**MEMORANDUM FOR:** The Record

**FROM:**  Dr. Yong Han, JPSS CrIS SDR Team Lead

**SUBJECT:** NPP CrIS SDR Validated status and public release

**DATE:**  1/8/2014

1. **Background**

The successful launch of the Suomi National Partnership Program (NPP) spacecraft on October 28th, 2011 with the Crosstrack Infrared Sounder (CrIS) ushers in a new generation of capabilities for operational environmental remote sensing for weather, climate, and other environmental applications. The CrIS SDR team consists of experts from NOAA, NASA, University of Wisconsin, Space Dynamic Laboratory (SDL), MIT/Lincoln lab, University of Maryland Baltimore County (UMBC), and industry partners Northrop Grumman, Exelis (formely ITT), and Raytheon. The team has been working intensively for instrument performance optimization and CrIS SDR calibration and validation.

The CrIS post-launch SDR Calibration and Validation (CalVal) process comprises three phases: Early Orbit Checkout (EOC), Intensive Calibration and Validation (ICV), and Long Term Monitoring (LTM). The EOC phase started on January 18 and ended on February 23, 2012. Following the EOC is the ICV process, which will be ended soon at the time when the product is declared as Validated. Following the ICV process is the LTM, which will last for the life of the NPP mission.

The NPP SDR product is validated in three stages named as Beta, Provisional and Validated. The Beta product is an early release product. It is calibrated, but minimally validated and may still contain significant errors. The Provisional product is an improvement over the Beta product, but it may not be optimal and incremental improvements are still occurring. At the Validated maturity level, the SDR product is well calibrated and validated and uncertainties are characterized over a range of representative conditions. The SDR product achieved Beta status on April 19 2012 and Provisional status on 31 January 2013.

The Suomi-NPP SDR Validated Status Review was held on December 18-20, 2013 at the NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, Maryland, hosted by NOAA/NESDIS/STAR. The purpose of this meeting was to assess the readiness of the CrIS SDR data product maturity level to be declared “Validated” by the Algorithm Executive Review Board (AERB).

CrIS SDR team members presented current Cal/Val progress since provisional maturity. Data assimilation users from different Numerical Weather Prediction (NWP) centers, including the NOAA National Centers for Environmental Prediction (NCEP), UK MetOffice and European Centre for Medium-Range Weather Forecasts (ECMWF), demonstrated impact studies by assimilating CrIS data in their NWP models. A total of 10 presentations related to CrIS SDR were made and are attached with this CCR package.

**1.1 Provisional product**

CrIS SDR product was declared to have reached Provisional maturity level on 31 January 2013, following successful EOC and early ICV CalVal work performed by the team. Important developments include software error fixes, updates of nonlinearity (NL) correction coefficients and Instrument Line Shape (ILS) parameters, on-orbit FIR digital filter update, temperature drift limit updates, geolocation software error correction and imaginary Quality Control (QC) algorithm implementation. A Readme file was provided to the Provisional product users, which summarized the following product caveats:

1. In the SDR product, certain granules contain intentionally 3 scans instead of nominal 4. These are called ‘short’ granules. The spectra of the fourth scan are filled values (-999.0 to -999.9). However, the data quality flags (DQFs) of the spectra in that fourth scan are set to valid. The users shall examine the spectra values for determining the validity of these spectra (DR 5011)
2. In rare case, a granule may contain spectra that are flagged as valid where they should have been flagged as invalid. These bad spectra have floating point values (not filled values) and they have distorted spectral features when compared to valid spectra.
3. In the case of missing Earth scene packet, the CrIS SDR produces ‘fake’ spectra with filled values (-999.0 to -999.9). The CrIS Overall data quality flag is correctly set to invalid. However, the “RDR Invalid” DQF is set to valid instead of invalid (DR 4963). The fix is planned for MX 7.1 (June 2013).

