36-01510.052

ACIS Verification Summary Report

Specification:	ACIS Contract End Item Specification
Requirement Number/Title:	3.2.1 Performance (VRSD 3.2.1d-3)

Requirement Statement: The CCD quantum efficiency shall nominally exceed 50% between 0.7 and 8 KEV.

Verification Method:	Measurement

Procedure Number:

Configuration:

Cycle Time:

Verification Discussion/Results:

Results of CCD quantum efficiency measurements are contained in ACIS PS-memo 131, M. Bautz, 25 Apr 1997. The ACIS CCD calibration plan is described in 36-01323A.

Memo attached ~~to 36-01510.051~~

29 May 1997 _____ ACIS Cognizant Engineer

Date

ACIS Memo # PS - 131

M. BAUTZ 37-521

Massachusetts Institute of Technology

Center for Space Research
Cambridge, MA 02139
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April 25, 1997

To: MIT ACIS Team
From: Mark Bautz for the ACIS CCD Calibration Team
Subject: ACIS Flight CCD Detector Performance

Attached find a number of tables and graphs summarizing ACIS flight CCD performance. These data were obtained from the ACIS CCD Sub-assembly calibration at the MIT Center for Space Research. The analysis represents a first reduction of the data. It is expected that continuing analysis will refine the results presented here.

Detectors have been installed in the flight focal plane at the positions indicated in the table 1. These location assignments are illustrated in Figure 1, and are consistent with the ACIS focal-plane-to- detector housing interface control document (MIT drawing number 36-02203), the Science Instrument to Observatory Interface Control Document.

Device	Focal Plane Location	Device Type
w203c4r	I0	Front-illuminated
w193c2	I1	Front-illuminated
w158c4r	I2	Front-illuminated
w215c2r	I3	Front-illuminated
w168c4r	S0	Front-illuminated
w140c4r	S1	Back-illuminated
w182c4r	S2	Front-illuminated
w134c4r	S3	Back-illuminated
w457c4	S4	Front-illuminated
w201c3r	S5	Front-illuminated
w198c1	backup	Front-illuminated
w461c4	backup	Front-illuminated

Table 1: Flight Focal Plane Detector Position Assignments

In an effort to characterize the relative performance of the detectors, I have assigned numerical ranks or grades (1-3) to the detectors using four criteria : spectral resolution, low-energy detection efficiency, high-energy detection efficiency and cosmetics. These ranks are listed in Table 2 and defined in Table 3. The ranks have been assigned on the basis of absolute performance, with the intent that differences in rank reflect real (statistically significant) differences inperformance. Note that performance differences among the front-illuminated flight detectors are small; the full-range of variation of each performance parameter is never more than ± 10 %, and most detectors are within ± 5 % of the mean in each parameter. In contrast, the back-illuminated candidate detectors show a very large range in spectral resolution.

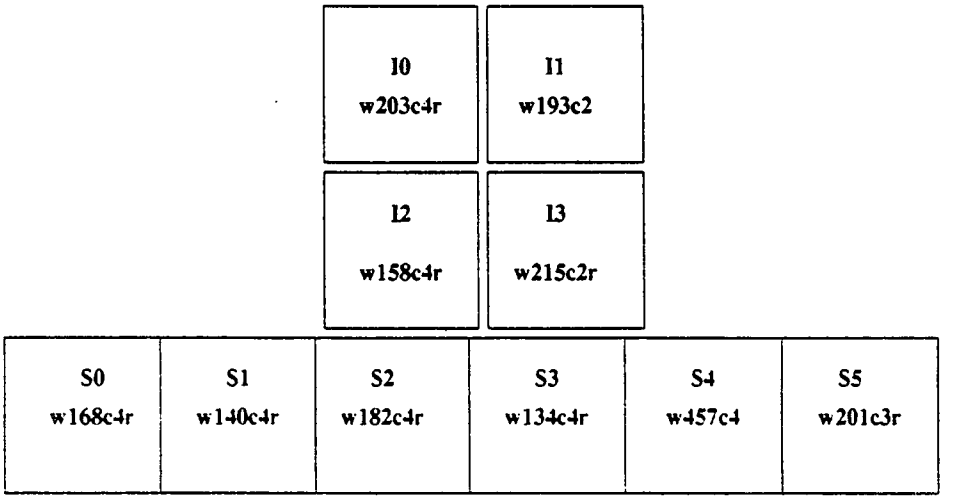

Figure 1: ACIS flight focal plane detector position assignments (viewed from HRMA).

