3.5 THE NPOESS CROSS-TRACK INFRARED SOUNDER (CrIS) AND ADVANCED TECHNOLOGY MICROWAVE SOUNDER (ATMS) AS A COMPANION TO THE NEW GENERATION AIRS/AMSU AND IASI/AMSU SOUNDER SUITES

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INTRODUCTION

This paper reviews the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) that together make up the Crosstrack Infrared and Microwave Sounding Suit (CrIMSS). CrIMSS will fly on the NPOESS Preparatory Project (NPP) spacecraft. The many hours provided by industrial and government team members have made CrIS and ATMS world class sensors. The CrIMSS sounding suit builds upon the rich heritage of currently flying sensor including: Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI) and Advanced Microwave Sounding Unit (AMSU).

SYSTEM OVERVIEW

The measurement concept of the CrIS and ATMS sensors is shown in Fig. 1. These two sensors are used in tandem to produce atmospheric temperature, water vapor, and pressure profiles from the NPP satellite. CrIS, a Michelson interferometer, collects data in the form of interferograms that are converted to calibrated atmospheric spectra on the ground. ATMS is a microwave radiometer. CrIS has higher spectral and spatial resolution, but ATMS has the advantage of being able to produce profiles through clouds. The CrIS and ATMS instrument footprints are co-aligned and scanned in the cross track direction so as to map a swath approximately 2500 km wide on the ground. The ATMS scan extends slightly wider than that of CrIS to ensure that there are no measurement gaps between successive satellite passes at the equator.

The raw CrIS and ATMS instrument data from the spacecraft are packaged into raw data record (RDR). These RDRs are transmitted to the ground and subsequently processed into calibrated radiance spectra by ground software. These sensor data records (SDR) from CrIS and ATMS are combined and further processed into environmental data records (EDR), which include atmospheric temperature, pressure, and water vapor profiles.

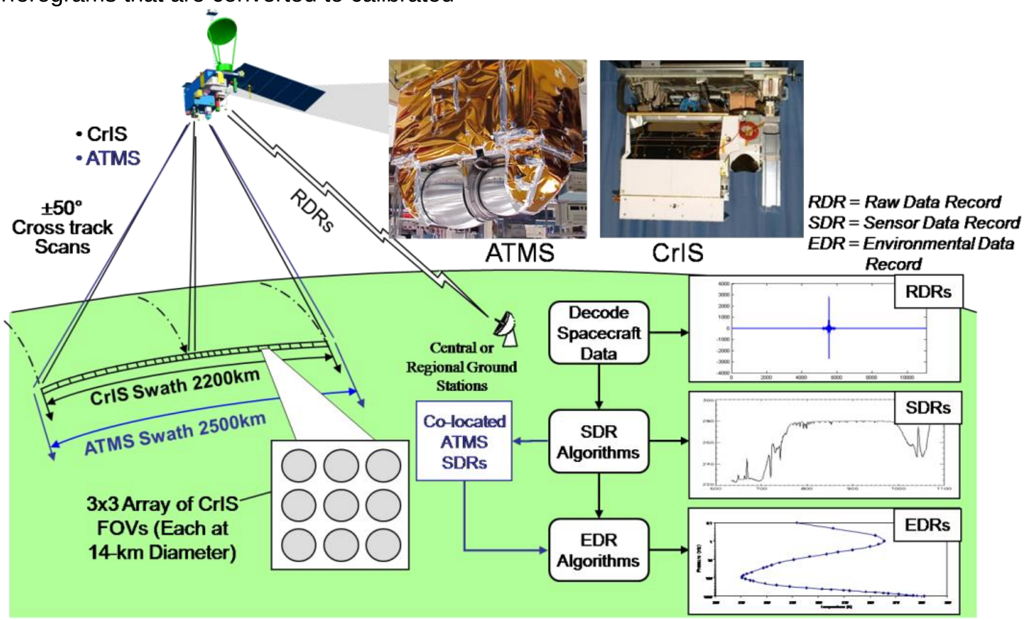

Figure 1. CrIS and ATMS system overview

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SOUNDING OVERVIEW

The spectral locations of the ATMS channels are indicated in Fig. 2. It can be seen that these channels are positioned so as to be sensitive to atmospheric H_2O and O_2. The corresponding temperature weighting functions are shown in Fig. 3.

