Implications of CrIS Full Spectral Resolution Operations on Suomi NPP High Rate Data (HRD) Direct Broadcast

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Background: Direct Broadcast

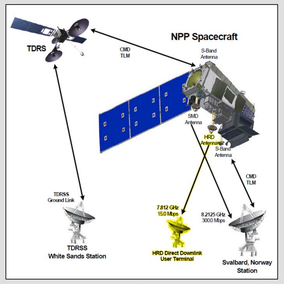


Figure 1.0: Spacecraft Communication Links

- On February 28, 2012, the Suomi National Polar-orbiting Partnership (Suomi NPP) began to broadcast instrument data real-time via the satellite's High Rate Data (HRD) antenna.
- The Direct Broadcast (DB) of HRD provides users around the world with access to free, high quality sensor data that they can use for a wide range of applications from weather forecasting to disaster response.
- Suomi NPP transmits HRD at a fixed rate of 15.0 Megabits per second (Mbps), appending fill data to variable-sized sensor data as necessary to maintain this rate.

Introduction: CrIS Full Spectrum

- In 2012, members of the Suomi NPP science community successfully advocated for a program directive to change the permanent configuration of the CrIS instrument to acquire full-length interferograms in the Short Wave Infrared (SWIR) and Mid Wave Infrared (MWIR) bands.
- When operating in this mode known as "full spectrum", CrIS generates data at a higher rate than the baseline, increasing the peak rate of the total mission data stream by about 0.81 Mbps, oversubscribing the 15.0 Mbps threshold for HRD, and potentially resulting in data loss.
- To address this problem, we developed an optimized approach for composition and configuration of Suomi NPP HRD. Our proposed method permits CrIS to operate in full spectrum mode, allows for HRD broadcast within its rate specification, and attempts to maintain Suomi NPP direct broadcast user requisites.

Methods: Data Rate Analysis

- VIIRS instrument data rates vary depending on the level of compression achieved prior to downlink. To determine the expected peak rate, we processed the 500 largest VIIRS granules seen over a two year period as reported by the NASA Product Evaluation and Analysis Tool Element (PEATE). We found a peak single-scan rate of 11.0 Mbps which exceeded the pre-launch estimate of 10.5 Mbps.
- Next, we tabulated the data rates for each component of HRD by adding the VIIRS peak single-scan rate to the known, fixed data rates of other instruments and the spacecraft.
- Finally, through close coordination with multiple mission elements and direct broadcast users, we then constructed a proposed HRD reconfiguration by removing select content (from HRD only) to support CrIS full spectrum.

Results: *Proposed* HRD Configuration

Data Type in HRD	Suomi NPP Present Configuration		Proposed Suomi NPP CrIS Full Spectrum Configuration	
	Peak Mbps	Total Mbps (Packet Rate)	Peak Mbps	Total Mbps (Packet Rate)
Spacecraft Attitude & Ephemeris	0.0057	0.0639	0.0057	0.0639
Spacecraft Telemetry	0.0582		0.0582	
CERES	0.0100	0.0100	Remove	0.0000
ATMS	0.0320	0.0320	0.0320	0.0320
OMPS Science Limb	0.1250	0.1903	Remove	0.1903
OMPS Science Nadir	0.0400		0.0400	
OMPS Housekeeping/Reserved	0.0253		0.0253	
OMPS Reserved (Diagnostic Data)	N/A		0.1250	
VIIRS Housekeeping	0.0021	11.0064	0.0021	10.5252
VIIRS Engineering	0.0437		0.0437	
VIIRS Calibration	0.5059		0.5059	
VIIRS Day/Night (DNB)	0.3391		0.3391	
VIIRS Imagery (I1-I5)	4.6269		4.6269	
VIIRS Moderate Resolution (M1-6, 8-16)	5.0073		5.0073	
VIIRS M7	0.4812		Remove	
CrIS LWIR (FOVs 1-6,8-9)	1.7042	1.9183	2.4267	2.4277
CrIS MWIR (FOVs 1-6,8-9)				
CrIS SWIR (FOVs 1-6,8-9)				
CrIS LWIR (FOV 7)	0.1129		Remove	
CrIS MWIR (FOV 7)	0.0761		Remove	
CrIS SWIR (FOV 7)	0.0241		Remove	
CrIS Other Telemetry	0.0010		0.0010	
Total Application Packet Rate		13.2209		13.2391
Total Packet Rate with HRD Overhead		15.3147		15.3358
HRD Threshold		15.0000		15.0000
HRD Margin Relative to Threshold		-0.3147		-0.3358
HRD Margin Relative to Present Config		0.0000		-0.0211

Clouds and the Earth's Radiant Energy System (CERES)

- CERES data will be removed from HRD.
- No known DB users of CERES data.