Subsequent tables contain detailed information on detector parameters (noise, dark current, charge transfer efficiency, and cosmetics; Table 4), X-ray detection efficiency (Tables 5 and 6), spectral resolution (Table 7), energy scale linearity and temperature sensitivity (Table 8), and depletion depth (Table 9), for each flight candidate detector. Some explanatory notes follow the last table.

The measured detection efficiencies of the flight detectors, relative to the I3 (w215c2r) detector, are shown in Figures 2 and 3. The absolute detection efficiency of the I3 (w215c2r) detector, as inferred from measurements made relative to a PTB/Bessy-calibrated transfer standard detector w190c3, are shown in Figure 4. Spectral resolution is shown as a function of energy in Figure 5.

Device	Focal Plane Location	Criterion				Remarks
		Spectral Resolution	Detection Efficiency		Cosmetics	
			@ 0.5 keV	@ 8 keV		
w158c4r	I2	1	1	3	1	
w168c4r	S0	2	1	3	1	
w182c4r	S2	2	1	2	1	
w201c3r	S5	2	2	2	2	low gain, qd. D
w203c4r	I0	1	3	3	3	bad col cluster, qd. A
w215c2r	I3	1	2	3	1	
w193c2	I1	1	3	3	1	
w457c4	S4	2	1	2	1	
w198c1		1	3	2	2	2 bad col. clusters
w461c4		3	2	1	1	low gain qd. A-D
w134c4r(BI)	S3	BI2	BI1	BI1	BI2	
w140c4r(BI)	S1	BI3	BI1	BI1	BI1	

Table 2: Detector Performance Rankings (Lower numbers are better)

Rank	Criterion (Fraction in Rank)			Remarks
	Spectral Resolution FWHM(eV) @ 0.5 keV	Detection Efficiency relative to w190c3(F1)		Cosmetics: Max. no. bad col. in any contiguous 32
		@ 0.5 keV	@ 8 keV	
1	44-47 (5/10)	1.03-1.06 (4/10)	1.06 (1/10)	1 (7/10)
2	48-50 (4/10)	1.00 - 1.02 (3/10)	0.95 - 1.03 (4/10)	2 (2/10)
3	52-57 (1/10)	0.97 - 0.99 (3/10)	0.90 - 0.94 (5/10)	3 (1/10)
BI1	90-111 (1/3)	All	All	1 (1/3)
BI2	130-140 (1/3)			2 (1/3)
BI3	155-170 (1/3)			~ 6 (1/3)

Table 3: Detector Performance Rank Definitions

Device	Focal Plane Location	Noise (e^- RMS) DEA s/n14	PCTI ($\times 10^{-6}$ at 5.9 keV)	Mean Dark Current ($\epsilon^-/pix/s$ at T=-120C)	Cosmetic Defects		
					Bright Cols.	Bad Cols.	Other/ Remarks
w158c4r	I2	2.5 - 4.0	< 1	< 0.01	0	2	bc 135,420
w168c4r	S0	2.2 - 2.5	< 1	< 0.01	0	4	bc 7,661,820,965
w182c4r	S2	2.0 - 3.9	< 1	0.02 - 0.05	0	3	bc 379,438,603
w201c3r	S5	1.9 - 2.1	< 1	0.04 - 0.06	0	5	bc 21,105. pbc 153,155,973
w203c4r	I0	1.8	< 1	0.01	3	1	bc 963 hc 71 - 73
w215c2r	I3	1.8 - 2.0	< 1	0.01 - 0.002	0	2	23?,644
w193c2	I1	1.8 - 2.0	< 1	< 0.01 - 0.02	2	1	pbc 991 hc 303,409
w457c4	S4	2.3 - 2.5	< 1	0.09	1	0	bc 977
w134c4r(BI)	S3	2.3 - 2.5	13 - 14	0.01 - 0.02	1	3	pbc 594,876,939,940 hc 497
w140c4r(BI)	S1	2.2 - 2.4	26 - 27	0.02-0.04	0	1	hc 383
w198c1		2.7 - 3.0	< 1	tbd	2	4	bc 254,392,407,806 hc 241,936
w461c4		2.9 - 3.1	< 1	< 0.03 - 0.05	0	1	bc 727

