36-01510.056

ACIS Verification Summary Report

Specification:	ACIS Contract End Item Specification
Requirement Number/Title:	3.2.1 Performance (VRSD 3.2.1g)

Requirement Statement: The mean (pixel averaged) quantum efficiency of each CCD, measured at wavelengths between 400 and 1100 nm, shall not exceed 10E-6 when the optical blocking filter is in place.

Verification Method:	Test at Lincoln Thermal Vac.

Procedure Number:

Configuration:

Cycle Time:

Verification Discussion/Results:

ACIS Cognizant Engineer 19 Jun 97

Date

ACIS Verification Summary Report (Continued)

Formally, detectors S0 and S1 do not meet the specification when measured at 880nm. See ACIS memo PS-137.

Massachusetts Institute of Technology

Center for Space Research
Cambridge, MA 02139
Room 37-521
mwb@space.mit.edu

June 19, 1997

To: MIT ACIS Team
From: Mark Bautz
Subject: Preliminary Analysis of ACIS light-leak test data from Lincoln Labooratory Instrument thermal vacuum test.

NOTE: This analysis is preliminary, and has been prepared solely to support formal ACIS verification reporting activities. More detailed, accurate analysis, examining in particular the spatial variation of visible light detection efficieny, is in progress.

1 Summary

The effective visible/near IR light detection efficiency of the ACIS flight system was measured in April, 1997 in the course the second ACIS instrument thermal vacuum test at MIT Lincoln Laboroatories. This memo summarizes preliminary analysis of the data obtained in this test. The instrument meets the Contract End Item Specification (section 3.2.1g) for incident light of wavelength 660 nm. At 880nm, the measured detection efficiency exceeds the specified upper limit by a factor up to 1.7 in detectors S0 and S1. Although uncertainties in the uniformity of the illumination pattern are at about the factor of 2 level, the observed localized regions of excess efficiciency are are a matter of concern. Additional analysis of other light-leak measurements, in particular those made at XRCF, may reduce the uncertainties. It may be necessary to make additional light-leak measurements, with a beam of known uniformity, to resolve this issue.

2 Test Description

2.1 Light Sources and Instrument Configuration

The data discussed here were acquired on 10 April 1997, near the end of the second ACIS Instrument thermal vacuum test at Lincoln Laboratory. The instrument was illuminated at two light levels using each of two light-emitting diode sources. Peak emission occurs at 660nm and 880 nm, respectively, for the two diodes. These wavelengths were chosen because they are near the peak CCD efficiency and maximum filter transmission, respectively. The outputs of the diode sources were calibrated at MIT CSR using a front-illuminated flight-sibling CCD detector. The detector used to calibrate the sources was not absolutely calibrated, but an approximate calibration, based on Lincoln Laboratory measurements, is expected to be be accurate to better than 30%. The detector efficiencies assumed for this report are 70% at 660 nm and 35% at 880 nm. Details of the LED calibration are presented elsewhere in a memo by S. Jones (ACIS memo PS-136).

LED Source Wavelenght(nm)	LED Current (mA)	Flux ($photons\,3.3s^{-1}\,pixel^{-1}$)	Remarks
660	0.61	9.4×10^4	assumed reference CCD efficiency 0.7
660	140	2.8×10^7	assumed reference CCD efficiency 0.7
880	0.41	1.8×10^5	assumed reference CCD efficiency 0.35
880	29.5	4.5×10^7	assumed reference CCD efficiency 0.35

Table 1: Illumination Levels

At Lincoln, the LED sources were located approximately 70.5 inches from the focal plane. The estimated illumination levels are listed in table 1. Only the high-illumination test results are discussed here.

The instrument was configured to operate in timed exposure mode with an integration time of 3.3 s. The parameter block used was deflbias.te. The focal plane temperature was near -110C, but not under active control during the data acquisition. The electronics were at hot case temperatures. Data were acquired from the high-speed tap. For each illumination condition, 10 frames were acquired from each chip in the focal plane. Two science runs were started in the test; the spectrometer detectors (s0-s5) were measured with the first science run, and the imager detectors (i0-i3) with the second. At the conclusion of each science run, 10 bias frames were acquired for each active CCD. Data were stored in directory /glenl/d5/10Apr97/0923 and archived on DLT tape LLTV2 number 22. See the README file there for other details.

