT	J. Choi, Y. Gu, B. Zhang, A. Wald	Flight & operations interface; maneuver support; VIIRS SDR cal/val (prelaunch studies; software code changes and ADL tests; postlaunch analysis, monitoring and LUT update; operations support; anomaly resolution); postlaunch cal/val tasks.
X. Shao$_{(1/2)}$	UMD/CICS	S. Uprety, Y. Bai, E. Lynch, and students	DNB operational calibration, straylight correction, geolocation validation, intercomparisons, solar/lunar calibration; image analysis& quality assurance; postlaunch cal/val tasks, documentation.
I. Guch	Aerospace	G. Moy, E. Haas, S. Farrar, F. Sun, and many others	Postlaunch cal/val tasks; independent analysis.
J. Xiong	NASA/VCST	G. Lin, N. Lei, J. McIntire, and others	Flight support, geolocation, postlaunch cal/val tasks; independent analysis,
C. Moeller	U. Wisconsin	C. Moeller, J. Li	VIIRS RSR, CrIS comparison, DCC calibration
JPSS	JPSS	R. Marley, C. Rossiter B. Guenther	Collaboration

VIIRS SDR Product Requirements from JPSS L1RD

Attribute	Threshold	Objective
Center Wavelength	412 to 12,013 nm	412 to 12,013 nm
Bandpass	15 to 1,900 nm	15 to 1,900 nm
Max. Polarization Sensitivity	2.5 to 3.0 %	2.5 to 3.0 %
Accuracy @ Ltyp	0.4 to 30 %	0.4 to 30 %
SNR @ Ltyp or NEdT @ 270 K	6 to 416 or 0.07 to 2.5 K	6 to 416 or 0.07 to 2.5 K
FOV @ Nadir	0.4 to 0.8 km	0.4 to 0.8 km
FOV @ Edge-of-Scan	0.8 to 1.6 km	0.8 to 1.6 km
Ltyp or Ttyp	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K
Dynamic Range	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K
See L1RD for details		

KPP: For latitudes greater than 60N in the Alaskan region:
VIIRS Imagery EDR at 0.64 um (I1), 1.61 um (I3), 3.74 um (I4), 11.45 um (I5), 8.55 um (M14), 10.763 um (M15), 12.03 um (M16), and Near Constant Contrast EDR

NOAA-20 VIIRS SNR/NEDT Performance (May 2018)

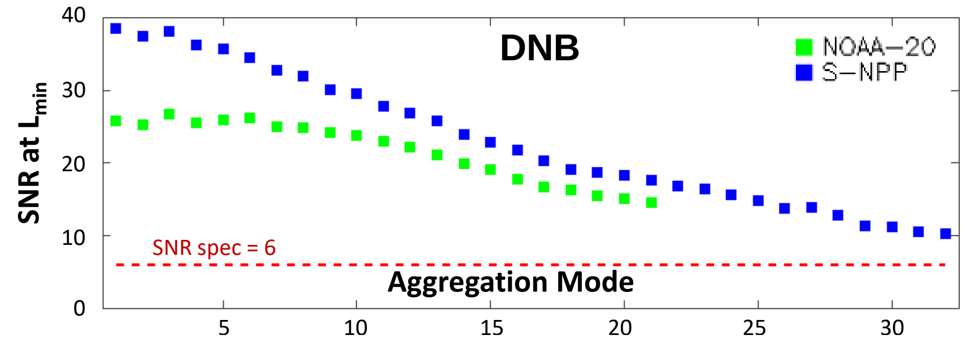
Band	L_typ	SNR Spec	NOAA-20 (on-orbit)	S-NPP (on-orbit)
M1 LG	155	316	1115	1045
M1 HG	44.9	352	644	588
M2 LG	146	409	1012	1010
M2 HG	40	380	573	572
M3 LG	123	414	1057	988
M3 HG	32	416	686	628
M4 LG	90	315	857	856
M4 HG	21	362	551	534
M5 LG	68	360	762	631
M5 HG	10	242	383	336
M6	9.6	199	413	368
M7 LG	33.4	340	708	631
M7 HG	6.4	215	523	457
M8	5.4	74	319	221
M9	6	83	297	227
M10	7.3	342	653	586
M11	1	90	198	22*
I1	22	119	224	214
I2	25	150	285	264
I3	7.3	6	174	149

