On-Board Calibration Techniques and Test Results for the Atmospheric Infrared Sounder (AIRS)

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ABSTRACT

The Atmospheric Infrared Sounder (AIRS) is a space based instrument developed for measurement of global atmospheric properties; primarily water vapor and temperature. AIRS is one of several instruments on board NASA's Earth Observing System Aqua spacecraft. AIRS operates in the 3.7 - 15.4 micron region and has 2378 infrared channels and 4 Vis/NIR channels. AIRS spatial resolution is 13.5 km from the orbit of 705 km and it scans +-49.5 degrees. AIRS has a set of on-board calibrators including a single infrared blackbody source, a parylene spectral calibration source, a space view and a Vis/NIR photometric calibrator. The on-board calibration subsystems are described along with a description of special test procedures for using them and results from several tests performed to date. Results are exceptional indicating that the instrument is performing better than expected.

Keywords: Earth Science, EOS, Aqua, AIRS, Sounder, Calibration, Operations

1. INTRODUCTION

The Atmospheric Infrared Sounder (AIRS) was launched on May 4, 2002, 2:55 am PST on a Delta II ELV from Vandenburg Air Force Base in California. The launch and activation of the instrument went according to plan and the AIRS instrument is currently in the checkout and calibration phase. AIRS will be placed in the normal operational mode approximately 80 days after launch. The bulk of the calibration activities discussed in this paper occur after the outgassing phase and after the instrument has achieved the operational temperature of approximately 155K. Figure 1 shows the nominal temperature of the spectrometer, and the activities performed after launch during the Activation and Evaluation (A&E) phase. All activities indicate the nominal plan at the time of launch and may change during the course of the mission.

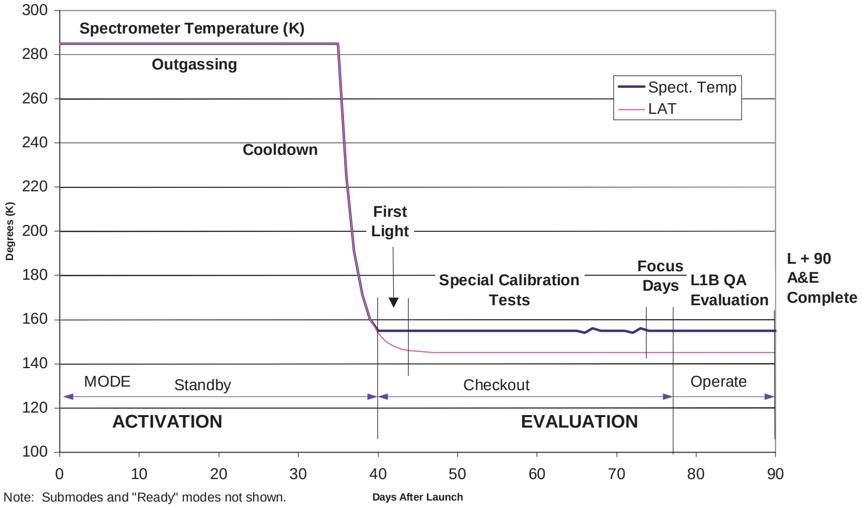

Figure 1. Nominal Activation and Evaluation Timeline for AIRS.

2. THE AIRS INSTRUMENT

The AIRS instrument (shown in Figure 2) incorporates numerous advances in infrared sensing technology to achieve a high level of measurement sensitivity, precision, and accuracy. This includes a temperature-controlled grating and long-wavelength cutoff HgCdTe infrared detectors cooled by an active pulse tube cryogenic cooler.

The AIRS Instrument provides spectral coverage in the 3.74 µm to 4.61 µm, 6.20 µm to 8.22 µm, and 8.8 µm to 15.4 µm infrared wavebands at a nominal spectral resolution of $\lambda/\Delta\lambda$ = 1200, with 2378 IR spectral samples. A cross section of the scan head assembly is shown in Figure 3. A 360-degree rotation of the scan mirror generates a scan line of IR data every 2.667 seconds. The scan mirror motor has two speeds:

1) During the first two seconds, the mirror rotates at 49.5 degrees/second, generating a scan line with 90 footprints of the Earth Scene, each with a 1.1-degree diameter Instantaneous Field of View (IFOV).

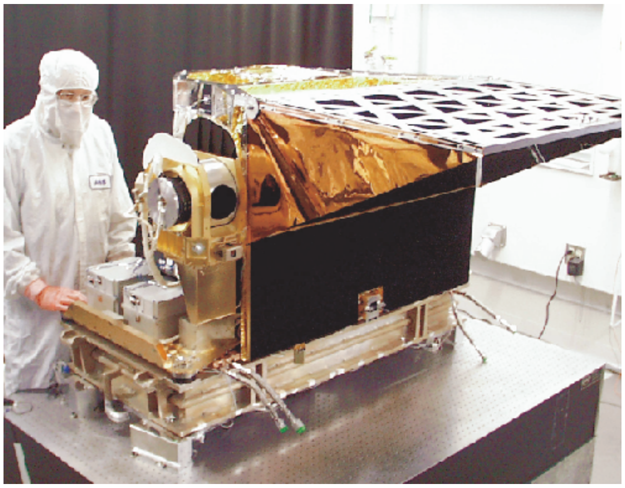

Figure 2. The Atmospheric Infrared Sounder (AIRS).

2) During the remaining 0.667 seconds, the scan mirror completes one complete revolution, with four independent views of cold space, one view into a 310 K radiometric calibrator (the On-Board Calibrator [OBC] blackbody), one view into a spectral reference source (Parylene), and one view into a photometric calibrator.

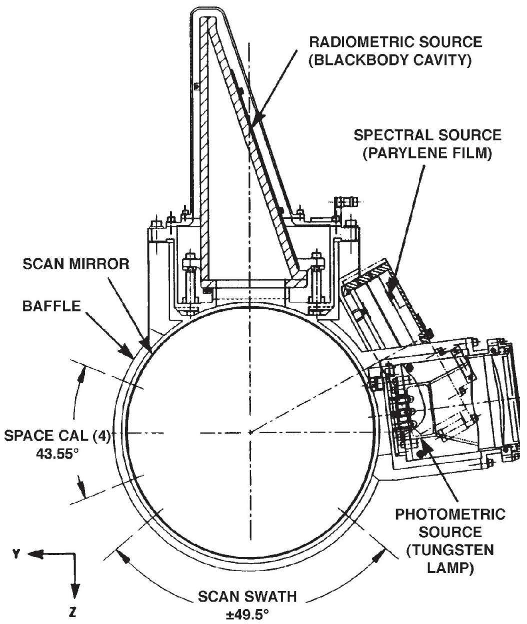

Figure 3. AIRS Scan Assembly.