Table 4: Detector Performance Characteristics

Device	F. P. Loc.	Mean (RMS) Efficiency at Energy (keV)							Ref. Det.	Remarks
		0.53	0.68	1.74	2.01	4.51	5.89	8.05 raw/cor.		
w158c4r	I2	0.922 (0.0142)	0.813 (0.018)	1.014 (0.024)	1.013 (0.024)	1.043 (0.027)	1.115 (0.029)	1.177/1.079 (0.034)	w103c4	cu@30μA
								1.108/1.076 (0.052)	w103c4	cu@10μA
w182c4r	S2	0.952 (0.021)	0.926 (0.023)	1.022 (0.037)	1.012 (0.024)	0.936 (0.021)	1.109 (0.026)	1.28/1.18 (0.038)	w103c4	cu ref?
w193c2	I1	0.893 (0.167)	0.779 (0.017)	1.069 (0.027)	0.997 (0.028)	1.040 (0.028)	1.114 (0.032)	1.191/1.091 (0.033)	w103c4	
w203c4r	I0	0.856 (0.026)	0.767 (0.022)	1.021 (0.033)	0.985 (0.033)	1.040 (0.036)	1.111 (0.037)	1.187/1.088 (0.054)	w103c4	
w203c4r	I0	0.970 (0.019)	0.996 (0.020)	1.000 (0.025)	0.989 (0.026)	0.999 (0.026)	0.983 (0.026)	0.948 (0.025)	w190c3	
w168c4r	S0	1.059 (0.023)	1.084 (0.024)	1.005 (0.021)	1.015 (0.022)	0.999 (0.022)	0.976 (0.021)	0.933 (0.022)	w190c3	
w201c3r	S5	1.007 (0.019)	1.034 (0.021)	1.002 (0.022)	0.995 (0.021)	1.002 (0.022)	1.003 (0.051)	1.008 (0.026)	w190c3	fe55 prob?
w215c2r	I3	1.002 (0.019)	1.018 (0.020)	1.000 (0.019)	0.993 (0.019)	0.984 (0.018)	0.988 (0.019)	0.944 (0.020)	w190c3	
w457c4	S4	1.022 (0.017)	1.074 (0.027)	1.012 (0.028)	1.012 (0.028)	1.006 (0.027)	1.004 (0.028)	1.006 (0.027)	w190c3	
w198c1		0.987 (0.019)	0.986 (0.021)	1.000 (0.030)	0.994 (0.030)	1.002 (0.030)	1.000 (0.032)	0.985 (0.032)	w190c3	
w461c4		1.003 (0.017)	1.059 (0.018)	1.012 (0.027)	1.022 (0.028)	1.009 (0.028)	1.017 (0.027)	1.061 (0.030)	w190c3	
w134c4(BI)	S3	1.06	1.01	1.00	0.99	1.07	1.03	0.98	w147c3	BI ref.
w134c4(BI)	S3	3.37 (0.06)		1.11 (0.018)	1.52 (0.033)	1.00 (0.030)	0.89 (0.030)	0.83 (0.045)	w203c2	FI ref.
w140c4(BI)	S1	2.95	2.50		1.38	0.94	0.83		w102c3	FI ref.
w140c4(BI)	S1		2.51 (0.07)	1.08 (0.030)	1.49 (0.066)	0.97 (0.094)	0.83 (0.065)	0.71 (0.029)	w103c4	FI ref.