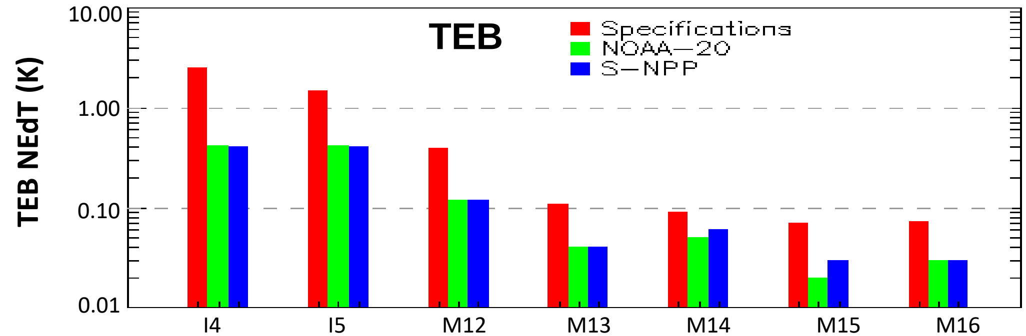
Band	T_typ	NEDT Spec	NOAA-20 (on-orbit)	S-NPP (on-orbit)
M12	270	0.396	0.12	0.12
M13	300	0.107	0.04	0.04
M14	270	0.091	0.05	0.06
M15	300	0.07	0.02	0.03
M16	300	0.072	0.03	0.03
I4	270	2.5	0.42	0.4
I5	210	1.5	0.42	0.4

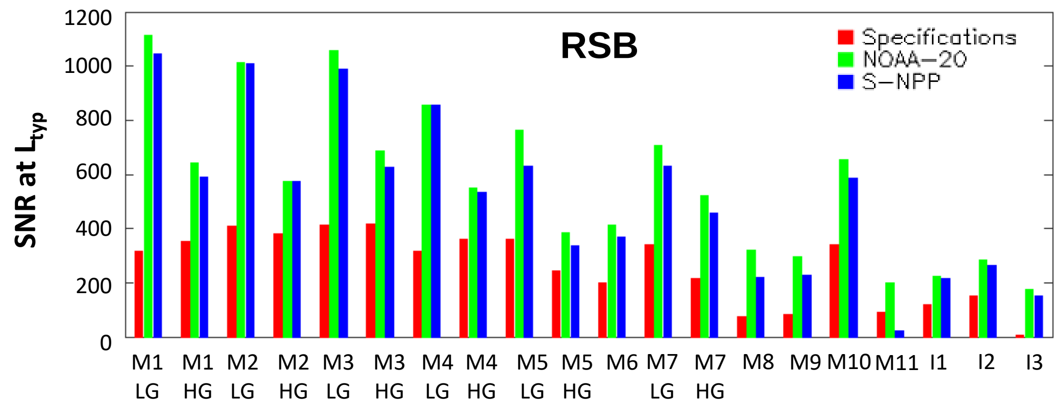
Band	L_min	SNR Spec	NOAA-20 (on-orbit)	S-NPP (on-orbit)
DNB**	3	6	>10	>10

* For S-NPP M11, L_{typ} = 0.12 W/m^2-sr-µm

** On-orbit SNR of DNB at L_{min} was evaluated by using the DNB OBC-BB data







All channel noise performance meet specification, comparable to SNPP (I3 bad detector excluded)

Issues Resolved since Provisional Review

1. VIIRS LWIR degradation

   Mitigation: supported the mission operations team in LWIR outgassing, which was very successful.

2. Saturation and "Roll-over" in band M6 (and other bands) below the required maximum radiance level resulting in large number of pixels with incorrect measurements above the level of 30-35 radiance units (Lmax = 41 r.u.):

   Mitigation: developed algorithm and software ready to be delivered to operations to flag roll-over pixels (W. Wang)

3. SDSM uncertainty reduction (to be reported by S. Blonski): recommendations: 1) extensive calibration/validation with vicarious sources, Lunar, Deep Convective Clouds.; 2) Consider additional yaw maneuvers.