The VIS/NIR photometer which contains four spectral bands, each with nine pixels along track, with a 0.185-degree IFOV, is boresighted to the IR spectrometer to allow simultaneous visible and infrared scene measurements.

The diffraction grating in the IR spectrometer disperses the radiation onto 17 linear arrays of HgCdTe detectors (see Figure 4) in grating orders 3 through 11. Each linear array is comprised of **N** elements by two rows (A and B) for redundancy. The IR spectrometer is cooled to 150 K by a two-stage passive radiative cooler.

The IR focal plane is cooled to 60 K by a Stirling/pulse tube cryocooler. The scan mirror operates at approximately 265 K due to radiative coupling to the Earth and space and to the 150-K IR spectrometer. Cooling of the IR optics and detectors is necessary to achieve the required instrument sensitivity. The VIS/NIR photometer uses optical filters to define four spectral bands in the 400- to 1000-nm region. The VIS/NIR detectors are not cooled and operate in the 293- to 300-K ambient temperature range of the instrument housing.

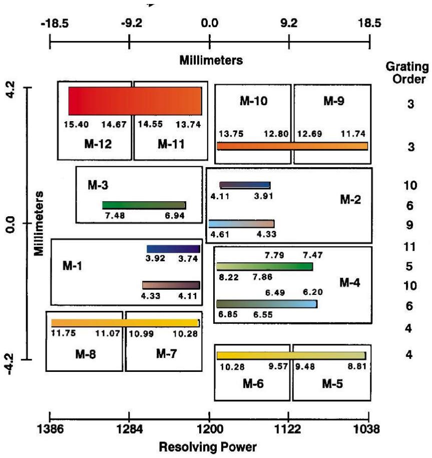

Figure 4. AIRS FPA Layout.

Signals from both the IR spectrometer and the VIS/NIR photometer are passed through onboard signal and data-processing electronics, which perform functions of radiation circumvention, gain ranging and DC Restore (DCR), signal integration, and output formatting and buffering to the high-rate science data bus. In addition, the AIRS instrument contains command and control electronics whose functions include communications with the satellite platform, instrument redundancy reconfiguration, the generation of timing and control signals necessary for instrument operation, and collection of instrument engineering and housekeeping data.

The Stirling/pulse tube cryocoolers are driven by separate electronics that control the phase and amplitude of the compressor moving elements to minimize vibration and to accurately control the temperature. Heat from the electronics is removed through coldplates connected to the spacecraft's heat-rejection system.

3. SPECIAL CALIBRATION TESTS

The AIRS project has prepared an In-Flight Calibration Plan[1] which describes the approach used to meet the requirements of the AIRS Level 1B Algorithm Theoretical Basis Document (ATBD)[2]. The approach combines pre-flight calibration data, spacecraft integration and early on-orbit checkout special test results, and long term monitoring of the data to achieve the calibration. Prior papers have focused on the pre-flight calibration[3,4], which showed excellent characterization, therefore we will not discuss that here. This paper focuses on the special test results performed during spacecraft integration and during early on-orbit checkout in the A&E phase. Figure 1 identifies this period as "Special Calibration Tests". For more details on the procedures for these tests, see the In-Flight Calibration Plan[1].

Table 1 identifies the special calibration tests. The tests are structured to provide the best spatial, radiometric, and spectral information possible using internal calibration sources and instrument telemetry. Tests are given an ID with designation AIRS-CX, where X ranges from 1 to 11 and identifies the test.

The AIRS Calibration Plan[1] requires these tests to be performed during spacecraft thermal vacuum and for the first time in orbit as soon as the optics are cooled. A subset of the tests are performed periodically throughout the life of the mission to obtain trending information on critical performance parameters. Also some tests may be repeated in the event that the temperature of the optics or FPAs change substantially due to planned or unforeseen circumstances. At the time of this writing, all special test procedures have been executed during spacecraft thermal vacuum testing (TVAC) and tests C1, C2, C7, C8, C10 and C11 have been executed in orbit.

Table 1. AIRS Special Test Procedures to support calibration.

Test ID	Name	Description
AIRS-C1	Normal Mode / Special Events	Establish normal DCR and Lamp operation. Determine spectral centroids using upwelling radiance. Flag data for special events such as Earth Scene targets of opportunity
AIRS-C2	Guard Test	Cycles through A, B and A/B Optimum Gains and acquires data. Data are used to trend the instrument radiometric response and for determination of x (spatial) and y (spectral) centration.
AIRS-C3	Channel Spectra Phase	Heat and cool spectrometer by ±1K to shift the channel spectra from the entrance filters. Gain data obtained is used to determine channel spectra phase.
AIRS-C4	AMA Adjust	Procedure moves the Adjustable Mirror Assembly (AMA) to the desired x (A/B Detector Balance) and y (spectral) position
AIRS-C5	OBC Cooldown	Blackbody heater is turned off. Data obtained during the cool down allows determination of the instrument non-linearity
AIRS-C6	Variable Integration Time	Integration time is varied on readout while scanning. This gives a measure of the electronics non-linearity that can be trended over time
AIRS-C7	Space View Noise	The scan mirror is stopped and parked at either the space view or the OBC BB with different A, B and AB optimum gains. Allows noise characterization
AIRS-C8	Radiation Circumvention	Same test as AIRS-C7 but with radiation circumvention turned on. Allows determination of the effectiveness of the radiation circumvention circuitry
AIRS-C9	Scan Profile	The AIRS nominal scan profile is rotated to allow the slow part of the scan to view either the space view or the combined OBC/Parylene view. Allows characterization of any stray light sources.
AIRS-C10	Lamp Operations	Test exercises each of the three lamps by user command at specified time and duration..
AIRS-C11	Warm Functional	Test runs a test pattern through the electronics to verify data packet integrity.