Table 5: Spatially Averaged Relative Detection Efficiency

Device		Mean (RMS) Efficiency at Energy (keV)							Ref. Detector	Remarks
		0.53	0.68	1.74	2.01	4.51	5.89	8.05 raw/cor.		
w190c3		0.899 (0.021)	0.786 (0.018)	0.988 (0.028)	0.957 (0.027)	1.076 (0.029)	1.154 (0.033)	1.336/1.195 (0.038)	w103c4	
w190c3		0.882	0.770	1.021	1.004	1.041	1.130	1.252/1.148	w103c4 *via* w203c4r	

Table 6: Spatially Averaged Relative Detection Efficiency of Reference Detectors

Device	F.P. Loc.	FWHM (eV) at Energy (keV)							DEA/ Cham
		0.53	0.68	1.74	2.01	4.51	5.89	8.05	
w158c4r	I2	45-47	47-49	73-76	76-78	110-112	127-130	152-156	12/bu
w168c4r	S0	45-49	48-51	73-79	76-80	111-116	129-136	157-165	14/be
w182c4r	S2	47-50	50-53	74-76	80-81	111-115	131-132	154-156	12/bu
w201c3r	S5	45-49	48-51	73-77	76-79	110-113	128-133	155-163	14/be
w203c4r	I0	45-46	48-49	73-75	76-77	110-111	128-129	156-158	14/be
w203c4r	I0	44-45	50-50	73-74	75-76	110-111	127-129	154-156	12/bu
w215c2r	I3	46-47	49-50	74-75	76-77	111-112	128-130	157-158	14/be
w461c4		52-57	54-59	78-84	80-85	115-120	134-142	163-176	14/be
w193c2	I1	45-46	48	74-75	77-78	112-113	128-129	154-155	12/bu
w457c4	S4	48	51	75-76	78-79	113-114	131-132	160-162	14/be
w198c1		46-47	50	74-75	77	111-112	129-130	156-158	14/be
w134c4(BI)	S3	130 - 140	124 -130	130 - 138	146 - 158	169 - 180	185 - 203	205 - 225	14/be
w140c4(BI)	S1	155 - 168	160 - 175	180 - 200	200 - 230	242 - 280	260 - 300	300 - 340	14/be

Table 7: Spectral Resolution

Device	F.P. Location	Mean Gain at T=-120C (eV/adu) (HIRFEFS)	Offset at T=-120C (eV)	RMS Dev. from Line (eV)	Gain Temp Variation (dln(G)/dC) $\times 10^{-5}$	Remarks
w158c4r	I2	3.865			-10	
w168c4r	S0	4.059			54	
w182c4r	S2	4.042			< 6	
w201c3r	S5	4.316			< 6	
w203c4r	I0	3.990			< 6	
w215c2r	I3	4.250			< 6	
w193c2	I1	3.972			< 6	
w457c4	S4	4.375			-8	
w198c1		4.200				9
w461c4		4.775			-12	
w134c4(BI)	S3	5.109			< 6	
w140c4(BI)	S1	5.134				< 6?

Table 8: Energy Scale Characteristics

Device	Proposed Location	Depletion Depth, μm		Remarks
		Φ PI = +2.+10V (standard)	Φ PI = -5.+5V (reduced dark current)	
w203c4r	I0	64-65	42-45	
w193c2	I1	64-65	48	
w158c4r	I2	64-65	48	
w215c2r	I3	64-65	47-49	
w168c4r	S0	63-64	45-46	
w182c4r	S2	75-76	49-51	red. d.c problem?
w457c4	S4	70-72	53-54	
w201c3r	S5	71-72	52-54	
w198c1		69-71	51-52	
w461c4		77	58-60	

Table 9: Depletion Depth Estimated from 5.9 keV branching ratio

Notes for Tables:

1 Parameter ranges indicate span observed on 4 output nodes of each chip.

2 "Bright" columns (bc) have anomalously high dark current; "bad" columns (bc) have anomalously low detection efficiency; "partial bad columns" (pbc) have detection efficiency at least 90% of nominal.

3 Spectral resolution quoted for event grades 02346, split threshold of $15e^-$.

4 Relative quantum efficiency is spatially averaged detection efficiency for ASCA grades 02346, within $\pm$ 3 σ of line center.

5 Pileup-corrected relative efficiencies for 8.05 keV assume 12.9% pileup in w103c4 and 3.3% pileup in w190c3 and all flight candidate detectors.