   Mitigation: developed methodology to mitigate SDSM uncertainties (J. Choi)

4. WUCD (to be reported by W. Wang)
   - Re-evaluate WUCD reduction: Completed with recommendation letter to the program.
   - WUCD algorithm implementation in operations: Developed and tested, to be delivered to operation after extended testing.

5. Radiometric bias monitoring:

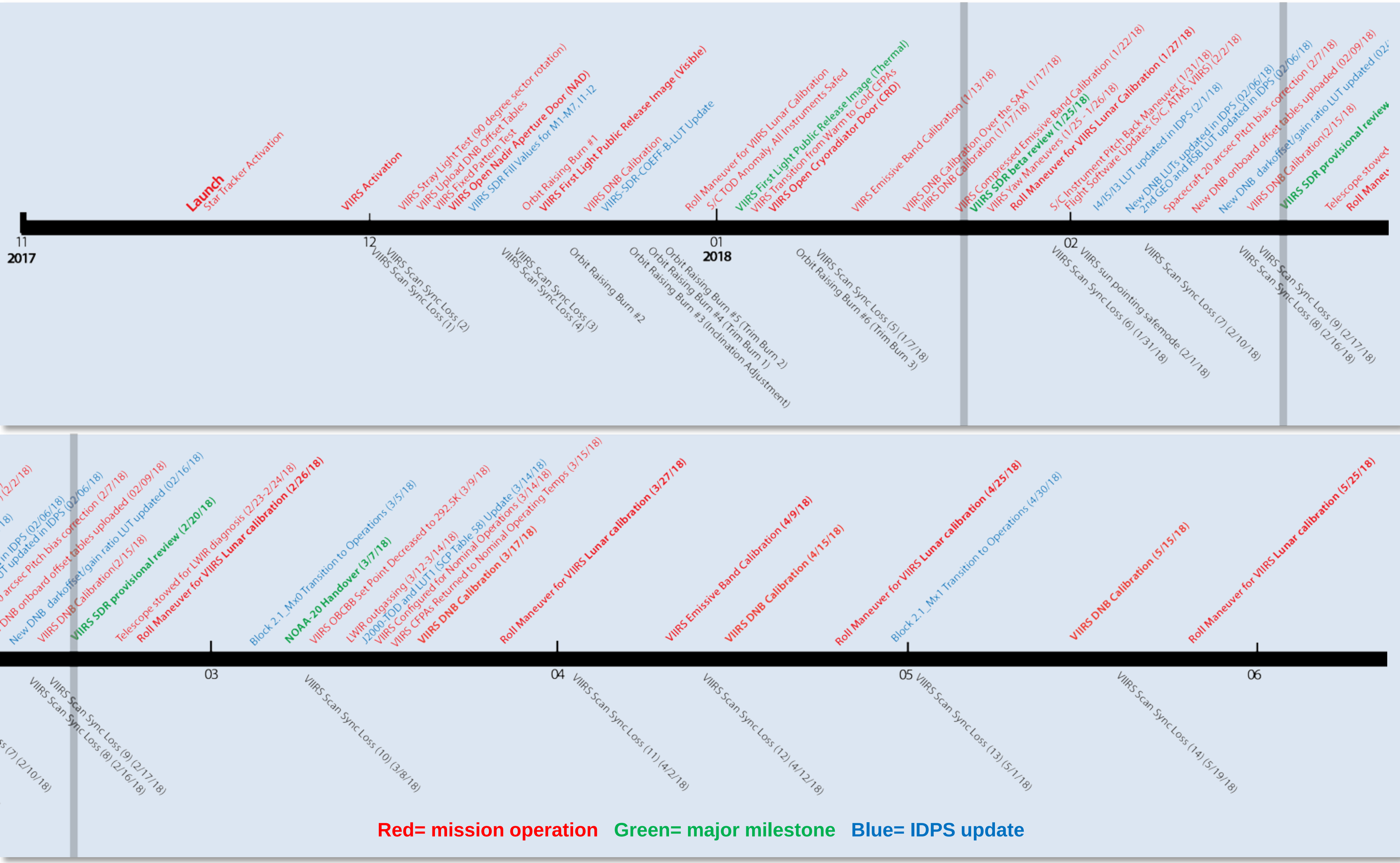
   Further characterized radiometric biases using various methods (to be reported by S. Blonski)

6. VIIRS DNB improvements: Straylight, artifacts, stability (to be reported by S. Uprety)

7. Lunar contamination algorithm: algorithm and software developed. To be delivered to operations after extensive testing (W. Wang).