4. TEST RESULTS

We present here the results of the special calibration tests to date. We go through each test and present primarily the results from TVAC testing on the Aqua spacecraft at TRW. In-orbit data are shown for the tests identified above where we have the results. Results are very encouraging for all tests.

4.1 C1: Normal Mode/Special Events

The C1 test is simply normal operation of AIRS with operational mode bits set to allow expediting of the data sets. The test simply changes the operational mode word in the data stream by setting the expedite bit to “on”. This flag is picked up by the EOS Data Operations Center and tells them to send the data to JPL as quickly as possible. We will use this test to acquire data of special, time critical events, additionally, during the initial activation, we used this to expedite the “First Light” imagery from AIRS.

4.1.1 Imagery Evaluation

Figure 5 shows the results of C1 acquisition on First Light data. We see at the top of the figure a nice clean image of a major storm over the South West coast of Africa. Expansion of a single pixel shows clear atmospheric features as we expect. Upon further examination of the spectra, we see the CO2 emission peak at 667 cm^{-1}.

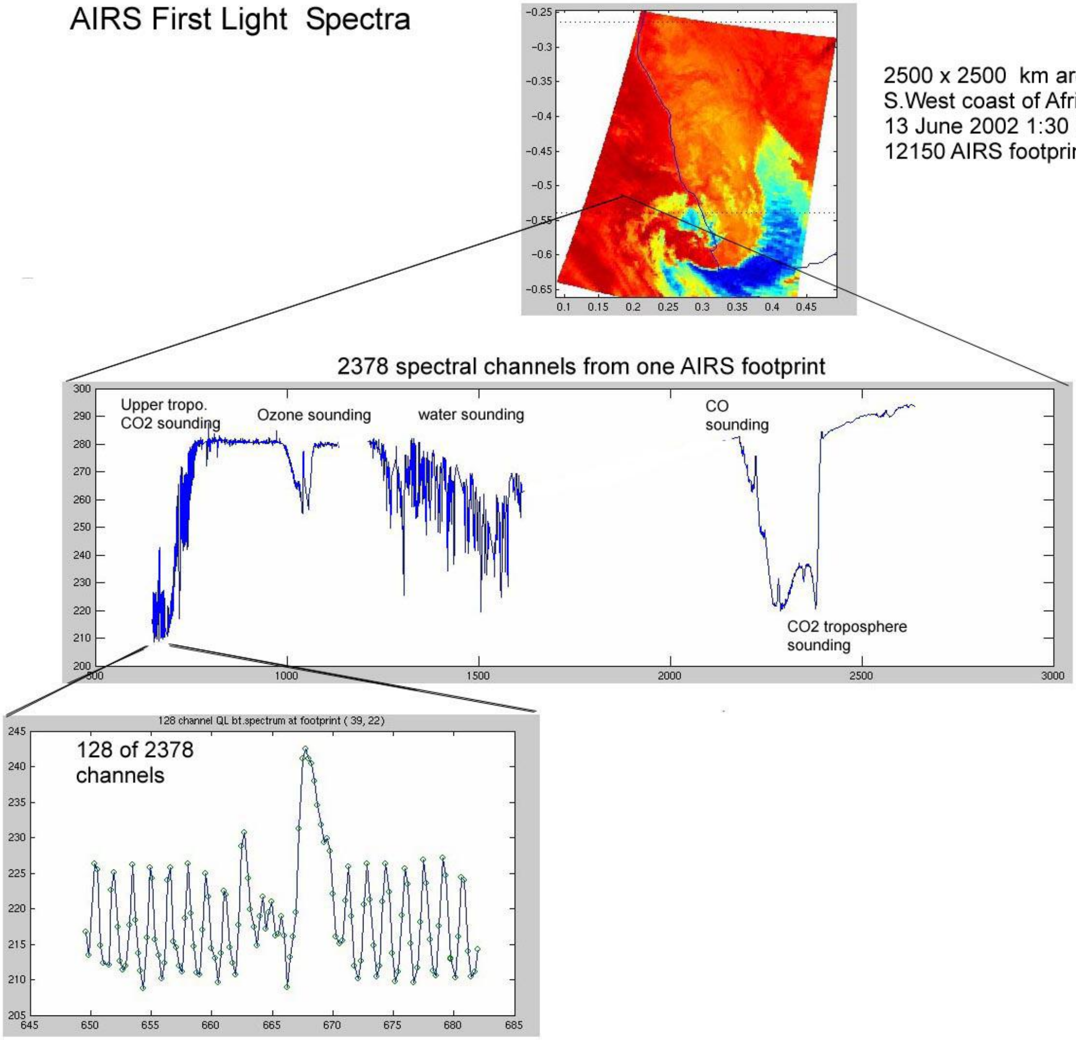

Figure 5. C1: Normal Mode. AIRS First Light data meets expectations.

4.1.2 DCR Checkout

A second analysis performed on the C1 test demonstrates that the DC Restore (DCR) process is working for AIRS. AIRS provides an electronic offset to the signals coming off the FPAs to compensate for drift that occurs naturally in infrared detectors. The offset keeps the signals coming from the FPAs within the range of the Analog-to-Digital (A/D) converter. Figure 6 shows the DCR for four detectors to be working as expected. The red star shows where we expected the DCR to occur. DCR is not performed on detectors with channels less than 514 or greater than 2103.

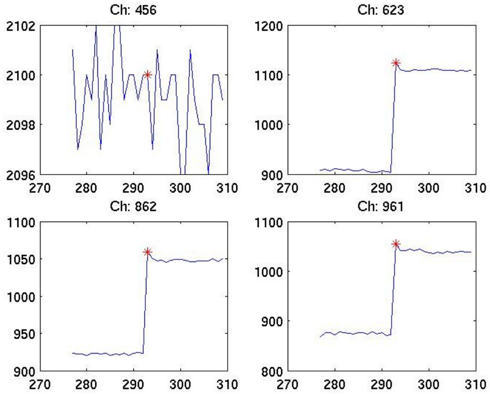

Figure 6. DCR is working as expected. Ch. 456 does not use DCR

4.1.3 Spectral Centroid Determination

Spectral response functions (SRFs) were measured pre-launch during the calibration of the AIRS[4]. Spectral centroids of the SRFs are determined in orbit by correlating observed upwelling radiance spectra with pre-calculated, modeled radiance spectra. Because some parts of the spectrum are more suitable than others, this is done for many separate spectral regions (referred to as 'spectral features'), rather than for the focal plane as a whole. The resultant correlations are fit to, and the location of the maximum correlation is determined. The focal plane shift corresponding to the maximum correlation is the observed shift of the feature. By combining the observed shifts from several different spectral features, the focal plane shift is determined. From that shift, the centroids of each detector can be calculated.