2.2 Data Acquisition and Analysis

Exposed and unexposed data sets for each chip and each illumination condition were averaged using the mean_biascplip2 program, which implements a precursor version of the med_mean flight bias algorithm, and thus removes most cosmic ray artifacts. Differences between the (10-frame) mean exposed and mean bias data were formed and overclock corrected. Typical overclock noise levels in the mean differences were of order 1.1 electrons, rms. To obtain the spatially averaged detection efficiency, the overclock-corrected differences were simply averaged over the frame. The RMS variation about the mean was also computed. We have also computed the effective filter transmission, assuming that the flight detectors and the reference detector had the same efficiency. This assumption may not be accurate for detectors S1 and S3, which are back-illuminated devices, and may therefore be more efficient than the reference detector.

2.3 Errors

If the bias correction were perfect, the standard error of the resulting detection efficiency numbers would be of order one part in 10^{-3}. In practice, there is considerable bias subtraction error (the test was done before the "jitter dacs" patch was available), and I estimate that systematic errors in the the mean could be as high a 5 electrons. Note also that the visible light detection efficiency assumed for the reference detector purposes of this analysis may be in error by as much as 30%. Uncertainties resulting from the geometry of the Lincoln Lab configuration, and the source reproducibility, are estimated to be less than 20%.

Undoubtedly, the largest uncertainty is the uniformity of the illumination pattern. The LED sources are not internally collimated, so substantial reflections from the inside of vacuum hardware or the instrument collimator may have been present. On the basis of images acquired during LED calibration, we estimate that non-uniformities in the illumination pattern might be as large as a factor of 2.

3 Results and Discussion

Mean estimated detection efficiencies at two wavelengths are listed in Tables ?? and ??. We present the inferred filter transmission separately, because it is unaffected by errors in the assumed bare-CCD detection efficiency.

The CEI requirement (system efficiency less that 1.e-5) is met by all detectors at 660 nm. Formally, detectors s0 and s1 fail to meet the specification at 880nm by about a factor of 1.5. Inspection of the image of the detected light (not presented here) shows that most of the light is concentrated along the +X edges of these detectors, and that in small regions the efficiency reaches about 5e-5. The pattern is observed at both wavelengths, but the ratio of effective filter transmissions at the two wavelengths in detector s0 is about what is expected for a 1300-angstrom-thick aluminum filter. The relative transmissions at 880 nm in s0 and s5, say, could result from an aluminum thickness variation of about 100 A (out of a nominal 1300A) from one side of the filter to the other. A thickness variation this large appears to be inconsistent with X-ray transmission measurements of the filters. As noted above, it is possible that the illumination is non-uniform, we cannot rule out the possibility that the apparently high detection efficiencies are merely an artefact of the illumination pattern. One the other hand, if the excess transmission were due to poor mating of the filter to the detector housing, one would expect the filter transmission in s0 to be similar at the 660nm and 880nm, so the the filter-to-housing seal is probably not the source of the apparent light leak.

Clearly, additional analysis is required to evaluate the causes and impact of the observed filter transmission. Data already acquired at XRCF may be useful for this purpose. It must be stressed that local regions of high detection efficiency (which are NOT well constrained by the CEI specification) could degrade ACIS performance significantly. It is therefore recommended that additional measurements be made with illumination of known uniformity be considered.

Detector	Inferred Filter Transmission	Mean Detection Efficiency (all pixels, filter + detector)	RMS Efficiency Variation
i0	3.1e-07	2.17e-07	8.47e-08
i1	1.13e-07	7.95e-08	4.9e-08
i2	4.36e-07	3.05e-07	1.11e-07
i3	1.59e-07	1.11e-07	5e-08
s0	6.64e-07	4.64e-07	1.63e-07
s1	4.96e-07	3.47e-07	2.63e-07
s2	2.36e-07	1.65e-07	6.2e-08
s3	1.64e-07	1.15e-07	6.56e-08
s4	9.3e-08	6.51e-08	5.57e-08
s5	1.23e-07	8.62e-08	5.3e-08
Specification:		<1.e-5	

Table 2: Detection Efficiency at 660 nm. All detectors meet the CEI specification. Note that systematic error in the mean efficiency and effective filter transmissions, which are dominated by uncertainties in the uniformity of the illumination pattern, may be as large as a factor of two.