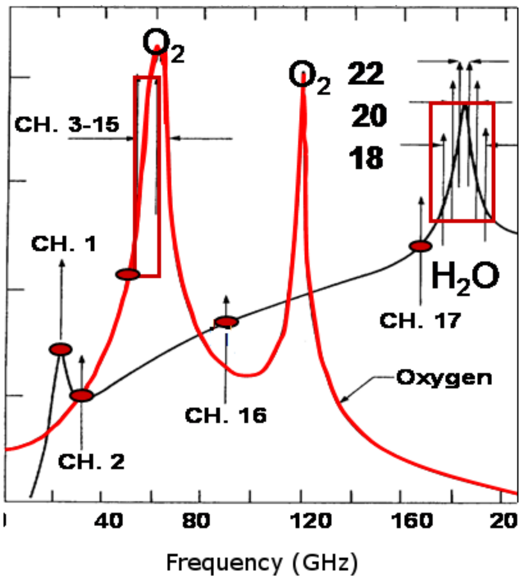

Figure 2. Spectral location of ATMS channels

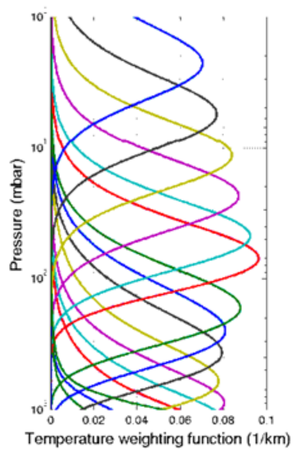

Figure 3. ATMS temperature weighting functions

The CrIS spectral coverage is composed of three bands; the LWIR band from 650 to 1095 cm^{-1} with a resolution of 0.625 cm^{-1}, the MWIR from 1210 to 1750 cm^{-1} with a resolution of 1.25 cm^{-1}, and the SWIR band from 2155 to 2550 cm^{-1} with a resolution of 2.5 cm^{-1}. The position of these bands is indicated in Fig. 4 along with the spectral bands of several other operating or proposed infrared sensors. In this figure, the spectral positions of several atmospheric absorbing molecules are also shown. The CrIS temperature weighting functions are shown in Fig. 5. In operation, the microwave ATMS data will be used to provide the first-guess atmospheric profiles. Then, for non-cloudy scenes, the profiles will be refined using CrIS data.