The method described above is being used successfully during the instrument checkout phase of the mission. Figures 7a and 7b show data for June 14-15, 2002. The change of state occurred when the instrument's control point temperature was lowered. Figure 7a shows the shifts calculated for each of the five spectral features used. Periodicity is seen at the orbital period, and is most pronounced for the fourth feature. The range of shifts seen from feature to features provides an estimate of the absolute accuracy of this method. Figure 7b shows the result of combining the shifts shown in Figure 7a. The periodicity is virtually eliminated, indicating that the instrument is, as expected, thermally stable over the orbital period. The current resolution using this technique is about +/- 0.5 μm (1 μm is 1% of the FWHM of the SRF). This is very good and we expect to improve upon this in time.

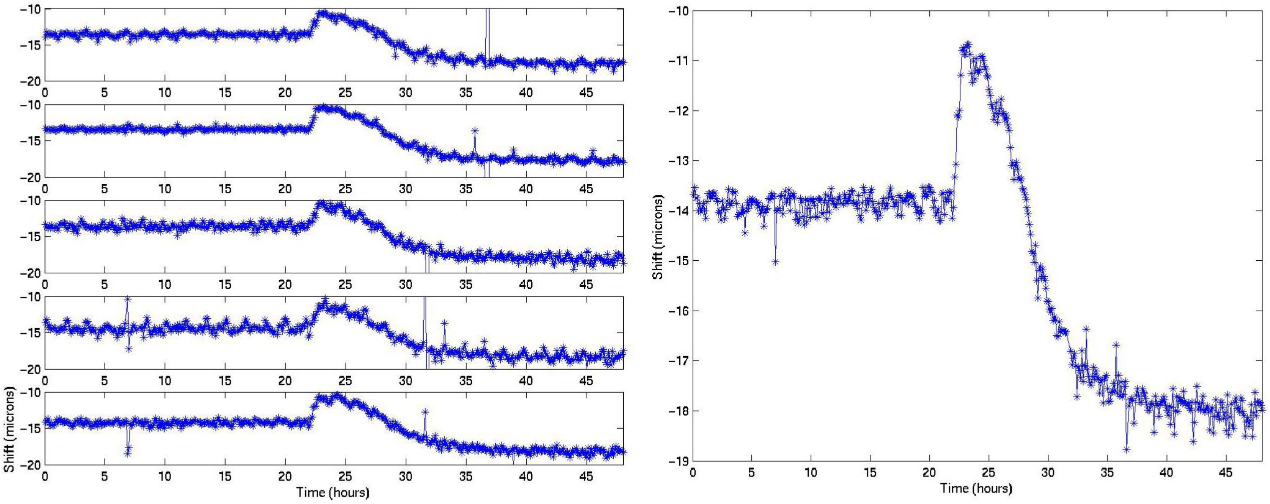

Figure 7. Observed shift in the FPA position in orbit in the spectral direction for a) 5 upwelling features, b) Combined

4.2 C2: Guard Test

The Guard test is used for assessing the radiometric and spectral stability of the AIRS instrument. The test uses the OBC Blackbody and the Spaceview to derive a two point radiometric gain and offset for the AIRS. Tables are loaded to exercise either the A side or B side detectors independently as well as a combined "AB optimum" set. The independent A and B side sets are used to determine the performance of each individual detector prior to being combined into an optimal set. The independent A and B side data are also used to assess the alignment of the projection of the entrance slit on the detectors by "balancing" the signals on the individual A and B rows of detectors.

By performing the test on a daily basis, we have been able to assess the stability of the instrument by watching the gains change with time. Figure 8 shows the results of the first guard test in orbit. In this figure we show the ratio of the gains acquired in orbit with the gains measured prior to launch. Results show a "banding". The three bands correspond to channels with gain weights on the A side only, B side only and AB combined sides of the detector array.

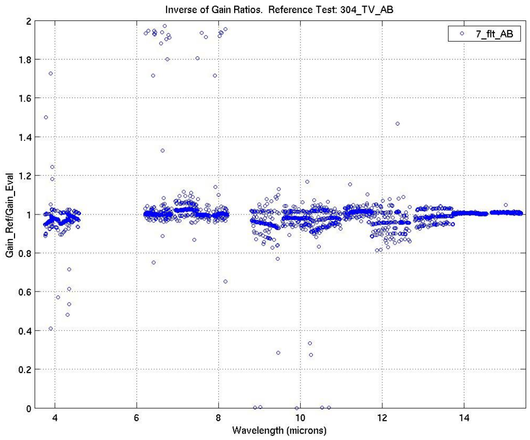

Figure 8. Gain ratios allow trending of instrument transmission

This data also shows a small icing signature that is revealed more clearly in later data sets. The AIRS spectrometer operates at 155K which is very close to the dew-point of water at the vacuum experienced in space at this time. A planned defrost cycle will occur some time early in the mission to remove frost from any surfaces in the spectrometer.

4.3 C3: Channel Spectra Phase Test

AIRS has plane parallel entrance filters placed perpendicular to the optical axis that cause a "channeling" effect in the spectrum of the detectors. The effect is small, on the order of 2% or less, yet does affect the calibration and needs to be characterized. Pre-flight measurements have characterized the channeling very accurately. The phase of the channeling can move with temperature, so this test measures the phase in the operational environment.

The channel spectra phase tests consist of measuring the response (gain) of the 2378 infrared detector channels to the OBC Blackbody, after space look correction, taken at 3 temperatures separated by at least +/- 1K. The response varies with temperature because the phase of the entrance filter channeling varies more rapidly with temperature than the centroids of the spectral response. Figure 9 is an example of the modulation seen in the gains due to channeling. As the temperature is varied the channeling perturbation is swept across the spectral response of each channel. In the short wavelength bands, where the channeling period is smaller than or comparable to the spectral width, the primary effect is to vary the spectral shape. In the long wavelength bands, where the channeling period is larger than the spectral width, the primary effect is to vary the radiometric response. Only data from the longwave channels (modules M6 – M12) are used in the analysis.