8. Polarization on-orbit characterization and impact studies
   - Investigated on-orbit characterization of polarization and compared with SNPP (A. Wald & W. Wang).

NOAA-20 VIIRS Event Chart

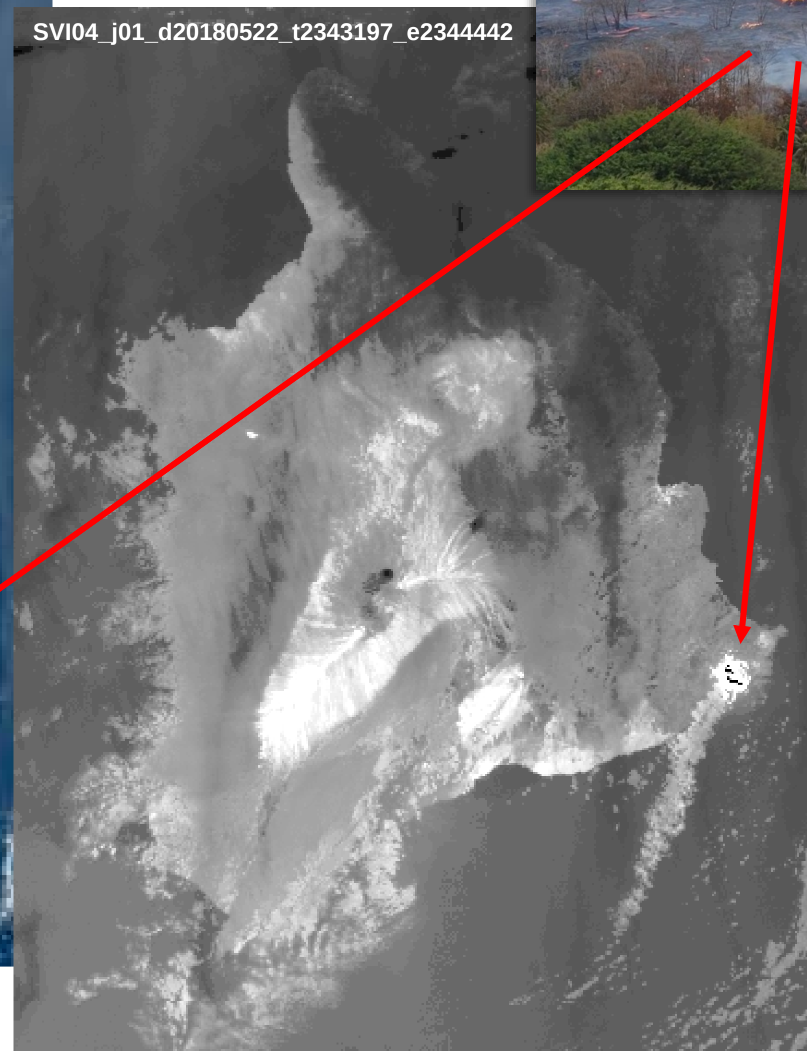


Red= mission operation Green= major milestone Blue= IDPS update

Hawaii Volcanic Eruption (May 22, 2018)

