Poster 701: CrIS On-Orbit Performance During NOAA-21 Commissioning Phase

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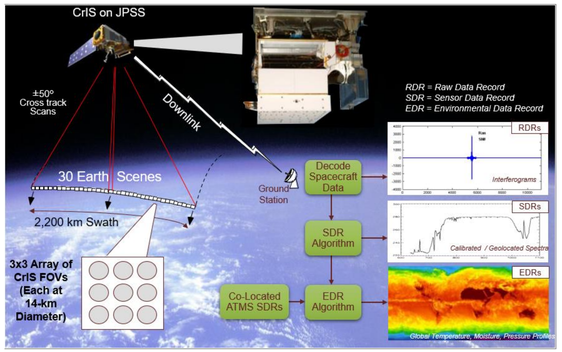
The Cross-Track Infrared Sounder (CrIS) program continues its legacy of operational excellence with the launch of the Joint-Polar Satellite System (JPSS)-2 satellite on November 10, 2022. JPSS-2, re-named National Oceanic and Atmospheric Administration (NOAA)-21 on-orbit, carries the third in the series of CrIS instruments manufactured by L3Harris. The CrIS instrument provides very high spectral resolution interferometric measurements of upwelling infrared radiance, which are then used to produce vertical atmospheric temperature and moisture profiles. These profiles lead to improved (1) global weather forecasts (2) hurricane track and intensity forecasts, and (3) severe weather predictions. The CrIS instruments also provide measurements to support monitoring of trace gases such as Carbon Dioxide (CO2), Ozone (O3), Methane (CH4), and Carbon Monoxide (CO).

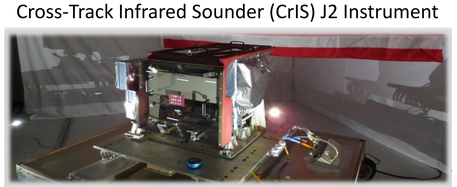
Results from the NOAA-21 on-orbit commissioning phase for calibration/validation of the CrIS instrument are provided herein. These on-orbit activities verify that NOAA-21 CrIS survived launch and include testing that enables refinement of calibration parameters prior to final instrument hand-off to NOAA's Office of Satellite and Product Operations (OSPO). Specifically, first light results are presented along with subsequent parameter optimization for radiometric, spectral, and geolocation verification. This work included significant collaboration between L3Harris, NOAA/STAR, NASA, and the extended science community and has resulted in the final parameter set for verifying validated data maturity. The results from the NOAA-21 commissioning phase demonstrate excellent instrument performance. The hand-off was completed successfully and the CrIS instrument is currently providing operational data.

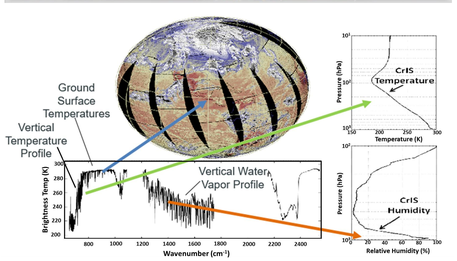
Operational Concept



The CrIS is a Fourier-Transform Spectrometer (FTS) that provides interferometric soundings of measured upwelling infrared radiance at very high spectral resolution. It is a low-earth orbiting instrument with on-board spectral and NIST-traceable radiometric calibration sources. The CrIS has 9 simultaneous ~14 km fields of view (FOV) stepping across a ~2200km cross-track swath ~ +/- 50° symmetric about nadir. Three spectral bands containing 2211 channels are collected at full spectral resolution (1305 channels at truncated resolution).

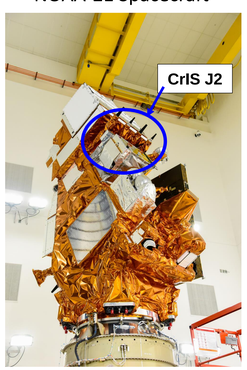
Cross-Track Infrared Sounder (CrIS) J2 Instrument





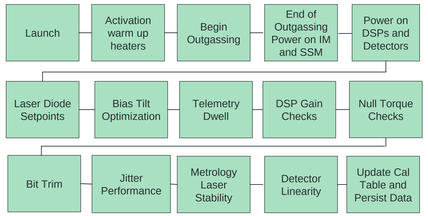
Atmospheric emissions at different wavelengths originate at different altitudes. This information is used to retrieve atmospheric profiles of Temperature from the CO2 band in the long-wave (LW) band and Moisture from the H2O band in the mid-infrared (MW) band.