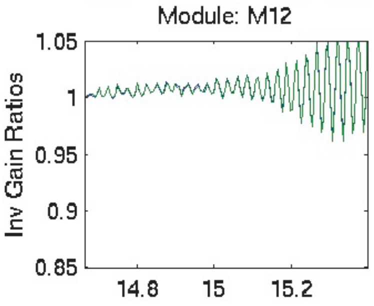

Figure 9. Channel spectra produce oscillations in gain ratios

The analysis compares the variation in the radiometric response vs. temperature to that expected from the measured spectral response adjusted for the effects of channeling, where the overall channeling phase is adjusted, by shifting the model temperature of the entrance filters, for a best fit to the data.

The results of the TVAC tests conducted before instrument delivery to the spacecraft are shown in Figure 10. The upper curve shows that the minimum in the fit is very close to zero offset, indicating good agreement between radiometric data and the channeling model, which was developed using spectral response data.

The results of the TVAC tests conducted after spacecraft integration did not show similar good agreement. This is probably because the instrument was not in thermal equilibrium so that knowledge of the spectral centroids was lost; this knowledge will be recovered when we repeat the test in-orbit and use upwelling radiance spectral calibration.

4.4 C4: AMA Adjust Test

This test is more of a procedure than a measurement of the performance of the AIRS instrument. The AIRS has the provision for moving the alignment of the optical axis relative to the FPAs by moving the final focus mirror in the optical chain. The Adjustable Mirror Assembly (AMA) can be commanded in three axes to affect the A/B detector signal balance, the spectral alignment and the focus of the FPAs.

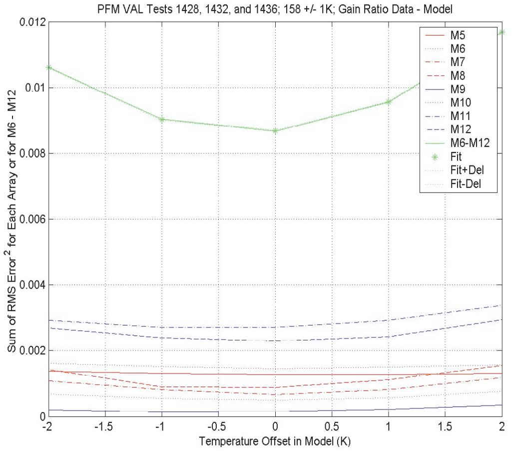

Figure 10. Minimum errors model allow determination of channel spectra phase in orbit

The procedure was performed in TVAC at TRW, and results are shown in Figure 11. We moved the AMA in the X direction and measured the displacement. Moves were of the magnitude expected, however we noticed displacements other than what were made deliberately. Investigation showed these displacements to correlate well with the temperature gradients in the optical bench. Figure 11 also shows the temperature differences for key sensors on the optical bench. The correlation is apparent. This test is a good demonstration of the need for temperature stability in the AIRS. The gradients in this chart were caused by unstable environmental conditions in the TVAC chamber at TRW and have not been seen in the orbital environment. Early results show the need for an AMA move in space to be unnecessary.

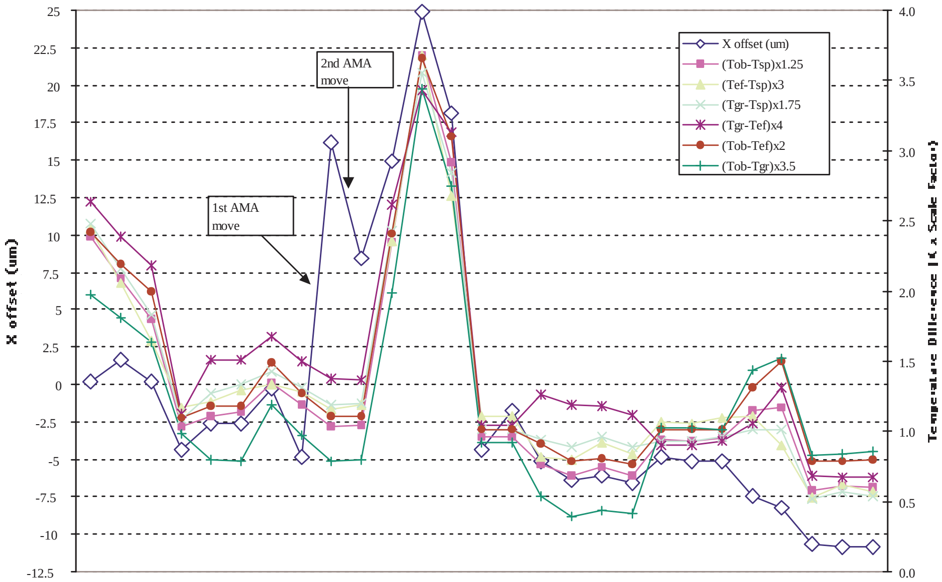

Figure 11. AMA Adjust test demonstrated ability to realign optical axis remotely. Test not required in orbit.

4.5 C5: OBC Cooldown Test

The AIRS OBC Blackbody operates nominally at 308K. It is temperature controlled with heaters within the blackbody assembly. In this test, we turn off the heater and the response to the OBC Blackbody is measured. This test allows us to check the nonlinearity of the instrument in orbit and compare it to a more accurate measurement made preflight.

Figure 12 shows the magnitude in absolute terms of the first and second order terms for TRW TVAC data compared to measurements made with an external blackbody calibration target during testing at BAE SYSTEMS. We see excellent agreement for the first order term, but some differences in the 2nd order term. AIRS is linear to better than 1.5%[4], so the measurement is very difficult to make. The small nonlinearity combined with an apparent deviation from calibration of the OBC blackbody at lower temperatures has resulted in limitations in this test. It will be repeated on-orbit for stability checks.