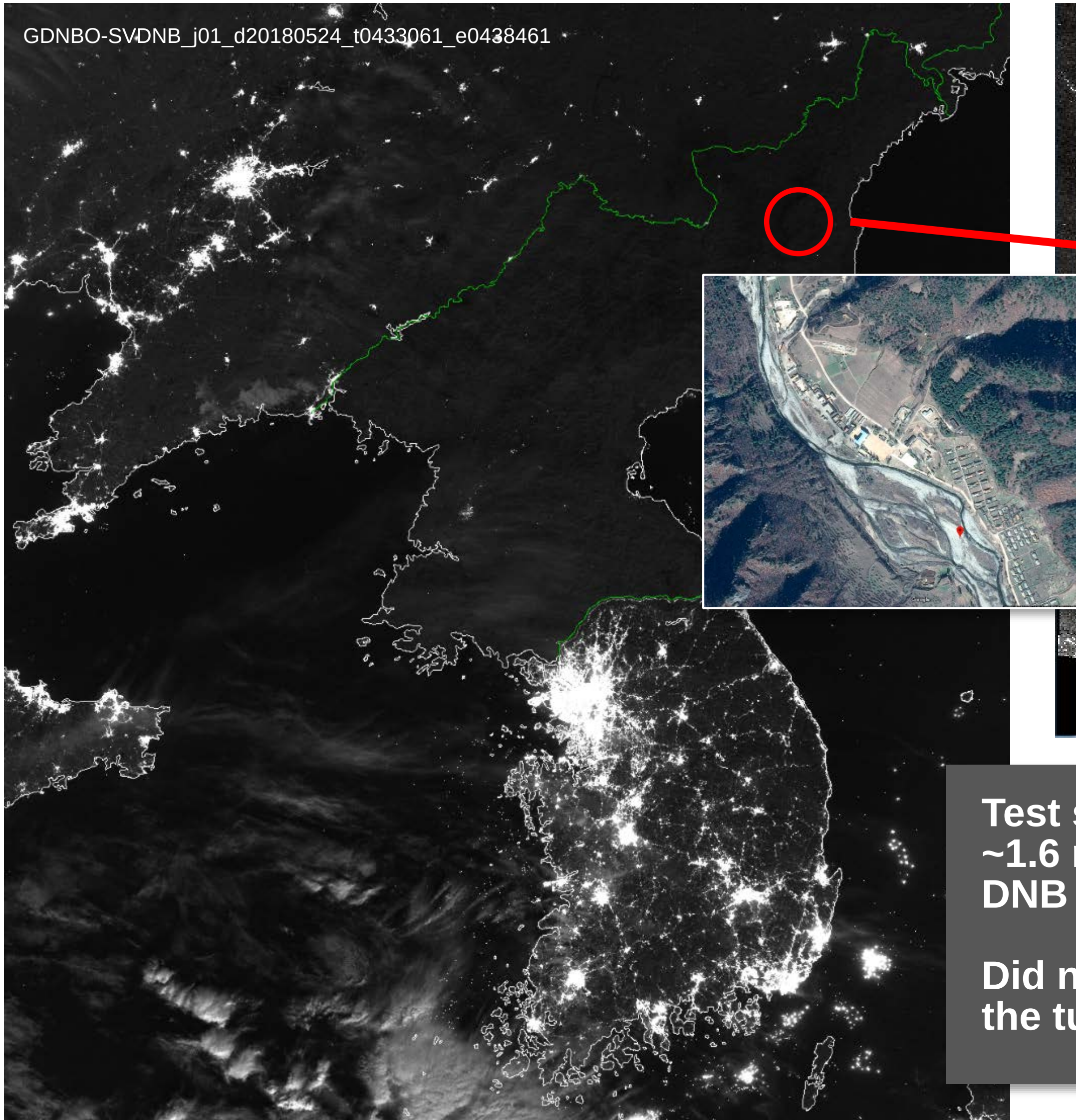
True Color

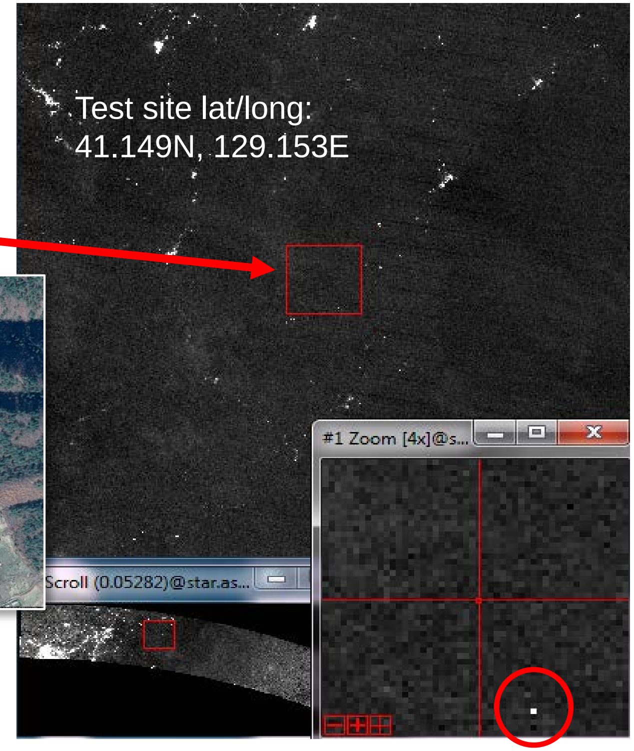
I-4



NOAA-20 VIIRS DNB Sample Imagery

N. Korea Nuclear Punggye-ri Test Site





Test site has night light (radiance ~1.6 nW/cm²-sr) which is below the DNB minimum spec of 3.

Did not change significantly after the tunnel blowup on May 24, 2018.

Error Budget

Compare and analyze validation results against requirements, present as a table. Error budget limitations should be explained. Describe prospects for overcoming error budget limitations with future improvement of the algorithm, test data, and error analysis methodology.

Attribute Analyzed	L1RD Threshold	Pre-Launch Performance	On-orbit Performance	Meet Requirement?	Latest results
RSB Bias	2%	2%	Most bands within 2% compared to SNPP VIIRS	Exceptions: M5, M7 (I2), (M4)	NOAA20 VIIRS M5/M7 calibration are more consistent with other radiometers
TEB Bias	0.1K @ OBCBB	0.1K	<0.1K compared to CrIS during nominal operations	Yes.	Bias during WUCD up to 0.05K. Recommended to reduce WUCD to annual.
DNB Bias	5-10% (LGS) 10-30% (MGS) 30-100% (HGS)	4.4-6.5% (LGS) 7.6-9.0% (MGS) 10.5-54.2%(HGS)	4%±1.4% compared to SNPP DNB (LGS) 3.5%±5% compared to SNPP DNB (HGS)	Yes.	Calibration consistent with Suomi NPP

Note: DNB L1RD threshold and prelaunch performance are for aggregation modes 1-21 and given at 3 gain stages, at 0.5 *Lmax and low radiance for LGS, at high and low radiance levels for MGS and HGS.

User and Downstream Product Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Andy Heidinger	STAR/UW	Cloud Mask	Positive feedback on NOAA20 M5/M7