Detector	Inferred Filter Transmission	Mean Detection Efficiency (all pixels, filter + detector)	RMS Efficiency Variation
i0	9.45e-06	3.31e-06	1.01e-06
i1	3.78e-06	1.32e-06	1.73e-07
i2	1.37e-05	4.78e-06	1.12e-06
i3	4.55e-06	1.59e-06	3.52e-07
s0	4.79e-05	1.68e-05	4.46e-06
s1	2.87e-05	1.01e-05	3.18e-06
s2	2.5e-05	8.77e-06	1.18e-06
s3	1.65e-05	5.78e-06	1.35e-06
s4	1.6e-05	5.59e-06	6.43e-07
Specification:		<1.e-5	

Table 3: Detection Efficiency at 880 nm. Formally, detectors s0,s1 and s2 do not meet the CEI specification. Note, however, that systematic error in the mean efficiency and effective filter transmissions, which are dominated by uncertainties in the uniformity of the illumination pattern, may be as large as a factor of two.

Massachusetts Institute of Technology
Center For Space Research
Cambridge, Massachusetts 02139

Room 37-662C, e-mail: sjones@space.mit.edu

From:	Stephen Jones
To:	ACIS Team
Subject:	Lincoln Labs Calibration Sources
Date:	June 20, 1997

This memo briefly describes the sources used at the Lincoln Labs calibration facility during the ACIS thermal-vac test. The source could provide for either x-ray or optical photons. The x-ray source is a fluorescent source similar to the HEXS sources used at the MIT CCD lab. However there is only a choice of 4 different targets, each producing corresponding k alpha x-rays: aluminum, silicon, titanium, and copper. In addition an Fe55 source can be inserted to produce manganese k alpha x-rays. Each source is emplaced by linear and rotary motion feedthroughs. Table 1 records the formal positions of the HEXS angular dial, HEXS axial position indicator, and Fe55 translator position for produce the desired x-ray spectrum. Table 2 displays the measured fluxes for each source. The measurements were made at both MIT and Lincoln Labs, with source - ccd distances of 42 inches and 70.5 inches, respectively. The flux is measured in units of G02346 counts per 3.3 second frame per quadrant. In the last two columns are the predicted number of frames and integration times required to achieve 100,000 G02346 counts. It is not clear why the detected ratios at both laboratories differ from the square of the stated distance ratios. The MIT measurement was conducted without the optical blocking filter which absorbs about 15 percent of aluminum photons. Also, the MIT measurements were conducted with a CCD not belonging to the flight focal plane, and with difference electronics.

The optical source uses a red LED and an infrared LED, with respective wavelengths of 660 and 880 nm. The intensity was calibrated at MIT using a CCD-17 at a distance of 48$\pm$1 inches. The goal was an optical source that could produce about $1\times10^{10} photons/sec/cm^2$ before the optical blocking filter. This number results from the filter's attenuation factor of about 10^7 Thus, the calibration measurement was tricky because it must span 6 orders of magnitude! This was accomplished using a set of neutral density filters and a pulse generator. Another significant problem was optical focusing from the hardware which caused uneven illumination on the CCD. The results are shown in Figure 1 for both the red LED (stars) and the infrared LED (squares). Printed at the top of the figure are the equations for the best fit quadratic curve. The current is in units of microamps, while the intensity is in units of ADU/pixel/3.3 seconds.

Note that the requirement of $1\times 10^{10} photons/sec/cm^2 = 1.9\times 10^5$ ADU/pixel/3.3 sec at 48 inches is provided by infrared and red currents of 410 and 620 microamps, respectively. Using the Lincoln Labs LED-source distance of 81.5 ± 2 inches, the flux at these current settings would be reduced by a factor of $(81.5/48)^2 = 2.9\pm0.1$, or $6.6\times 10^4 photons/sec/cm^2$. Data at Lincoln Labs was also taken at 140 mA and 29.5 mA for the red and infrared LED, respectively: the corresponding fluxes are calculated to be 2.0×10^7 and $1.6\times10^7 photons/sec/cm^2$. It is felt that the uncertainty of the flux at the Lincoln Labs focal plane is about a factor of two, mostly due to uncertainty about internal reflections by the hardware.