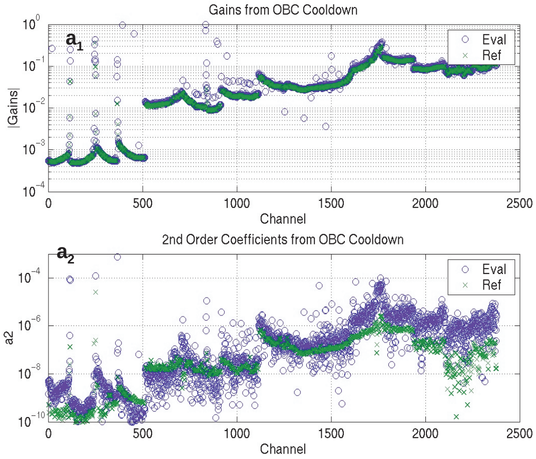

Figure 12. First and 2nd order term calculated from OBC Cooldown

4.6 C6: Variable Integration Time

In this test, the integration time of each channel is varied to produce a variable signal from the detectors. The test is purely functional in nature and is not intended to produce a calibration parameter. The test worked fine in TVAC and will be performed again in orbit. At some point we would like to examine the data more closely for possible merit as a calibration check on the linearity of the AIRS, but all efforts to date have shown this test to only be functional.

4.7 C7: Space View Noise Test

This test allows us to characterize the noise properties of the individual 2378 infrared detectors of AIRS. The AIRS scan mirror is commanded to stop and stare into the space view while data are acquired. The long view into the space view provides an excellent cold target for noise evaluation. A variant of this test commands the mirror to stop and stare into the OBC blackbody. This provides a second reference for noise that allows determination of the signal dependence of the noise.

This test has been extremely useful in characterizing the noise properties of the AIRS detectors. Side A and Side B noise properties are measured from this test and the best mix of A and B detectors are selected in the form of a gain table that is uploaded to the instrument. This results in the best possible noise performance of AIRS with the available detectors.

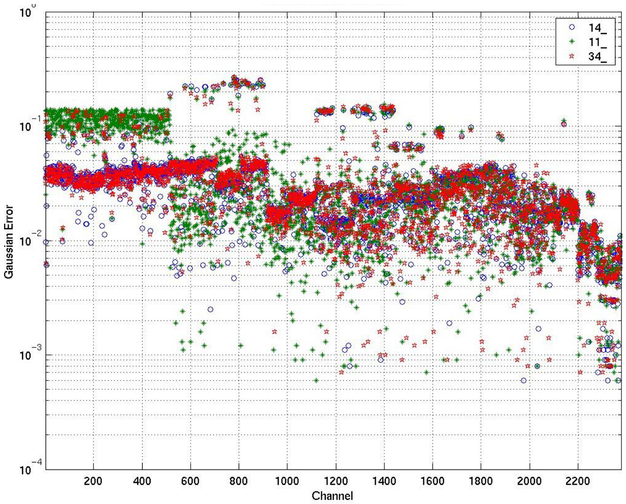

Figure 13. Deviation from Gaussian behavior for AIRS A-side detectors. Test 11 and 34 are in the SAA. Test 34 had radiation circumvention processing engaged.

Figure 13 shows the deviation from Gaussian behavior for all A side channels in AIRS measured in orbit. This term is calculated by comparing the histogram of data measured while viewing space to a pure Gaussian distribution and taking the deviation from ideal and normalizing to the integral. We have set a threshold of 0.08 as the normalized Gaussian error that we can tolerate. Data are shown for the normal operational mode in a low radiation part of the orbit (test 14). There are some detectors that violate our threshold as shown for the A side. We simply check the corresponding B side for these detectors and use them by programming the gain tables if they pass. We also see the effects of the South Atlantic Anomaly (SAA) and radiation circumvention processing. This is discussed in the next section.

The C7 test is also useful for measuring the noise performance of AIRS at any scene temperature. Figure 14 shows the Noise Equivalent Differential Temperature (NEΔT) measured for AIRS preflight (test 304) and in orbit (test 35). The variation with wavelength is due to the grating efficiency which varies with wavelength and grating order. The NEΔTs shown are for each channel of AIRS. We see excellent agreement with preflight results. Since the AIRS oversamples spectrally, we effectively get about a factor of root 2 better than these on a "resolution element" basis. This data were generated by scaling the photon noise while viewing the OBC radiance to the scene radiance and multiplying by the gain according to the equation

$$NEN_{scene} = Gain \times \sqrt{\left(N_{scene} \big/ N_{obc} \right)\left(DN_{obc}{}^{2} - DN_{sv}{}^{2} \right) + DN_{sv}{}^{2}}$$

$$NE\Delta T_{scene} = \frac{NEN_{scene}}{\partial N / \partial T \big|_{T=Tscene}}$$

where

NEN_{scene} = *Noise Equivalent Radiance of the Scene* *(W/m^2-st-cm^{-1})*

$NE\Delta T_{scene}$ = *Noise Equivalent Temperature of the Scene (K)*

T_{scene} = *Temperature of the Scene (K)*

N_{scene} = *Radiance of the scene (W/m^2-st-cm^{-1})*

N_{obc} = *Radiance of the OBC Blackbody (W/m^2-st-cm^{-1})*

Gain = Instrument Linear Response Term ((W/m^2-st-cm^{-1})/dn)

DN_{obc} = *Noise while viewing the OBC (dn)*

DN_{obc} = *Noise while viewing space (dn)*

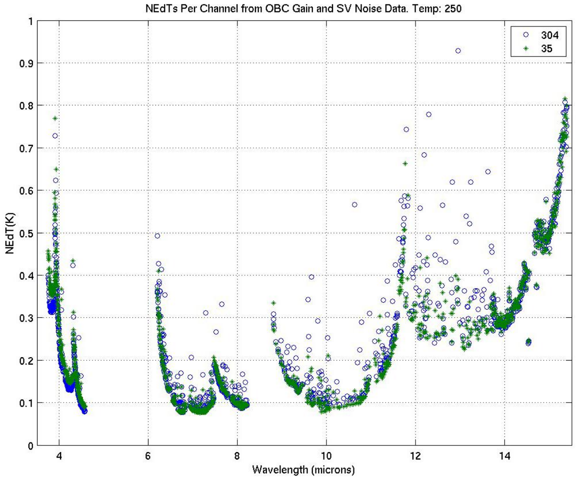

Figure 14. NEΔTs for AIRS at 250K measured pre-launch and in orbit

4.8 C8: Radiation Circumvention Test

The AIRS instrument includes on-board signal processing to detect and remove signal spikes resulting from orbital proton radiation hits in the PV HgCdTe detector channels. The signals are internally sampled at 8 or 16 times the output signal rate, depending on the detector group. The radiation-hits affect only a single sample, resulting in significant isolated spikes, especially for the shorter wavelength detectors. The second difference of the signals is compared with a threshold value, programmable for each detector. For each threshold crossing, the processor substitutes for the signal sample in the output stream at that time with the mean of the samples in the input stream that occurred just before and after the detected hit. Thus, radiation-hit events are circumvented from the output stream, with nearly negligible effect on the radiometric accuracy of the signal after summing by 8 or 16 samples into the final output data stream.