Menghua Wang	STAR	Ocean Color	Ocean view website: https://www.star.nesdis.noaa.gov/sod/mecb/color/ocview/ocview.html#date=20180607/zoom=2/lat=0/lon=0/tc=true/l2=true/sens=VIIRSJ1/proj=4326/algo=noaa_msl12_nrt/prod=chl/ave=daily/cbar=false/gran=false/coast=true/grid=false
Tom Atkins/Lihang Zhou	STAR	Alaska Watch	Alaska watch website: https://www.star.nesdis.noaa.gov/jpss/alaskawatch/
Alex Ignantov	STAR	SST	SST website: https://www.star.nesdis.noaa.gov/sod/sst/micros/#
Ivan Cisiszar	STAR	Fire	Fire website: http://viirsfire.geog.umd.edu/map/map_v2.php
Don Hillger	STAR/CIRA	Imagery	Presentation later
Eric Steven	Alaska/GINA	Operational user	http://feeder.gina.alaska.edu/
Shobha Kondragunta	STAR	Aerosol	IDEA website: https://www.star.nesdis.noaa.gov/smcd/spb/aq/index.php

Documentation

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes (updated)
System Maintenance Manual (for ESPC products)	OAD available
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes (SNPP) Coming (NOAA-20) NASA tech report vol. 8
Regular Validation Reports (at least. annually) (Demonstrates long-term performance of the algorithm)	At annual meetings and conferences

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Performance has been demonstrated globally since launch with seasons.
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Caveats are provided in the readme file for all major known anomalies and artifacts.
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	A variety of methods have been used to quantify the radiometric biases through quantitative analysis.
Product is ready for operational use based on documented validation findings and user feedback.	Yes. User feedbacks are very positive.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes. The VIIRS SDR team will continue providing stewardship for mission life.