6 Depletion depth can be estimated from branching ratio only for front-illumianted detectors.

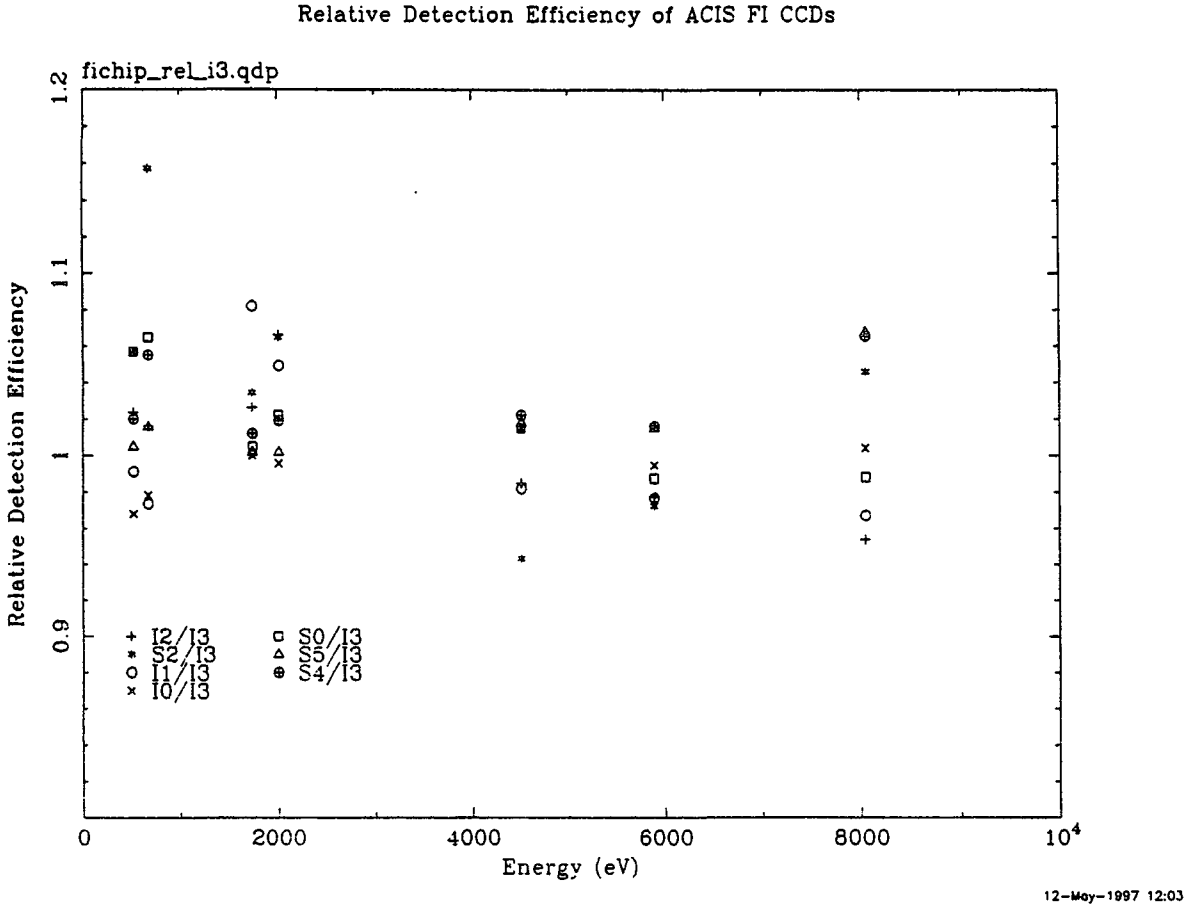

Figure 2: Measured, spatially averaged, detection efficiency of ACIS flight CCDs, relative to the detector in I3 (w215c2r). These data were obtained from flat field measurements made at MIT CSR. Each measurement represents approximately 10^7 detected photons per detector, so errors due to counting statistics are neglible.