Advanced Technology Microwave Sounder (ATMS)

- No changes to HRD content.

Ozone Mapping Profiler Suite (OMPS)

- OMPS Limb data will be removed from HRD.
- No known DB users of OMPS Limb data.
- HRD bandwidth will be preserved for periodic Nadir diagnostic mode collects to support volcanic ash retrievals.

Cross-track Infrared Sounder (CrIS)

- Full-length interferograms will be included in HRD for all bands.
- CrIS FOV7 will be removed from HRD.
- No known operational DB users that require all 9 FOVs.
- No DB algorithm updates required.

Why FOV7?

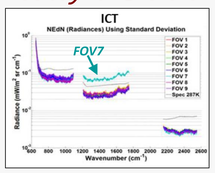


Figure 3.0 (left): The MWIR FOV7 Noise Equivalent change in Radiance (NEdN) is slightly out of spec, possibly due to migrating impurities in the IR detector interface [Vladimir Zavyalov, USU/SDL].

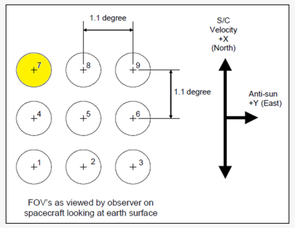


Figure 2.0 (right): Each CrIS Field of Regard (FOR) has nine Fields of View (FOVs). FOV7 is highlighted in yellow.

Visible Infrared Imaging Radiometer Suite (VIIRS)

- VIIRS Moderate Resolution Band M7 (865nm) will be removed from HRD.
- DB algorithms will require an update to reconstruct M7 data from Imagery Band I2 data aggregated to the M7 resolution. This approach is possible because I2 has exactly twice the spatial resolution of M7 and both share a nearly identical bandpass.

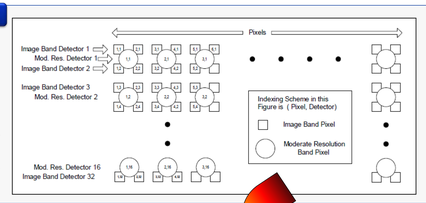


Figure 4.0 (right) : VIIRS M7 pixels can be reconstructed by averaging the corresponding 2x2 pixel aggregation from I2. As M7 is a dual-gain gain, and I2 is single-gain, a study is underway to assess differences between reconstructed and actual M7 data.

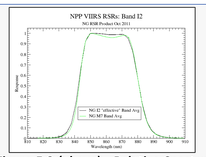


Figure 5.0 (above) : Relative Spectral Response (RSR) for VIIRS M7 and I2 [Chris Moeller, UWISC/SSEC].

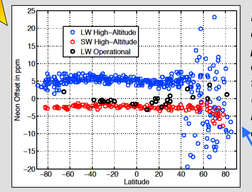


Figure 7.0 (left) : Full spectrum SWIR data provide more calibration points per orbit with lower variability. Each circle represents a 360 second period that allowed an accurate calibration. Unlike the LWIR, the SWIR can be modeled and calibrated more accurately [Larrabee Strow, UMBC].

What is full spectrum and why are we doing this?

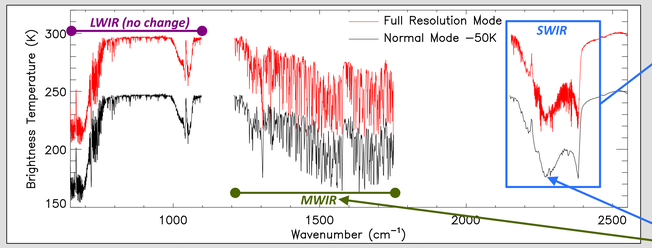


Figure 8.0: Comparison of current "truncated" configuration and full spectrum Sensor Data Records (SDRs) generated offline from full-length inteferogram data collected during an on-orbit engineering test on March 12, 2013 [Yong Chen, NOAA/STAR].