Conclusion

VIIRS SDR performance is comparable to S-NPP VIIRS

- NOAA-20 VIIRS DNB unique **aggregation mode 21** works well as implemented;
- Operational algorithm is performing well with updated LUTs;
- Continued **fast track LUT** update (provided by STAR) is necessary to ensure SDR data quality;

Major issues addressed since provisional review:

- Algorithm/software developed to mitigate saturation in M6 and other bands
- Methodology developed to reduce SDSM uncertainty which affect stability of RSB calibration
- Further characterized radiometric biases in most bands
- LWIR degradation resolved with outgassing

NOAA20 VIIRS SDR performance is stable. Meets requirements and validated criteria. VIIRS SDR validated maturity is achieved.

Path Forward

Planned improvements and future Cal/Val activities / milestones

1. Continued monthly Lunar calibration

   Algorithm correction for TEB during lunar intrusion transition to operations.

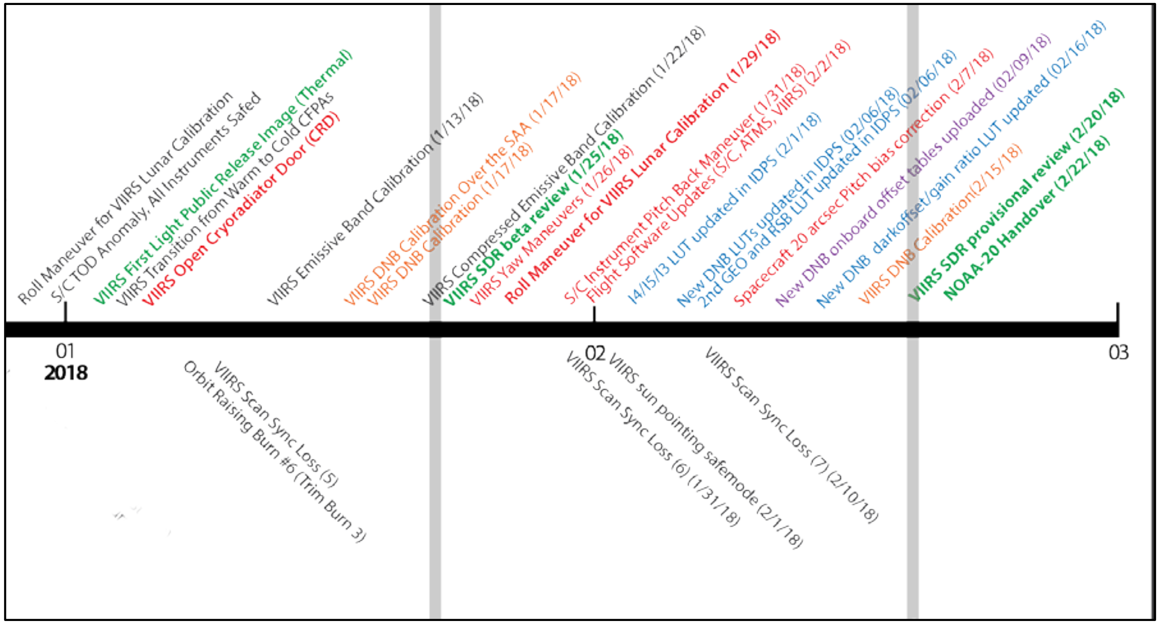
2. Continued DNB straylight LUT development:
   - Require monthly update of DNB straylight correction LUT;
3. Continued vicarious monitoring using DCC, cal/val sites, and geolocation
4. Reprocess three months of missing data on GRAVITE; continue developing the OnDemand reprocessing capabilities; establish interface with NCEI/CLASS.
5. Contribute to the NASA technical book Volume VIII;
6. Possible field campaign: VIIRS DNB SI traceable calibration in collaboration with SDSU and USGS calibration center. Leverage light source developed under NOAA SBIR;
7. J2 prelaunch calibration support;
8. Other issues and path forward (to be studied towards calibrated/validation maturity)
   - Polarization on-orbit characterization and impact studies
   - SWIR band nonlinearity study
   - Uncorrected, residual non-uniformity of the RSB radiometric response, especially between HAM sides (creates low-magnitude striping in imagery): root cause requires further study
   - Differences in RSB radiometric calibration between low-gain and high-gain: to be further investigated (may be causing anomalies in observed gain transitions)
   - Difference in radiometric response of band I5 sub-samples: may add noise and/or striping (needs to be investigated)
   - Continuing F factor changes for some thermal emissive bands; additional changes during WUCD tests