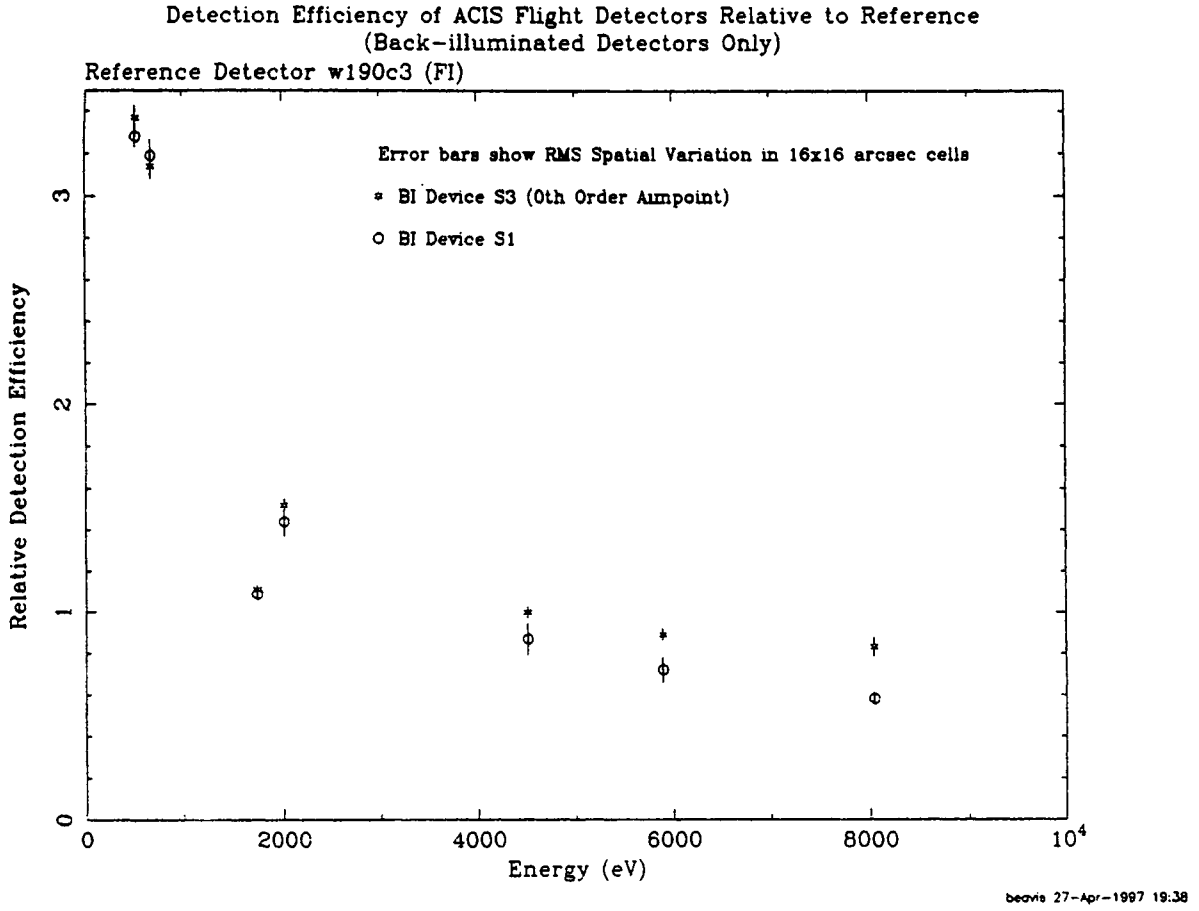

Figure 3: Measured, spatially averaged, detection efficiency of ACIS flight CCDs, relative to the reference detector in w190c3. These data were obtained from flat field measurements made at MIT CSR. Each measurement represents approximately 10^7 detected photons per detector, so errors due to counting statistics are neglible.