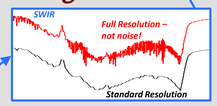
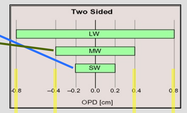


Figure 9.0 (below) : In the current configuration, MWIR interferograms are downlinked at half the length of the LWIR, and SWIR at half the length of the MWIR. In full spectrum mode, full-length interferograms are collected in all bands.



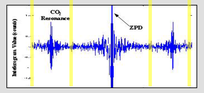


Figure 10.0 (left): Full-length interferograms capture CO_2 resonance.

Full-length interferogram data provide:

- Offline access to improved atmospheric humidity profiles for Numerical Weather Forecast models
- Offline retrieval of atmospheric trace gas products such as carbon monoxide
- On-orbit validation of SWIR and MWIR spectral calibration throughout the mission

	Current Band Resolution (cm^{-1})	Full Spectrum Band Resolution (cm^{-1})
LWIR	0.625	0.625
MWIR	1.25	0.625
SWIR	2.5	0.625

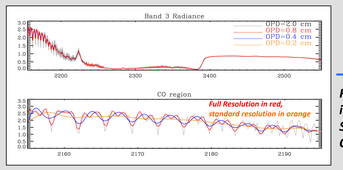


Figure 11.0 (right): Bias map from ECMWF for one CrIS CO channel [Larrabee Strow, UMBC].

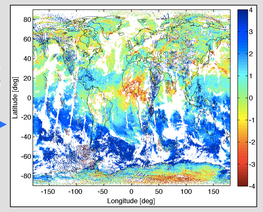


Figure 12.0 (left): Full-length interferograms in the MWIR and SWIR bands support retrieval of CO [Larrabee Strow, UMBC].

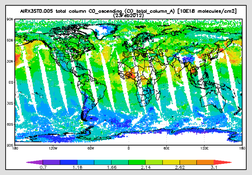
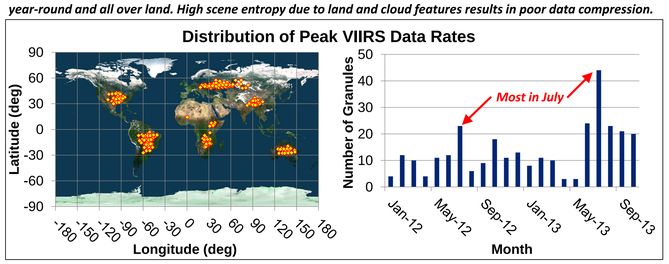


Figure 13.0 (above): CO retrieval from AIRS for the same day as Figure 10 (left) [Larrabee Strow, UMBC].

Sidebar: *What did we learn by analyzing VIIRS data rates?*

Figure 6.0 (below): Geographic and seasonal distribution of VIIRS granules with at least one scan that exceeded the estimated pre-launch rate of 10.5 Mbps. The peak rate was identified as 11.0Mbps, with exceedances occurring year-round and all over land. High scene entropy due to land and cloud features results in poor data compression.



Status to Date

The program has moved forward in several areas in an effort to baseline CrIS full spectrum mode as the permanent operational configuration for Suomi NPP:

- ✓ On-orbit engineering tests to capture CrIS full spectrum data and assess mission segment performance were successfully completed in February 2012, March 2013, and August 2013.
- ✓ The operational CrIS IDPS algorithm was updated in July 2013 to autonomously produce normal resolution SDRs from either truncated or full spectrum RDR data.
- ✓ The direct broadcast Community Satellite Processing Package (CSPP) has been updated with code to produce full spectrum SDRs from full spectrum RDR data, and also with a patch for automatic reconstruction of VIIRS M7 SDRs from aggregated I2 pixels when it detects missing M7 data.

Path Forward

- Continue to collect and assess direct broadcast (DB) user feedback for the proposed HRD configuration. **We need YOUR feedback!**
- Assess whether the proposed HRD margin relative to the present configuration is sufficient. Adjust HRD content accordingly.
- Assess common calibration between VIIRS M7 and I2. Release DB code updates for reconstruction of VIIRS M7 data accordingly.
- Complete Common Ground System (CGS) infrastructure updates so all data are routed correctly following the HRD reconfiguration.

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