**1.2 Major Cal/Val activities after the Provisional version**

Since the Provisional Review Meeting in October 23, 2012, the CrIS SDR team has focused on the following activities:

1. CrIS performance characterization
	1. NEdN and responsivity evaluation and trending
	2. RDR data quality assessment and trending
	3. Instrument event investigation (e.g. CREEBIT error impact on SDR)
2. Radiometric CalVal
	1. Radiometric Uncertainty (RU) estimates and evaluations
	2. CrIS vs. AIRS/IASI/VIIRS comparisons
	3. CrIS vs. RT model comparisons
	4. FOV-to-FOV and Forward-to-Reverse comparisons
	5. Nonlinearity correction algorithm improvement and coefficient adjustment
	6. Scene scan mirror polarization investigation
3. Spectral CalVal
	1. Spectral uncertainty estimates and evaluations with radiative transfer (RT) model, cross-sensor comparisons and FOV to FOV-5 comparisons
	2. ILS correction algorithm improvement and calibration parameter adjustments
	3. Neon calibration monitoring/trending
	4. Spectral Correction Matrix Operator (CMO) monitoring
	5. Spectral ringing investigation and characterization
4. Geolocation CalVal
	1. Off-nadir geolocation assessment
	2. Band-to-band co-registration evaluation
	3. Assessment of ILS update (v35 to v36) on geolocation accuracy
5. SDR software improvement
	1. Implementation of algorithm updates
	2. SDR quality monitoring and evaluation on a daily basis
	3. IDPS and ADL/G-ADA SDR comparisons
	4. Software DR investigations and code fixes
	5. SDR anomaly event investigations
6. Enhancement of CrIS instrument and SDR trending and monitoring
	1. 29 new items added to the web-based STAR CrIS Integrated Calibration and Monitoring System (ICVS), including the global images and time series of CrIS radiance bias against CRTM/NWP simulations.
7. Development of full spectral resolution data processing capability
	1. IDPS RDR truncation module development
	2. IDPS SDR evaluation/validation for 2 on-orbit full resolution tests
	3. Bit trim mask evaluation/adjustment to meet data rate
	4. Full resolution SDR processing experiments
8. Documentation
	1. The first version of the CrIS SDR User’s Guide (55 pages)
	2. Revised CrIS SDR ATBD
	3. Six published peer-review Journal papers that summarize Cal/Val results
	4. Error budget report
9. **Justifications for Promoting CrIS SDR Product from Provisional to Validated Level**

**2.1 Review panel’s assessment**

The CrIS SDR Validated Product Review Meeting was very successful. After presenting progress results by all PIs on remaining tasks after provisional, the review panel provided the following assessment to the CrIS SDR product:

1. CrIS SDR product has reached a validated maturity level
2. On-orbit instrument performance is stable and well within specification
3. SDR uncertainties meet requirements, with NEdN and uncertainties of radiometric and spectral calibration well below specifications
4. ILS and NL correction algorithms/code and coefficients are improved and adjusted
5. All the important SDR quality flags are functioning as expected
6. All DRs with impacts on data quality have been addressed
7. 99.98% of the SDR data are in good quality
8. IDPS capability to process full resolution RDRs is implemented and tested
9. Over 100 parameters are continuously monitored by the STAR ICVS CrIS monitoring system
10. Instrument performance and SDR uncertainties are well characterized and documented (e.g. ATBD, peer-reviewed publications, user’s guide, error budget analysis)
11. The remaining issues at the Provisional review meeting (e.g. spectral ringing and cold bias) have been investigated and addressed

 The detailed justifications for promoting the CrIS SDR from Provisional to Validated maturity level are summarized in the followings and the supporting materials [1] – [20], presented in the SDR validated product review meeting by the CrIS SDR team and data product users.

**2.2 The SDR product has met the specifications**

CrIS SDR product has met the specification since it reached the Provisional maturity level on 31 January 2013 (see CCR Memo for the Provisional product release). Since the Provisional review meeting, further Cal/Val work has been performed (see section 1.2). Below is a simplified table that compares the achieved on-orbit values with the specifications (see the Error Budget report [19] for details).