VIIRS Science Team will continue providing operational cal/val support.

- Backup slides

Findings/Issues from Beta Review

- I-3 band has a noisy low response detector which is causing striping. This is somewhat expected prelaunch but it is not as good as predicted. Additional cal/val work may improve the performance but not dramatically. The detector maybe considered in-operable.
- Initial geolocation error can be up to a few kilometers depending on the scan angle. An updated on-orbit mounting matrix was delivered and went in the operations on January 5, 2018 which significantly reduced the geolocation errors down to within one pixel level.
- An unexpected intense straylight is found in the extended view portion of the DNB. Developing straylight correction will be challenging, although this new feature may allow us to better trace the source of straylights.
- Occasional sync loss between the RTA and HAM, which persisted for Suomi NPP VIIRS and was supposed to have been fixed for NOAA-20, still exists
- I4/I5 were not producing images consistently due to lower than expected instrument component temperatures.



Improvements since Beta Review

- Four SDR LUTs updated on February 1, 2018 (starting with the 15:38 UTC granule)
  - Enabled uninterrupted production of VIIRS SDR for **bands I4 and I5**
  - Flagged **I3 detector #29** as inoperable to replace its measurements with fill values
- Eight SDR LUTs updated on February 6, 2018 (starting with the 14:15 UTC granule)
  - Improved **DNB image quality and radiometric calibration** (e.g., reduced striping)
  - Corrected **DNB stray light artifacts** that occur near the terminators
  - Improved radiometric calibration for the **SWIR bands (I3 and M8 to M11)**
  - Further reduced **geolocation uncertainty to below 200 m** and removed scan-angle dependence of geolocation errors
- Four **DNB onboard tables uploaded to the NOAA-20 spacecraft** on February 9, 2018
  - Derived from the VIIRS data collected during the pitch maneuver to avoid contamination from the airglow
  - Two corresponding, updated DNB LUTs submitted for deployment in IDPS February 16, 2018

All "fixable" issues identified during the Beta review are fixed with the 16 LUT updates, although further improvements are needed towards validated maturity

Waivers and Status

J1 Waivers	Description	Status
DNB Non-linearity	High nonlinearity in radiometric response especially at edge of scan	Verified, prelaunch code change works correctly for Op21
DNB Stray Light	When VIIRS itself is sunlit and DNB is viewing night side of the earth	1st DNB stray light correction LUT has been developed and deployed in IDPS. Requires monthly update of LUT for one full year cycle.
Crosstalk	Dominated by static electrical crosstalk	No impact based on study by VCST team
Dynamic Range	M5LG, **M8**, M9, M10, M11, I1, **I3**, and I4 saturation; DNB	M6 is out of spec which requires mitigation; further study on other bands
Polarization Sensitivity	Linear polarization sensitivity (M1-M4)	To be studied after provisional review
SWIR non-linearity and uncertainty	SWIR M-bands at low radiance	To be studied after provisional review
Emissive band radiometric calibration	RRU: M12, M13(HG), & M14 RRCU: M12 & I5	To be studied after provisional review
Spatial Resolution-DFOV	Smaller DFOV due to normal sensor-to sensor build variability	Minimal impact
Spatial Resolution -MTF	M1-M7/M13	Minimal impact
Near Field Response (NFR)	M7, M13, M16A; I3	Minimal impact
Relative Spectral Response (RSR)	Mainly in several SWIR&LWIR bandpass/center wavelength	Minimal impact
Band-to-Band Registration (BBR)	Dominated by in-track registration; I-bands	Minimal impact