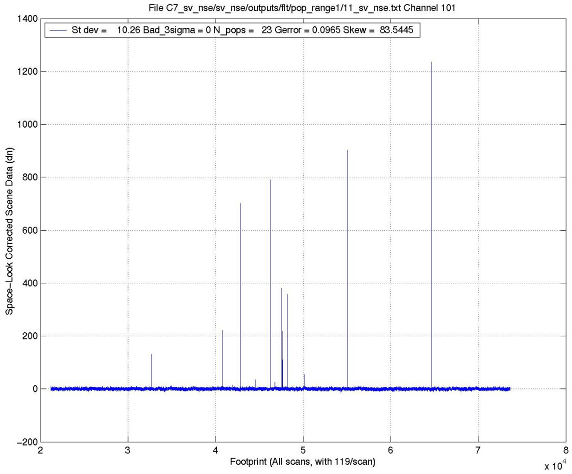

Figure 15. Time sequence of data shows radiation induced noise spikes

Figure 15 shows a time sequence of output signals (after the summation by 8 samples) for a selected detector used to detect 3.9 µm IR radiation. This sequence was taken while the instrument was passing through the intense proton radiation environment of the SAA. The large spikes in the signal are the result of proton radiation hits in the detector.

The C8 test involves acquiring data within and outside of the SAA, measuring the noise properties as done in C7 and applying thresholds that satisfactorily remove the isolated noise spikes. This test was performed in orbit and thresholds of 5 times the RMS noise used for channels 0 to 1116 corresponding to the shortest wavelength modules. Figure 13 compares the departure from Gaussian shape of the histograms with (test 34) and without (test 11) circumvention processing while inside the SAA. The process returns the noise histograms to their expected Gaussian shapes by eliminating the radiation hit spikes.

We conclude that although radiation events can significantly degrade the noise performance of the shorter wavelength detectors, the radiation spike circumvention processing implemented in AIRS effectively eliminates the deleterious effects of radiation on detector sensitivity.

4.9 C9: Scan Profile Test

The data from the two scan registration tests consist of the response of the 2378 infrared detector channels to the on-board calibrator (OBC blackbody), parylene on-board spectral calibrator (OBS), and space views, taken with the scan profile offset by fixed amounts to allow the slow IR scene part of the scan to view the calibrators or the space look region. The offset angles are: a) 214 degrees, to place both the OBC and OBS in the IR scene and to have one footprint (normally viewing the OBS) at a space look cold reference; and b) 79.5 degrees, to place the space look region in the scene and to have one footprint (normally one of the space views) as an OBC look warm reference (approximately 308K). The offset profiles are illustrated schematically in Figures 16a and 16b. With the assumption that the temperature is known at one point in the rotated IR scene (either the OBC temperature at its center or 0K in the center of the space look region) the temperature can be found at all other points using a slight modification of the standard AIRS two-point calibration algorithms which include correction for scan mirror polarization effects.[5]

The analysis determines the mean brightness temperature as a function of the rotated scan angle and makes a contour plot of this temperature vs. scan angle and detector channel. The program also calculates the mean brightness temperature for all good detectors in each of the 11 entrance apertures, plots this temperature vs. scan angle for all entrance apertures, and, for the 214-degree-offset case, finds the angular positions where these curves cross the 300K temperature and then determines the full-width at 300K and the mean of these positions.

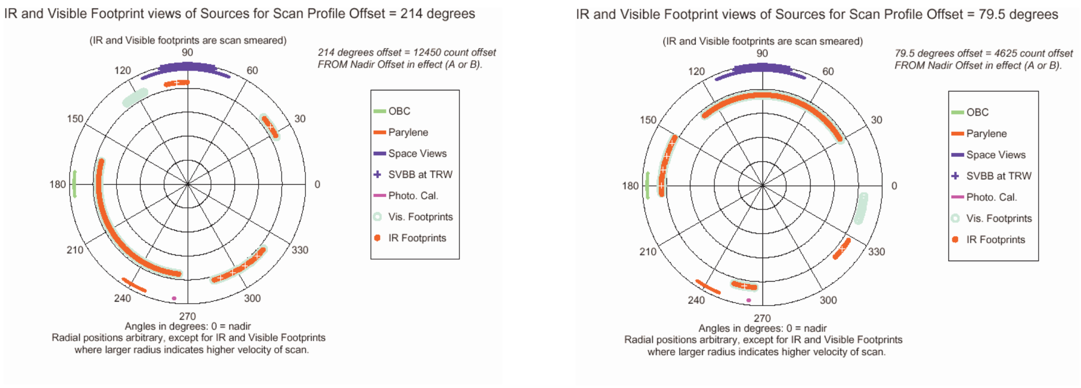

Figure 16 Rotated (offset) scan profile data sectors for a) left, Space view, b) right) OBC/Parylene View

The results of the TVAC tests, in Figures 17a and 17b, show that the scan profile needed no adjustments. The in-orbit data will be analyzed in a similar fashion to assess centering of the internal calibration views, and to determine when these views are impacted by stray light so that only uncontaminated views can be used as the cold look for the two-point calibration of the AIRS radiance data.