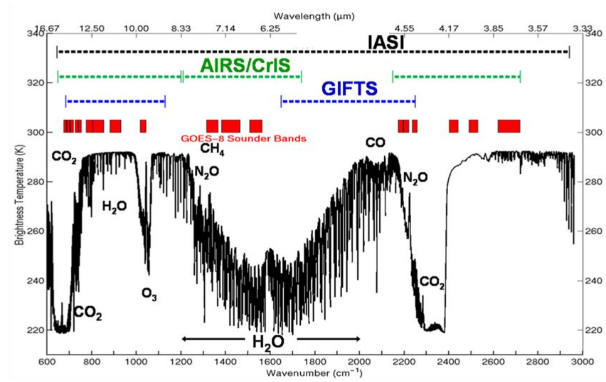

Figure 4. Spectral coverage for CrIS and several other infrared sensors

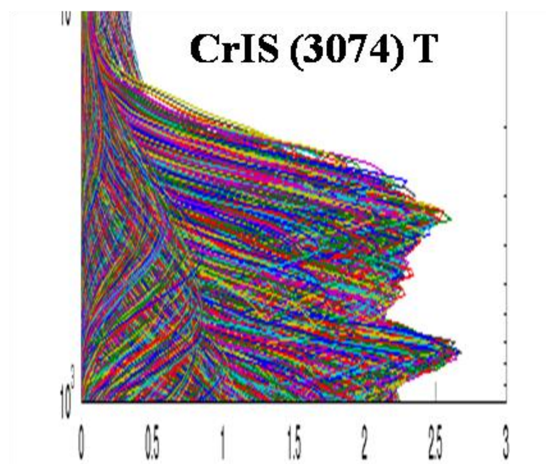

Figure 5. CrIS temperature weighting functions

The vertical resolution of the retrieved temperature profiles is dependent on the number, peak distribution, and sharpness of the weighting functions. In clear or partly clouding conditions, CrIS provides far more information about the profile since it has so many more spectral channels and higher spatial resolution. However, as previously mentioned, ATMS can "see through" cloudy conditions to provide full global atmospheric coverage.

SENSOR STATUS

The ATMS for NPP has already been delivered and is presently being integrated onto the NPP spacecraft. Prior to being delivered, an extensive ground calibration and validation campaign for the sensor was performed. Environmental tests included: thermal vacuum (TVAC), electromagnetic interference (EMI) and launch vibration loading. Radiometric tests included: noise equivalent delta temperature (NEdT), repeatability, antenna pattern, beamwidth and efficiency, radiometric uncertainty, and linearity testing. A small issue was discovered in the calibration of the scan-angle radiometry. A plan to address this issue with on-orbit maneuvers has been proposed.

The functionality and calibration of the CrIS Flight Model One (FM1) instrument is also being verified by an extensive ground testing and validation campaign. FM1 has undergone a full range of environmental and radiometric tests. Radiometric tests include: field of view (FOV) and co-registration between bands, short and long term repeatability, NEdT and instrument line shape (ILS), and spectral accuracy. A considerable amount of effort was put into the radiometric accuracy calibration of CrIS as this is needed for accurate retrievals of atmospheric profiles. An important part of the radiometric accuracy is detector nonlinearity. The LWIR and MWIR detectors are not sufficiently linear to meet requirements without a nonlinearity correction. This nonlinearity correction has been built into the ground-based SDR processing software and has been validated using TVAC test data. TVAC testing also uncovered an electronic design flaw that resulted in an error of approximate ±20 mK in the measured temperature of the internal calibration target and the metrology laser diode. This problem has been corrected and the proper functionality of the sensor will be validated in an upcoming TVAC test. The delivery of CrIS FM1 to the spacecraft is currently planned for the summer of 2010. A second flight model is currently under development using the lessons learned from FM1.

CrIS VALIDATION RESULTS

The absolute spectral calibration of CrIS is tied to the emission of an on-board neon lamp. This spectral calibration is then transferred to the on-board diode laser metrology system. The spectral performance was validated during TVAC testing by using gas absorption cells so that CrIS could observe the spectra of three gases for which the spectral line positions are well known: CO_2 for the LWIR band, CH_4 for the MWIR band, and HBr for the SWIR band. A model was then used to calculate spectra for these well know gases and the results compared to the spectra measured by CrIS. The results show excellent agreement with residual differences in spectral line position of less than one part per million. The ILS widths are also well within specifications.

The noise performance of the CrIS instrument is outstanding, as shown in Fig. 6. It is interesting to note that the as-built CrIS has lower noise than the noise predicted during the Critical Design Review. It can also be seen that the noise for CrIS is lower than that of either AIRS or IASI for the LWIR and MWIR bands. For the SWIR band the noise is lower than IASI and nearly as low as AIRS. Thus, CrIS will provide equal to or better measurement performance as AIRS and IASI, and will continue the excellent data trend that they have begun. The bottom panel of Fig. 6 is provided as a reference to show the effective temperature of the atmosphere for the different CrIS bands.