Table 1. Positions for Different X-ray Sources

Source	HEXS Angular Dial [degrees]	HEXS Axial Position [inches]	Fe^{55} Translator Position [inches]
Al	15°	1.0	0.0
Si	105°	1.0	0.0
Ti	285°	1.0	0.0
Cu	195°	1.0	0.0
Fe^{55}	Anything	0.0	1.5
LED	Anything	0.0	0.0

Table 2. Expected X-ray Flux for X-ray Sources

Source	CSR Flux (/qd@42 in)	LL Flux (/qd@70.5 in)	No. Frames for 10^5 G02346 cnts.	Time (min) for 10^5 G02346 cnts.
Fe^{55}	1215	603	166	9.7
X-ray Target Al	320 (100 uA)	598 (400 uA)	170	9.7
Si	490 (100 uA)	801 (400 uA)	125	7.3
Ti	*	1100 (120 uA)	90	5.3
Cu	1060 (100 uA)	740 (100 uA)	180	10.6

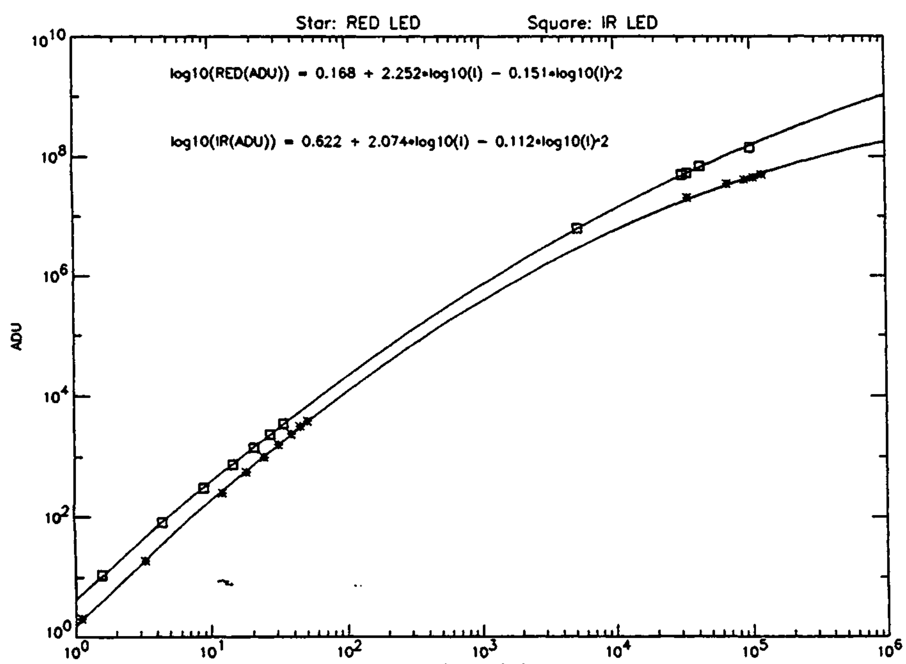

Figure 1: LED Flux (ADU/Pixel/3.3sec) vs. Current (48 inches apart)

AXAF-I Verification Requirement Compliance Data Submittal

Element: ACIS

Requirement Number: 3.2.1g-1

Verification Item: 3.2.1g-1-1

Evaluators: CHE, SAO, IN&C

Type of Review:
- ☐ Verification Item Closure
- ☒ Requirement Closure

Requirement Title: Performance

Compliance Data/Location: MA-288/36-01510.056/Rm 522 Bldg 4200 (Closure Report)

Verification Method: Test

Comments:

IN&C - Disapprove: According to the verification data, this requirement is possibly not met for two CCDs. Issue needs to be resolved.

Waiver submitted to MSFC on 8/4/97
#36-007

Status: Open 6/24/97

Recommendation:
- ☐ Approve
- ☐ Disapprove
- ☐ Other (Explain)

Action Required for Closure:

MSFC Evaluator:	Date:	Organzation:	Phone Number:

Disposition:
- ☐ Approve
- ☒ Disapprove
- ☐ Other (Explain)

Action Required for Closure: Kurt is correct; S0 and S1 do not quite meet the filtering req't to get down to 1 X 10-5 between 400 and 1100 nm. They have an efficiency of about 1.7 X 10-5 (system level, including the OBF's obviously). So, ACIS it is preferred that ACIS write a waiver.