CrIS J2 integrated onto NOAA-21 Spacecraft



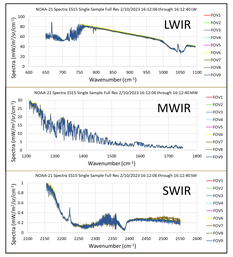
Courtesy: National Aeronautics and Space Administration (NASA)

NOAA-21 Commissioning Cal/Val Results

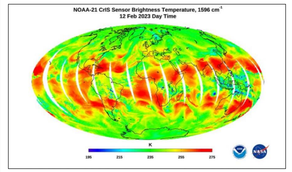


During early-orbit checkout, operational procedures are run to accurately calibrate the CrIS Sensor Data Record (SDR) data. L3Harris participates in orbit adjustments and initial checkout, verifying the safety of temperature transients, power profiles, acceptability of the thermal state, and adequacy of the cooler outgas operation. Interferometer bias tilts and metrology laser setpoints, programmable detector electronic gains, bit trim mask/impulse noise mask levels, and geolocation parameters are adjusted for optimal performance. L3Harris also evaluates NEdN (including sensitivity to jitter), detector nonlinearity, and metrology laser and neon bulb performance. Further optimizations for radiometric, spectral, and geolocation performance are coordinated between L3Harris, NOAA/STAR, NASA, and the extended science cal/val community to yield a final instrument configuration for eventual validation maturity.

NOAA-21 First Light Earth Scene Spectra

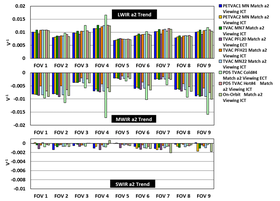


First Light Earth Scene spectra is prior to final thermal stabilization and final calibration parameter verification/ optimization.



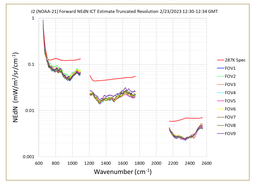
The First Light image in brightness temperature was captured by the NOAA-21 CrIS sensor at the 1596 cm-1 water vapor channel on Feb 12, 2023. Image generated using NOAA-21 Preliminary Non-Operational Data. Courtesy: NOAA/NESDIS/STAR/ CrIS SDR team.

Detector Nonlinearity Correction Term (a2)

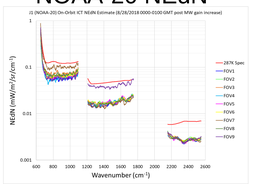


The a2 parameter is the nonlinear correction term applied to the CrIS MWIR and LWIR detectors. SWIR a2 is so small no correction is needed. The a2 values are very stable across a full range of temperatures and test phases, ground to on-orbit, resulting in a highly stable radiometric response.

NOAA-21 NEdN

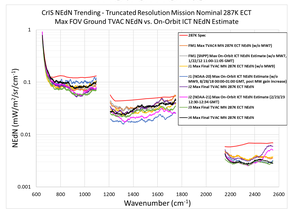


NOAA-20 NEdN



The NOAA-21 CrIS instrument shows excellent radiometric noise performance (NEdN) that is consistent across all 9 FOVs. Improved performance variability from NOAA-20 is also seen (and expected). Truncated resolution (cm^{-1}): 0.625 (LW), 1.25 (MW), 2.5 (SW)

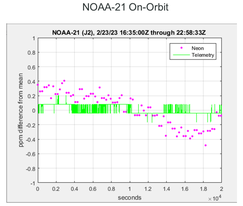
Worst-Case NEdN for 5 CrIS Instruments



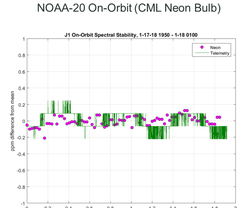
CrIS shows repeatable in-family NEdN performance with margin over 5 sensors for ground and on-orbit conditions. S-NPP MW FOV7 and NOAA-20 MW FOV9 excluded per NEdN requirement allowance. Truncated resolution.

Metrology Laser Stability

NOAA-21 On-Orbit



NOAA-20 On-Orbit (CML Neon Bulb)

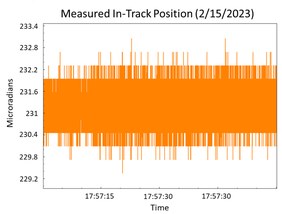


The CrIS instrument is extremely stable spectrally. On-orbit measurements of the metrology laser wavelength show less than +/- 0.4 ppm of variation over 3 orbits. These measurements are made using a Neon lamp and via the laser diode temperature as a proxy. Spectral calibration is performed operationally using spectral lines from the atmosphere (not shown). Differences in the Neon measurements from NOAA-20 to NOAA-21 are due to a successful mitigation of bulb obsolescence, minimizing unit to unit variation.