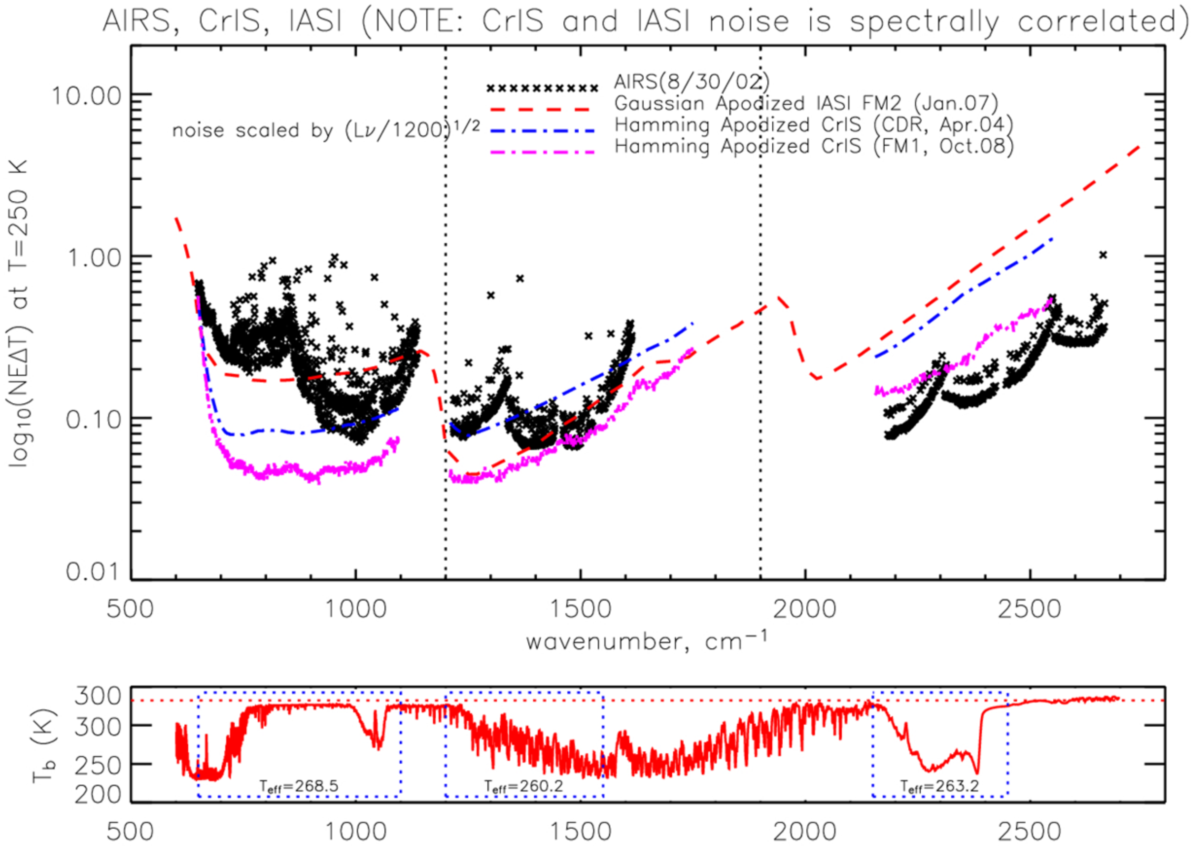

Figure 6. Noise performance of CrIS as compared to other sensors

CrIS SDR PROCESS

A schematic of the CrIS SDR ground processing software, which converts raw RDRs into geolocated calibrated radiance spectra, SDRs, is shown in Fig. 7. Every 8 seconds CrIS collects a crosstrack earth scan, which includes a deep space (DS) interferogram and a warm internal calibration target (ICT) interferogram in each interferometer scan direction to be used for calibration. A running average of 30 of these calibration spectra (covering 4 minutes) is used to calibrate the individual earth scene (ES) interferograms. All interferograms are sampled based on the fringes of the diode metrology laser. Since it is possible to lose track of the fringe count, fringe count error (FCE) processing is part of the SDR algorithm. Before the radiometric calibration, a nonlinearity correction is applied to all spectra. After the radiometric calibration, the off axis ILS effects are corrected so that each spectra appears to have been collected by the center detector. Along with calibrated spectra, an estimate of the NEdN is also produced. The SDR algorithm was developed in parallel with the sensor testing. SDR processing software performance is still being validated by processing TVAC test and simulated data. The SDR software will be extensively tested and validated before it is used to process on-orbit data.