Chief Engineer: Anthony R. Lavoie

Date: 7/3/97

Massachusetts Institute of Technology
CENTER FOR SPACE RESEARCH

WAIVER REQUEST

Date Prepared: 8/1/97	**Waiver No.** 36-007
Initiated By: Brian Klatt	
COMPONENT AFFECTED: **P/N:** 36-10104.0120 **Name:** CCD Array Assembly	**ITEM AFFECTED:** **P/N:** 36-10115.02 **Name:** Spectrometer OBF
Original Requirements: ACIS CEI specification 36-01101, paragraph 3.2.1g, requires that the mean (pixel averaged) quantum efficiency of each CCD, measured at wavelengths between 400 and 1000 nm, shall not exceed 10^{-6} when the optical blocking filter is in place.	
Waiver Requested: It is requested that the 10^{-6} requirement be waived.	
Justification/Reason: In order to achieve Xray sensitivities desired, the spectrometer Optical Blocking Filters (OBFs) were constructed using 2000Å polyimide with 300Å of aluminum on one side and 1000Å of aluminum on the other side. The Principal Investigator (PI) specified, tested, and selected the flight OBFs. This results in detector S0 and S1 seeing visible light with an efficiency of $1.68e^{-5}$ and $1.01e^{-5}$ respectively. The average detection efficiency is $6.45e^{-6}$. See the attached light -leak test results dated 6/19/97.	
Related Action and Effect: **(include cost/price)**	

FUNCTION	APPROVAL SIGNATURE	DATE
MIT Performance Assurance Manager	Brian Klatt	8/4/97
MIT Project Engineer	[signature]	8/4/97
MIT Project Manager	William Mayer	8/4/97
NASA Representative		
NASA Project		

ACIS Memo # PS - 137
MWB

Massachusetts Institute of Technology

Center for Space Research
Cambridge, MA 02139
Room 37-521
mwb@space.mit.edu

June 19, 1997

To: MIT ACIS Team
From: Mark Bautz
Subject: Preliminary Analysis of ACIS light-leak test data from Lincoln Labooratory Instrument thermal vacuum test.

NOTE: This analysis is preliminary, and has been prepared solely to support formal ACIS verification reporting activities. More detailed, accurate analysis, examining in particular the spatial variation of visible light detection efficieny, is in progress.

1 Summary

The effective visible/near IR light detection efficiency of the ACIS flight system was measured in April, 1997 in the course the second ACIS instrument thermal vacuum test at MIT Lincoln Laboroatories. This memo summarizes preliminary analysis of the data obtained in this test. The instrument meets the Contract End Item Specification (section 3.2.1g) for incident light of wavelength 660 nm. At 880nm, the measured detection efficiency exceeds the specified upper limit by a factor up to 1.7 in detectors S0 and S1. Although uncertainties in the uniformity of the illumination pattern are at about the factor of 2 level, the observed localized regions of excess efficiciency are are a matter of concern. Additional analysis of other light-leak measurements, in particular those made at XRCF, may reduce the uncertainties. It may be necessary to make additional light-leak measurements, with a beam of known uniformity, to resolve this issue.

2 Test Description

2.1 Light Sources and Instrument Configuration

The data discussed here were acquired on 10 April 1997, near the end of the second ACIS Instrument thermal vacuum test at Lincoln Laboratory. The instrument was illuminated at two light levels using each of two light-emitting diode sources. Peak emission occurs at 660nm and 880 nm, respectively, for the two diodes. These wavelengths were chosen because they are near the peak CCD efficiency and maximum filter transmission, respectively. The outputs of the diode sources were calibrated at MIT CSR using a front-illuminated flight-sibling CCD detector. The detector used to calibrate the sources was not absolutely calibrated, but an approximate calibration, based on Lincoln Laboratory measurements, is expected to be be accurate to better than 30%. The detector efficiencies assumed for this report are 70% at 660 nm and 35% at 880 nm. Details of the LED calibration are presented elsewhere in a memo by S. Jones (ACIS memo PS-136).