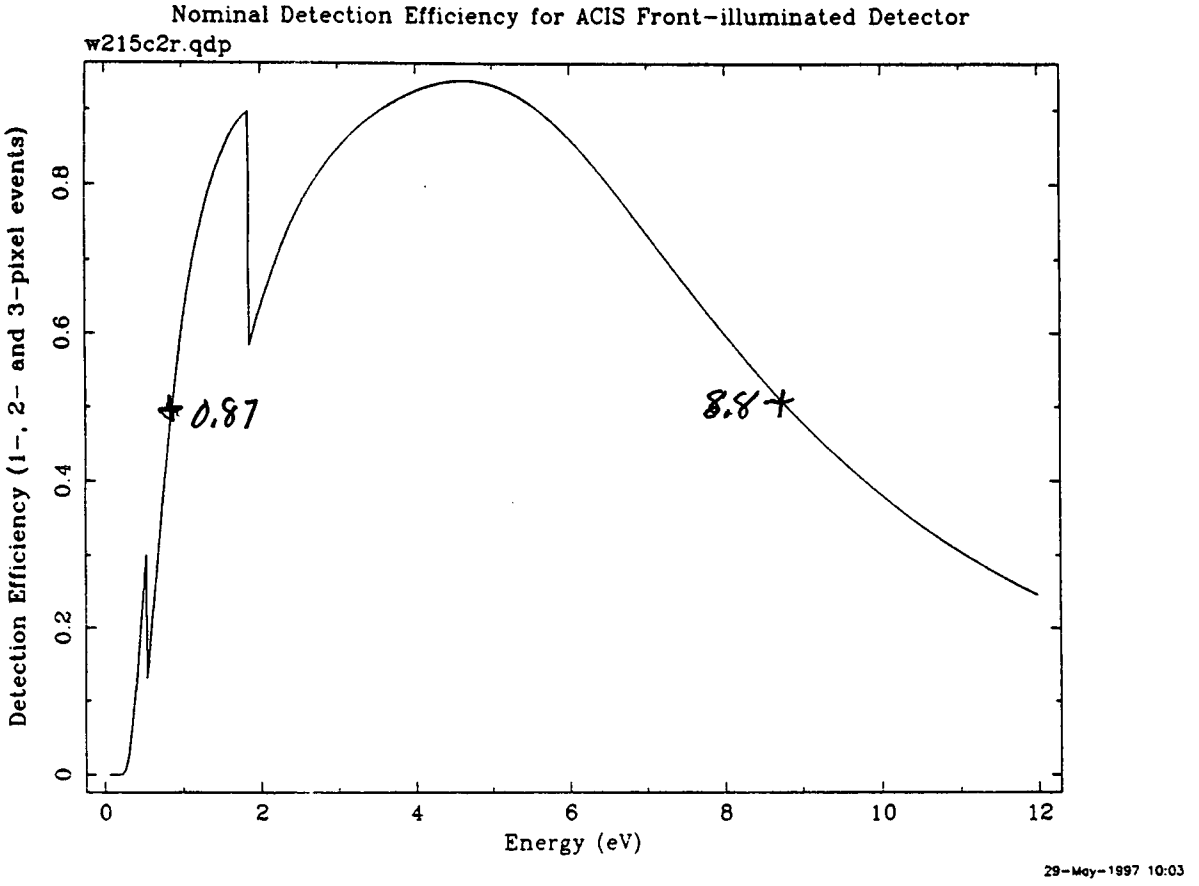

Figure 4: Best-fit model for the absolute detection efficiency of the detector in the I3 location of the ACIS flight focal plane (device serial number w215c2r). The curve gives detection efficieny for 1-, 2- and 3-pixel events with a split-event threshold of 15 electrons. It was obtained from absolute measurements of the detection efficiency of reference detector w190c3 made at the PTB/BESSY synchrotron, together with measurements of the detection efficiency of w215c2r relative to w190c3 made at MIT CSR.