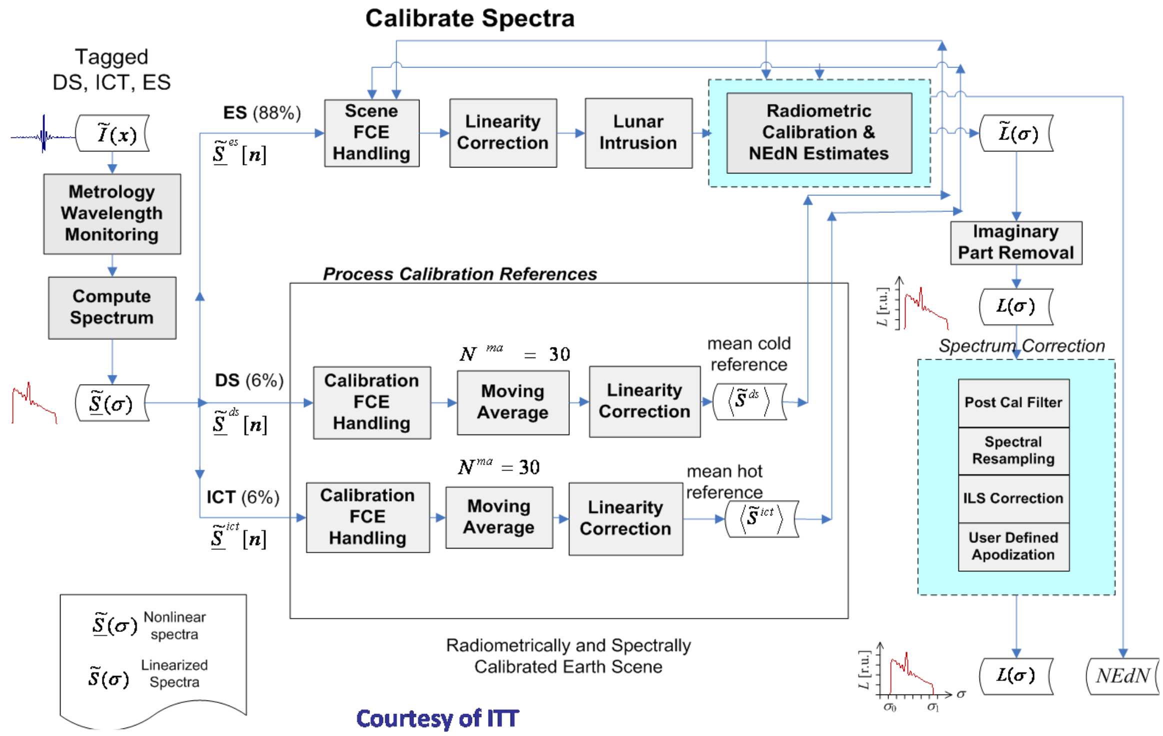

Figure 7. Block diagram of RDR to SDR ground processing software

CALIBRATION AND VALIDATION (CAL/VAL)

The planned CrIS and ATMS on-orbit Cal/Val plan follows a well developed path, based in a large part on the heritage of the AIRS/IASI/AMSU sensors. It is expected that CrIS and ATMS in orbit measurements will overlap with these previous sensors, offering an opportunity for cross calibration. Plans include significant use of the World Meteorological Organization (WMO) Global Space-based Inter-Calibration System (GSICS) and Committee on Earth Observation Satellites (CEOS) calibration procedures. Industry and government Cal/Val team members have developed over the years a number of approaches for inter-satellite comparisons and transfer standard establishment that will be applied. These on-orbit calibration tools developed to support the AIRS/IASI calibration and comparison will also work well with CrIS. Such methods include the double difference method used by the University of Wisconsin and the University of Maryland - Baltimore County, and the Sea Surface Temperature method of JPL. Aircraft underflights with NIST traceability sensors are also part of the Cal/Val plan.