**Table 1. CrIS SDR specifications (Black) and corresponding CalVal values (Red)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Band** | **LW**  | **MW**  | **SW**  |
| **Spectral Range (cm-1)** | 650-1095 | 1210-1750 | 2155-2550 |
| **Number of Channels** | 713 | 433 | 159 |
| **Resolution (cm-1)** | 0.625 | 1.25 | 2.5 |
| **FORs Per Scan** | 30 | 30 | 30 |
| **FOVs Per FOR** | 9 | 9 | 9 |
| **NEdN @ 287K BB mw/m2/sr/cm-1** | 0.14(**0.098**) | 0.06(**0.036**) | 0.007(**0.003**) |
| **Radiometric Uncertainty @ 287K BB (%)** | 0.45 (**0.12**) | 0.58 (**0.15**) | 0.77 (**0.2**) |
| **Spectral (Channel Center) Uncertainty ppm** | 10 (**3**) | 10(**3**) | 10 (**3**) |
| **Geolocation Uncertainty (km)** | 1.5(**1.2 \***) | 1.5(**1.2 \***) | 1.5(**1.2 \***) |

**\*Within 30o zenith angles**

**2.3 IDPS CrIS SDR processing is stable since November 2013**

 Except the timestamp overflow bug, the CrIS SDR software has been running since the release of Mx7.1 (10 July 2013) without significant processing errors. The timestamp overflow bug was introduced in Mx7.1, when another timestamp bug was fixed. It caused SDR anomaly event occurred once every 49.7 days, with each lasting about two orbits. This bug was fixed in Mx8.0 on 14 November 2013. On average, 99.98% of the SDR data are in good quality status.

**2.4 The Discrepancy Reports (DRs) in Open status are not critical to the Validated product**

 There are a total of 34 DRs processed after the Provisional product review meeting (23 October 2013). Twenty-three of them have been closed or to be closed soon. The status of the remaining DRs and their impact to the data quality is described below

 DRs 7201, 7204, 7239, 7273 and 7365 deal with the ILS and NL correction improvements (which have been implemented and will become operational on 20 February 2014). These DRs improve SDR radiance accuracy up to 0.1K, but are not critical to the Validated product because the spectral and radiometric calibration uncertainties are still well below specifications even if they are not implemented.

 DRs 7363, 7383 and 7445 deal with a lunar intrusion flag error and two minor code errors (the fixes have already been implemented and will become operational on 21 April 2014). The Lunar Intrusion flag is an event indicator and therefore it has no impact on the data quality (The spectra measured during a lunar intrusion event are valid spectra.) The lunar intrusion flag error is due to a software bug, causing that the software does not set the flag back to the normal status at the end of a lunar intrusion event and results in the flag remaining at the ON status for about two orbits. The two minor code fixes do not have impact on data quality and the SDR quality flag.

 The processing of DRs 7230, 7279 and 7361 are ongoing. The DRs have no impact to the data quality and quality flags.

**2.5 The remaining issues are not critical to the validated product**

The CrIS SDR geolocation accuracy within the 30 degree zenith angle has been rigorously validated using the VIIRS IR channels (see [5] and [15]), taking advantages of their high spatial resolution and geolocation accuracy. However, due to the bowtie deletion of VIIRS pixels, the method is difficult to apply for CrIS scan positions with large zenith angles. Consequently, the accuracy of geolocation calculations for pixels beyond 30 degree zenith angle has not been validated. The team is developing a new method to validate the geolocation accuracy for pixels with zenith angles larger than 30 degree.

1. **CrIS Validated SDR Product Caveat**

The following caveat is presented in the product produced with Mx versions 7.1 to 8.2:

The Lunar Intrusion flag associated with a spectrum may be incorrectly set to the ON status for a period of about two orbits following a lunar intrusion event. The lunar intrusion flag error is due to a software bug, causing that the software does not set the flag back to the normal status at the end of a lunar intrusion event and results in the flag remaining at the ON status for about two orbits. The lunar intrusion flag error has no impact to the data quality. This lunar intrusion flag error was introduced in Mx7.1 (released on 10 July 2013) and will be fixed in Mx8.3, scheduled to be in operation on 10 March 2014.