LED Source Wavelenght(nm)	LED Current (mA)	Flux ($photons\, 3.3s^{-1}\, pixel^{-1}$)	Remarks
660	0.61	9.4×10^4	assumed reference CCD efficiency 0.7
660	140	2.8×10^7	assumed reference CCD efficiency 0.7
880	0.41	1.8×10^5	assumed reference CCD efficiency 0.35
880	29.5	4.5×10^7	assumed reference CCD efficiency 0.35

Table 1: Illumination Levels

At Lincoln, the LED sources were located approximately 70.5 inches from the focal plane. The estimated illumination levels are listed in table 1. Only the high-illumination test results are discussed here.

The instrument was configured to operate in timed exposure mode with an integration time of 3.3 s. The parameter block used was deflbias.te. The focal plane temperature was near -110C, but not under active control during the data acquisition. The electronics were at hot case temperatures. Data were acquired from the high-speed tap. For each illumination condition, 10 frames were acquired from each chip in the focal plane. Two science runs were started in the test; the spectrometer detectors (s0-s5) were measured with the first science run, and the imager detectors (i0-i3) with the second. At the conclusion of each science run, 10 bias frames were acquired for each active CCD. Data were stored in directory /glenl/d5/10Apr97/0923 and archived on DLT tape LLTV2 number 22. See the README file there for other details.

2.2 Data Acquisition and Analysis

Exposed and unexposed data sets for each chip and each illumination condition were averaged using the mean_biascplip2 program, which implements a precursor version of the med_mean flight bias algorithm, and thus removes most cosmic ray artifacts. Differences between the (10-frame) mean exposed and mean bias data were formed and overclock corrected. Typical overclock noise levels in the mean differences were of order 1.1 electrons, rms. To obtain the spatially averaged detection efficiency, the overclock-corrected differences were simply averaged over the frame. The RMS variation about the mean was also computed. We have also computed the effective filter transmission, assuming that the flight detectors and the reference detector had the same efficiency. This assumption may not be accurate for detectors S1 and S3, which are back-illuminated devices, and may therefore be more efficient than the reference detector.

2.3 Errors

If the bias correction were perfect, the standard error of the resulting detection efficiency numbers would be of order one part in 10^{-3}. In practice, there is considerable bias subtraction error (the test was done before the "jitter dacs" patch was available), and I estimate that systematic errors in the the mean could be as high a 5 electrons. Note also that the visible light detection efficiency assumed for the reference detector purposes of this analysis may be in error by as much as 30%. Uncertainties resulting from the geometry of the Lincoln Lab configuration, and the source reproducibility, are estimated to be less than 20%.

Undoubtedly, the largest uncertainty is the uniformity of the illumination pattern. The LED sources are not internally collimated, so substantial reflections from the inside of vacuum hardware or the instrument collimator may have been present. On the basis of images acquired during LED calibration, we estimate that non-uniformities in the illumination pattern might be as large as a factor of 2.

3 Results and Discussion

Mean estimated detection efficiencies at two wavelengths are listed in Tables ?? and ??. We present the inferred filter transmission separately, because it is unaffected by errors in the assumed bare-CCD detection efficiency.

The CEI requirement (system efficiency less that 1.e-5) is met by all detectors at 660 nm. Formally, detectors s0 and s1 fail to meet the specification at 880nm by about a factor of 1.5. Inspection of the image of the detected light (not presented here) shows that most of the light is concentrated along the +X edges of these detectors, and that in small regions the efficiency reaches about 5e-5. The pattern is observed at both wavelengths, but the ratio of effective filter transmissions at the two wavelengths in detector s0 is about what is expected for a 1300-angstrom-thick aluminum filter. The relative transmissions at 880 nm in s0 and s5, say, could result from an aluminum thickness variation of about 100 A (out of a nominal 1300A) from one side of the filter to the other. A thickness variation this large appears to be inconsistent with X-ray transmission measurements of the filters. As noted above, it is possible that the illumination is non-uniform, we cannot rule out the possibility that the apparently high detection efficiencies are merely an artefact of the illumination pattern. One the other hand, if the excess transmission were due to poor mating of the filter to the detector housing, one would expect the filter transmission in s0 to be similar at the 660nm and 880nm, so the the filter-to-housing seal is probably not the source of the apparent light leak.