Continuous communication between team members during ground testing and early in the on-orbit checkout and calibration phase is being emphasized in the CrIS and ATMS Cal/Val plan. This includes direct access to SDR and EDR code sets that are identical to those used in the operational code, quick access to ground testing and on-orbit instrument data, easy open paths for feedback and review, and frequent conversation between team members via teleconferencing and web-meetings. Formal procedures are being established so that issues that arise and enhancements to the SDR algorithm can be reviewed and incorporated in the operational software in an efficient and controlled manner. For example, a block diagram of the Product Issues Tracker and Discrepancy Report (DR) tracker is shown in Fig. 8. Processes are already being implemented and reviewed and will be thoroughly exercised before NPP launch.

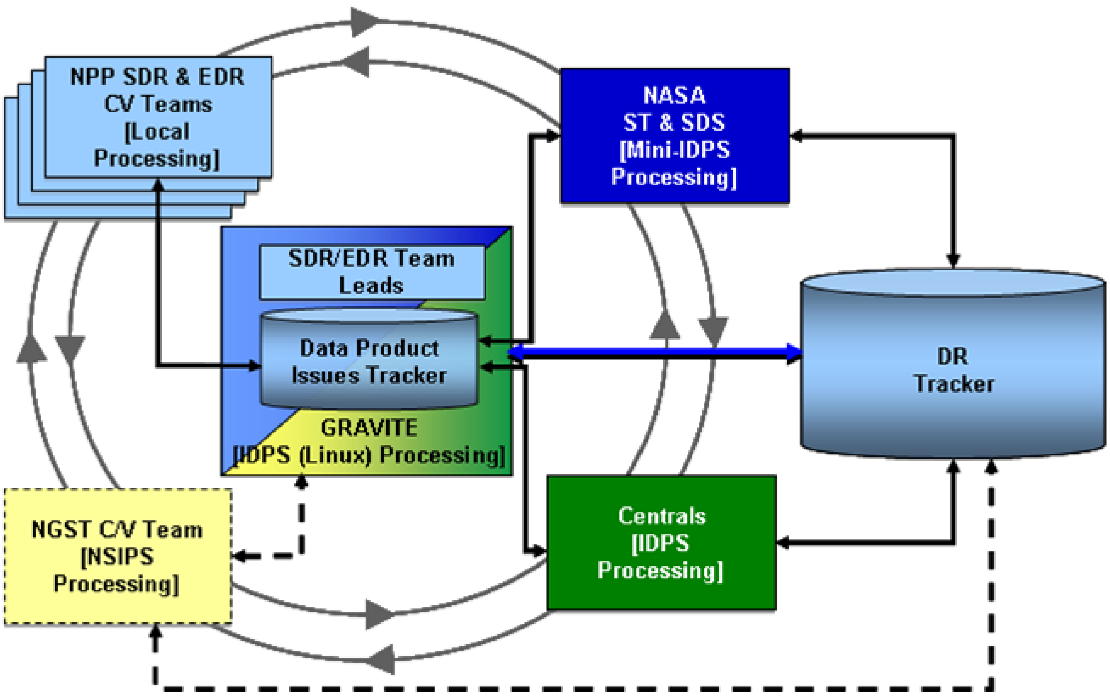

Figure 8. Software tracking system used in the CrIS and ATMS Cal/Val plan

Finally, to make sure that all components of the Cal/Val effort are covered, the plan task items have been assigned ownership to varying industry and government leads. Functional Cal/Val task areas have been identified, phases for task completion have been determined, and possible on-orbit inter-satellite and target standard operations have been assigned.

SUMMARY

The CrIS and ATMS sensors are meeting and in some cases exceeding their performance specifications. CrIMSS SDR and EDR codes are being developed and verified using TVAC test data and proxy data derived from AIRS/AMSU and IASI/AMSU sensors. A Cal/Val plan is being developed to enhance communication between teams and to ensure that software tools and procedures are in place before CrIS and ATMS are launched. While CrIS and ATMS are new instruments, this is the second and third time around for most of the team members.