SSM Null Torque On-Orbit Measurement Updates Geolocation Parameters

Excellent CrIS line-of-sight geolocation begins with an initial geolocation parameter update for the In-Track (IT) angles of the Earth Scene commanded pointing positions for the Scene Selection Module (SSM) once on-orbit in a gravity-free environment. The IT null torque offset is determined by measuring the offset angle when commanding the IT to zero. The extended science cal/val team further updates both the SSM IT and Cross-Track (CT) Earth Scene angles when the CrIS is later geolocated to VIIRS via landmarking.

Measured In-Track Position (2/15/2023)



NOAA-21 Validated Maturity Summary

Presented by Flavio Iturbide-Sanchez and the CrIS SDR Cal/Val Science Team Date: 09/28/2023

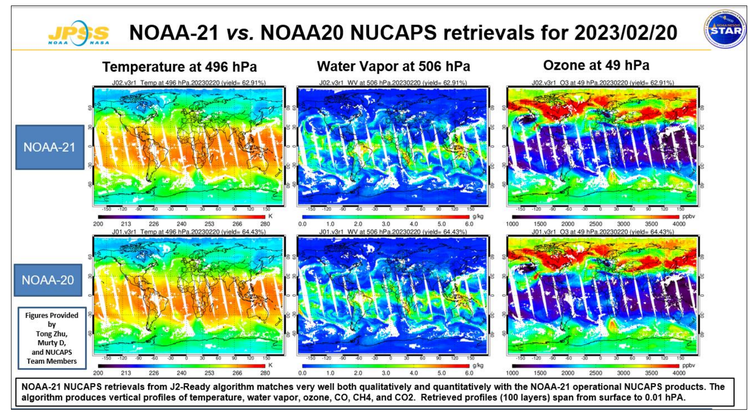
NOAA-21 (J2)

- Validated maturity status declaration for NOAA-21 CrIS SDR Effective Date September 26!
- Satellite declared Secondary in Constellation Effective Date November 3
- Satellite declared Operational Effective Date November 8

NOAA-21 CrIS SDR Performance vs JPSS L1-Requirements

Band	Minimum Wavenumber Range[1] (cm^{-1})	# of Channels [4]	Spectral Resolution (cm^{-1})[1,3]	Maximum NEdN @287K BB[2] ($mW/m^2/sr/cm^{-1}$)	Radiometric Accuracy @287K[1,2] (%)	Maximum Spectral Uncertainty[1] (ppm)	Geolocation Mapping Uncertainty (3σ)[1] (km)
LWIR	650-1095	713	0.625	(0.2084) 0.45 @ 670 cm-1, (0.1195) 0.15 @ 700 cm-1, (0.0746) 0.15 @ 850 cm-1, (0.0682) 0.15 @ 1050 cm-1	(0.15) 0.45	(2) 10	(0.76) 5
MWIR	1210-1750	865	0.625	(0.02485) 0.078 @ 1225 cm-1 (0.02223) 0.064 @ 1250 cm-1 (0.02419) 0.069 @ 1500 cm-1 (0.03082) 0.075 @ 1700 cm-1	(0.18) 0.58	(2) 10	(0.76) 5
SWIR	2155-2550	633	0.625	(0.00568) 0.013 @ 2200 cm-1 (0.00466) 0.014 @ 2350 cm-1 (0.00935) 0.014 @ 2550 cm-1	(0.35) 0.77	(2) 10	(0.76) 5

[1]JPSS Algorithm Specification Volume I: Software Requirement Specification (SRS) for the CrIS RDR/SDR, 474-00448-01-03, Revision I, October 24, 2019.
[2]JPSS Level 1 Requirements Document Supplement (L1RDS) – Final, JPSS-REQ-1002/470-00032, Revision 2.11, Rev. 2.1, 02/07/2019. The NEdN Maximum values for the MWIR and SWIR are the result of scaling the NEDN values, defined in Table 4.3, by a factor of √2 and 2, respectively. Noise Performance values do not account for the self-apodization effect.
[3]JPSS-2 CrIS Performance Requirements Document (PRD), 472-00346, Revision B, 03/10/2016.
[4]JPSS CrIS SDR ATBD) for Full Spectral Resolution, June 14, 2018.



Acknowledgements (Toward NOAA-21 CrIS Validated Maturity)

Acknowledgement and thanks are extended to all individuals and organizations participating in the intensive NOAA-21 CrIS Pre-launch analysis, Early Checkout, and Intensive Cal/val toward Validated Maturity, an example of Team Effort, Hard Work, Dedication and Professionalism: **NOAA/STAR, NASA, University of Wisconsin, University of Maryland Baltimore County, L3Harris, Logistikos, Northrop Grumman, and MIT.**

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