Clearly, additional analysis is required to evaluate the causes and impact of the observed filter transmission. Data already acquired at XRCF may be useful for this purpose. It must be stressed that local regions of high detection efficiency (which are NOT well constrained by the CEI specification) could degrade ACIS performance significantly. It is therefore recommended that additional measurements be made with illumination of known uniformity be considered.

Detector	Inferred Filter Transmission	Mean Detection Efficiency (all pixels, filter + detector)	RMS Efficiency Variation
i0	3.1e-07	2.17e-07	8.47e-08
i1	1.13e-07	7.95e-08	4.9e-08
i2	4.36e-07	3.05e-07	1.11e-07
i3	1.59e-07	1.11e-07	5e-08
s0	6.64e-07	4.64e-07	1.63e-07
s1	4.96e-07	3.47e-07	2.63e-07
s2	2.36e-07	1.65e-07	6.2e-08
s3	1.64e-07	1.15e-07	6.56e-08
s4	9.3e-08	6.51e-08	5.57e-08
s5	1.23e-07	8.62e-08	5.3e-08
Specification:		<1.e-5	

Table 2: Detection Efficiency at 660 nm. All detectors meet the CEI specification. Note that systematic error in the mean efficiency and effective filter transmissions, which are dominated by uncertainties in the uniformity of the illumination pattern, may be as large as a factor of two.

Detector	Inferred Filter Transmission	Mean Detection Efficiency (all pixels, filter + detector)	RMS Efficiency Variation
i0	9.45e-06	3.31e-06	1.01e-06
i1	3.78e-06	1.32e-06	1.73e-07
i2	1.37e-05	4.78e-06	1.12e-06
i3	4.55e-06	1.59e-06	3.52e-07
s0	4.79e-05	1.68e-05	4.46e-06
s1	2.87e-05	1.01e-05	3.18e-06
s2	2.5e-05	8.77e-06	1.18e-06
s3	1.65e-05	5.78e-06	1.35e-06
s4	1.6e-05	5.59e-06	6.43e-07
Specification:		<1.e-5	

Table 3: Detection Efficiency at 880 nm. Formally, detectors s0,s1 and s2 do not meet the CEI specification. Note, however, that systematic error in the mean efficiency and effective filter transmissions, which are dominated by uncertainties in the uniformity of the illumination pattern, may be as large as a factor of two.

Massachusetts Institute of Technology
Center For Space Research
Cambridge, Massachusetts 02139

Room 37-662C, e-mail: sjones@space.mit.edu

From: Stephen Jones
To: ACIS Team
Subject: Lincoln Labs Calibration Sources
Date: June 20, 1997

This memo briefly describes the sources used at the Lincoln Labs calibration facility during the ACIS thermal-vac test. The source could provide for either x-ray or optical photons. The x-ray source is a fluorescent source similar to the HEXS sources used at the MIT CCD lab. However there is only a choice of 4 different targets, each producing corresponding k alpha x-rays: aluminum, silicon, titanium, and copper. In addition an Fe55 source can be inserted to produce manganese k alpha x-rays. Each source is emplaced by linear and rotary motion feedthroughs. Table 1 records the formal positions of the HEXS angular dial, HEXS axial position indicator, and Fe55 translator position for produce the desired x-ray spectrum. Table 2 displays the measured fluxes for each source. The measurements were made at both MIT and Lincoln Labs, with source - ccd distances of 42 inches and 70.5 inches, respectively. The flux is measured in units of G02346 counts per 3.3 second frame per quadrant. In the last two columns are the predicted number of frames and integration times required to achieve 100,000 G02346 counts. It is not clear why the detected ratios at both laboratories differ from the square of the stated distance ratios. The MIT measurement was conducted without the optical blocking filter which absorbs about 15 percent of aluminum photons. Also, the MIT measurements were conducted with a CCD not belonging to the flight focal plane, and with difference electronics.

The optical source uses a red LED and an infrared LED, with respective wavelengths of 660 and 880 nm. The intensity was calibrated at MIT using a CCD-17 at a distance of 48±1 inches. The goal was an optical source that could produce about $1 \times 10^{10} photons/sec/cm^2$ before the optical blocking filter. This number results from the filter's attenuation factor of about 10^7 Thus, the calibration measurement was tricky because it must span 6 orders of magnitude! This was accomplished using a set of neutral density filters and a pulse generator. Another significant problem was optical focusing from the hardware which caused uneven illumination on the CCD. The results are shown in Figure 1 for both the red LED (stars) and the infrared LED (squares). Printed at the top of the figure are the equations for the best fit quadratic curve. The current is in units of microamps, while the intensity is in units of ADU/pixel/3.3 seconds.