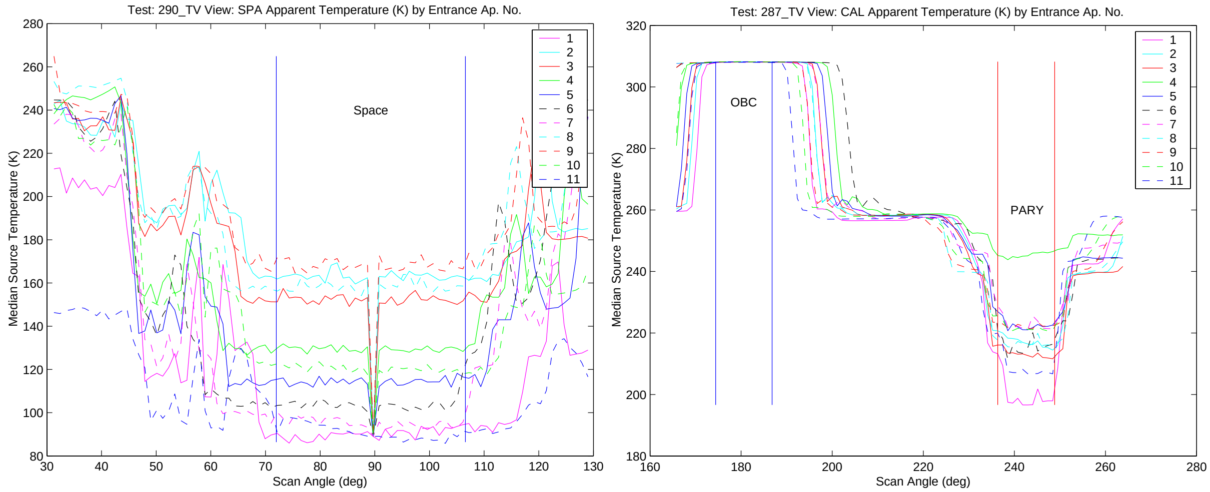

Figure 17. Scene temperature profiles show clear fields of view for a) left, space, b) OBC and Parylene

4.10 C10: Vis/NIR Lamps

The approach for calibration of the Vis/NIR channels is discussed in more detail in the Vis/NIR L1B ATBD[6]. The C10 test is simply a procedure that allows each of three lamps to be turned on for an adjustable length of time, to monitor Vis/NIR stability over time. Eight minutes is typically used to characterize the signal from each lamp, but times up to 1 hour are used to search for variability approaching the orbital frequency. Within hours of starting flight operations, three 8-minute C10 tests were run to establish a baseline for each lamp, and to compare performance with ground-test results. Signal levels in orbit are similar, but not identical to those on the ground. These differences are not considered significant.

Figure 18 shows the lamp signal collected in orbit. Each channel has 9 detectors (color coded as per the legend at the top of the figure), which are scanned across the photocalibrator assembly, collecting 8 samples per scanline. The x-axis of each panel is sample number, and the y-axis is instrument counts after subtracting off the temperature dependent offset term. Note how the peak signal in Channel 2, Detector 9 is saturated. This behavior was not observed during

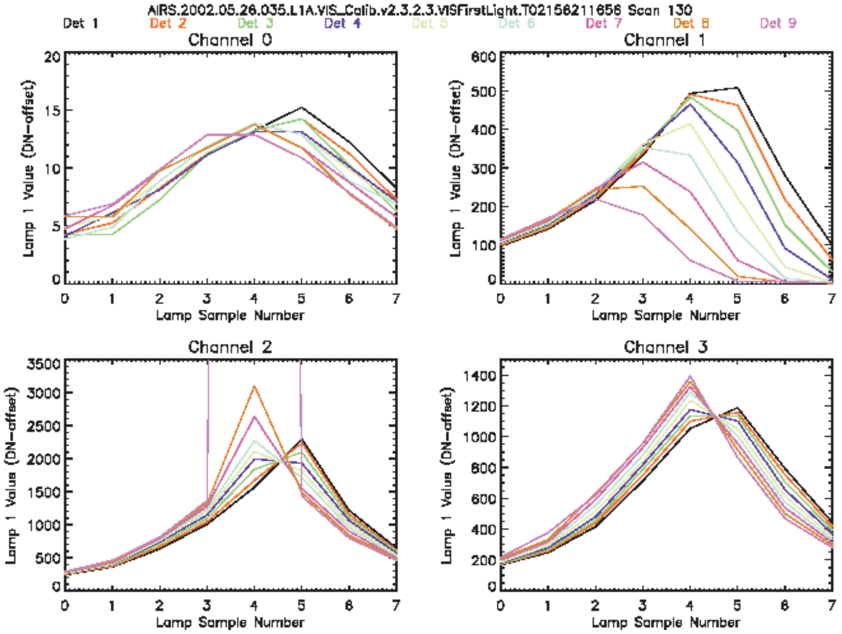

Fig. 18: Lamp 1 signal on-orbit. Each panel is for one of the Vis/NIR channels.

thermal vacuum testing and is under investigation. These data are from scanline 130 of granule 035, collected on 26 May 2002. After several days of operating Lamp #1 for 8 minutes every 3 hours, we are currently using Lamp #3 only once per day. The system has been stable in flight, with no changes in lamp performance observed to date.

C11: Warm Functional Test
With the instrument configured for science data acquisition, a mode is commanded which inserts a fixed pattern of digital data into a point equivalent to the A/D converter outputs in the instrument electronics signal chain. Examination of the received data therefore verifies the on-board signal processing as well as the data links through the spacecraft and to ground sites. The analysis examines the AIRS telemetry to verify proper setup of the instrument and then compares the output of every IR spectral sample for every footprint and scan to a table of expected values. Where values depart from expected, the scan, footprint and spectral sample numbers (or a range) are reported.

The test was successfully run as the first special test for AIRS in orbit and verified our data path from end to end.

7. SUMMARY

The AIRS project has adopted eleven special tests to characterize the functional and performance behavior of the AIRS instrument. Many of these have been performed in orbit at the time of this writing. AIRS-C1 has produced exceptional imagery and spectra identifying no obvious problems with the instrument. Tests C2, C4, C7, C8 and C10 have characterized the noise and radiometric performance to be exceptional. Tests C3, C5, C6 and C9 have not yet been run in orbit, but have demonstrated our ability to accurately characterize the spectral channeling, to trend the nonlinearity, and characterize the alignment and radiometric environment around the on-board calibrators. These tests have allowed us to demonstrate that the AIRS performance as measured on the ground matches the performance observed in orbit. We expect the scientists to be pleased with the performance from the AIRS instrument and we have the tools to monitor its performance over the years.

For additional information on the launch operations and overall project activities at JPL, please consult the references.[7]

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