1. **Path forward after Validated maturity level**

The team will move forward to perform the following work:

Suomi NPP

1. Continuation of RDR and SDR monitoring
2. Fine adjustment of geolocation mapping parameters
3. Fine adjustment of spectral and radiometric calibration parameters, if needed
4. Continuation of Full Spectral Resolution work
5. Continue uncertainty and accuracy analysis - get down to 0.1 C if possible

JPSS J1/J2

1. Support of and participation in pre-launch testing and instrument characterization
2. Calibration data (LUTs and coefficients) development/validation
3. Algorithm/software development and improvements, including full resolution SDR capability and calibration algorithm updates, delivering the SDR code in January 2015
4. Development of a comprehensive test data set using NPP and J1 TVAC data, and simulated data for J1/J2 algorithm and software development
5. Remove spectral gaps and extend the coverage in SWIR band for J2
6. Revisit level 1 spec in light of actual on orbit performance
7. **Reference**

[1] Y. Han, “Suomi NPP CrIS CalVal Overview”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[2] D. Tobin et al., “CrIS Radiometric Uncertainty Estimates and Evaluations”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[3] V. Zavyalov et al., “On-orbit Noise Performance of the CrIS Instrument”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[4] L. Strow et al., “CrIS Spectral Calibration and Trending”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[5] L. Wang et al., “Suomi NPP CrIS On-orbit Geometric Calibration Performance”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[6] D. Mooney, “Sources and Effects of Ripple in CrIS Measurements”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[7] X. Jin et al., “SNPP CrIS SDR processing Quality Improvements Since Provisional Review”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[8] A. Smith et al. (UK MetOffice), “Assimilation of CrIS data at the Met Office”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[9] A. Collard et al. (NOAA/NCEP), “Assimilation of CrIS in the NCEP Global Model”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[10] R. Eresmaa (ECMWF), “CrIS data in ECMWF”, Suomi NPP SDR Science and Product Review Meeting, December 18-20, 2013.

[11] Han, Y*.*, et al. (2013), Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality, J. Geophys. Res. Atmos., 118, doi:[10.1002/2013JD020344](http://dx.doi.org/10.1002/2013JD020344%22%20%5Co%20%22Link%20to%20external%20resource%3A%2010.1002/2013JD020344).

[12] Tobin, D., et al. (2013), Suomi-NPP CrIS radiometric calibration uncertainty, J. Geophys. Res. Atmos., 118, 10,589–10,600, doi:[10.1002/jgrd.50809](http://dx.doi.org/10.1002/jgrd.50809%22%20%5Co%20%22Link%20to%20external%20resource%3A%2010.1002/jgrd.50809).

[13] Zavyalov, V., M. Esplin, D. Scott, B. Esplin, G. Bingham, E. Hoffman, C. Lietzke, J. Predina, R. Frain, L. Suwinski, Y. Han, C. Major, B. Graham, L. Phillips (2013), Noise performance of the CrIS instrument, J. Geophys. Res., doi: 10.1002/2013JD020457.

[14] Strow, L. L., H. Motteler, D. Tobin, H. Revercomb, S. Hannon, H. Buijs, J. Predina, L. Suwinski, and R. Glumb (2013), Spectral calibration and validation of the Cross‒track Infrared Sounder (CrIS) on the Suomi NPP satellite, J. Geophys. Res. Atmos., 118, doi:[10.1002/2013JD020480](http://dx.doi.org/10.1002/2013JD020480%22%20%5Co%20%22Link%20to%20external%20resource%3A%2010.1002/2013JD020480).

[15] Wang, L., D. A. Tremblay, Y. Han, M. Esplin, D. E. Hagan, J. Predina, L. Suwinski, X. Jin, and Y. Chen (2013), Geolocation assessment for CrIS sensor data records, J. Geophys. Res. Atmos., 118, doi:[10.1002/2013JD020376](http://dx.doi.org/10.1002/2013JD020376).

[16] Chen, Y., Y. Han and F. Weng (2013)**,** Detection of Earth-rotation Doppler Shift from Suomi National Polar-Orbiting Partnership Cross-track Infrared Sounder. Appl. Opt., 52, 6250–6257.

[17] Y. Han, Y. Chen, X. Jin, D. Tremblay, L. Wang (2013), Cross Track Infrared Sounder (CrIS) Sensor Data Record (SDR) User’s Guide, NOAA Technical Report NESDIS 143.

[18] Revised CrIS Sensor Data Record (SDR) Algorithm Theoretical Basis Document (ATBD)

[19] Error Budget report

[20] CrIS NPP SDR Validated Maturity Requirement Checklist