Note that the requirement of $1 \times 10^{10} photons/sec/cm^2 = 1.9 \times 10^5$ ADU/pixel/3.3 sec at 48 inches is provided by infrared and red currents of 410 and 620 microamps, respectively. Using the Lincoln Labs LED-source distance of 81.5 ± 2 inches, the flux at these current settings would be reduced by a factor of $(81.5/48)^2 = 2.9 \pm 0.1$, or $6.6 \times 10^4 photons/sec/cm^2$. Data at Lincoln Labs was also taken at 140 mA and 29.5 mA for the red and infrared LED, respectively: the corresponding fluxes are calculated to be 2.0×10^7 and $1.6 \times 10^7 photons/sec/cm^2$. It is felt that the uncertainty of the flux at the Lincoln Labs focal plane is about a factor of two, mostly due to uncertainty about internal reflections by the hardware.

Table 1. Positions for Different X-ray Sources

Source	HEXS Angular Dial [degrees]	HEXS Axial Position [inches]	Fe^{55} Translator Position [inches]
Al	15°	1.0	0.0
Si	105°	1.0	0.0
Ti	285°	1.0	0.0
Cu	195°	1.0	0.0
Fe^{55}	Anything	0.0	1.5
LED	Anything	0.0	0.0

Table 2. Expected X-ray Flux for X-ray Sources

Source	CSR Flux (/qd@42 in)	LL Flux (/qd@70.5 in)	No. Frames for 10^5 G02346 cnts.	Time (min) for 10^5 G02346 cnts.
Fe^{55}	1215	603	166	9.7
X-ray Target Al	320 (100 uA)	598 (400 uA)	170	9.7
Si	490 (100 uA)	801 (400 uA)	125	7.3
Ti	*	1100 (120 uA)	90	5.3
Cu	1060 (100 uA)	740 (100 uA)	180	10.6

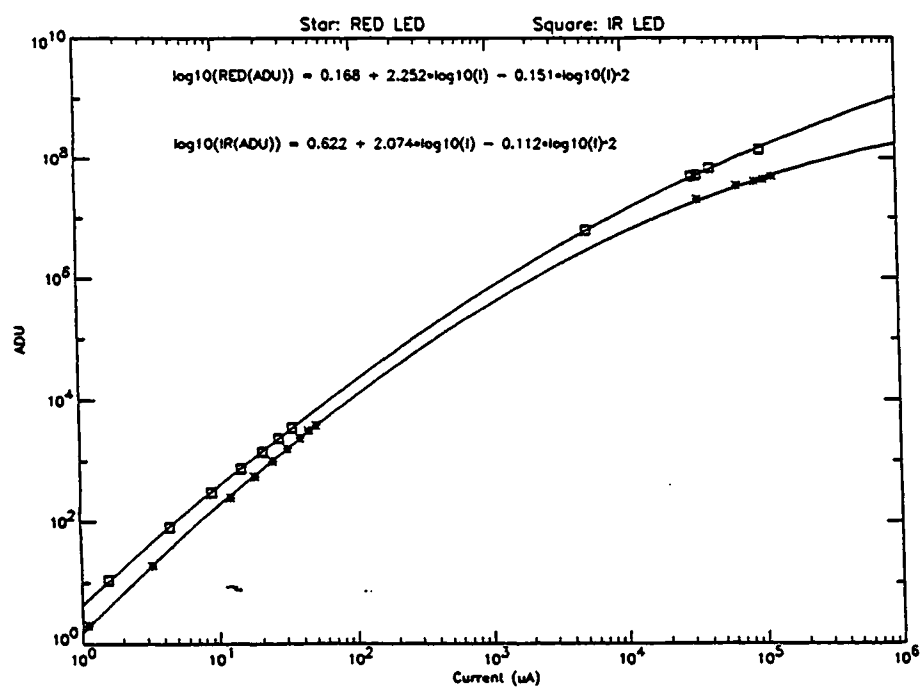

Figure 1: LED Flux (ADU/Pixel/3.3sec) vs. Current (48 inches apart)