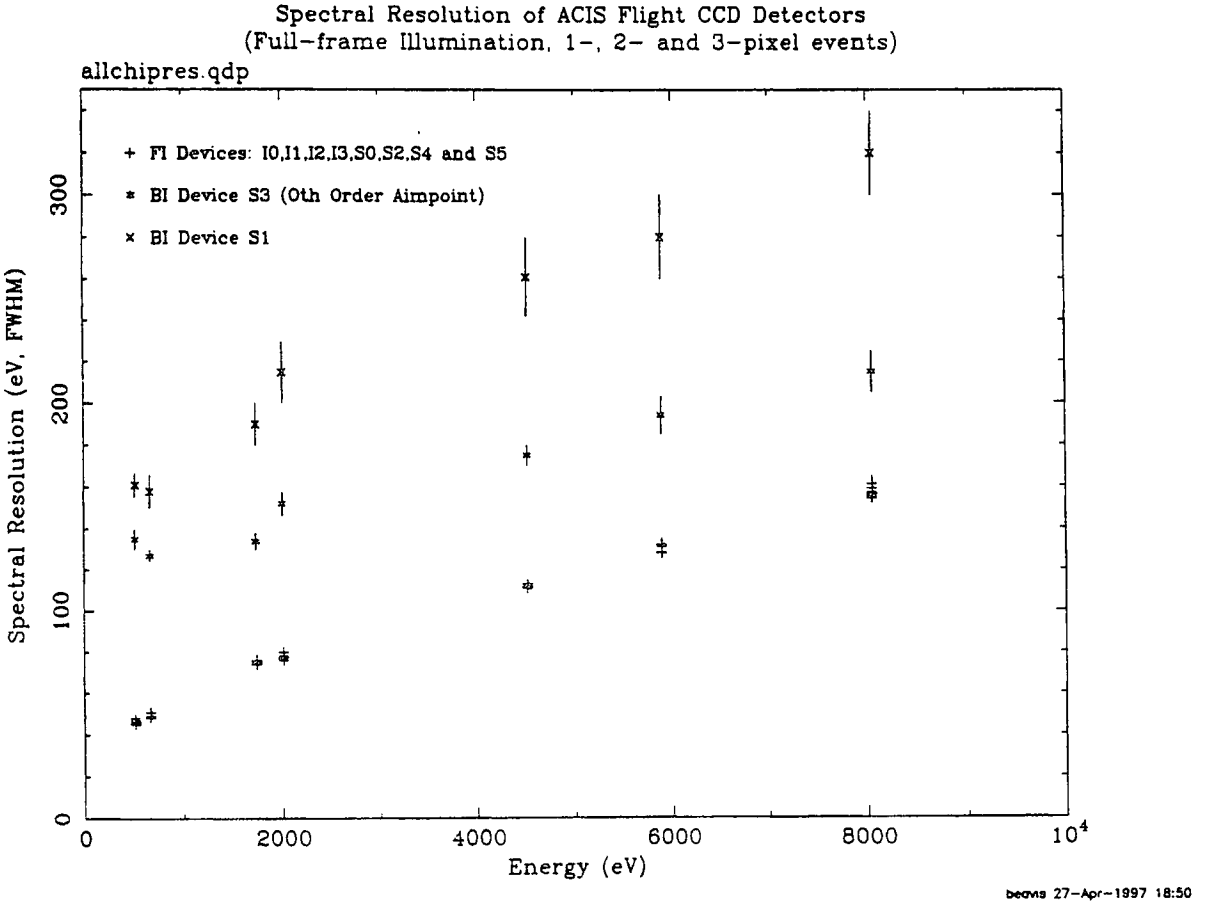

Figure 5: Measured spectral resolution (full-width at half-maximum) for ACIS flight detectors.

AXAF-I Verification Requirement Compliance Data Submittal

Element: ACIS

Requirement Number: 3.2.1

Verification Item: 3.2.1d-3 -1

Evaluators: CHE, SAO, IN&C

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

Requirement Title: Performance

Compliance Data/Location: MA-170/36.01510.052/Bldg 4200 Rm 522 (MIT Closure Report)

Verification Method: Test

Comments:

SAO/COJ-APPROVED, 6-24-97

IN&C - Disapprove: According to MIT, the Front Illuminated CCDs do not meet this requirement. Issue needs to be worked.

Disposition is incorrect due to an MIT error in the Acceptance Review presentation. See attached memo

William Mayer 7/21/97

Status: Open 6/3/97 due 6/27/97

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

Action Required for Closure:

MSFC Evaluator:	Date:	Organization:	Phone Number:

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

Action Required for Closure: Kurt correctly points out that ACIS does not quite get to 50% efficiency until about 0.88 KeV, but the spec says 0.7 KeV. The good news is that the Level I specifies the 50% line at 1 KeV, which ACIS meets. In any event, the preferred course of action is to submit a waiver.

Chief Engineer:	Date:
Anthony R. Lavoie	7/3/97

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

Room NE80-6043 617-253-7552

Memorandum

To: Tony Lavoie
From: W Mayer W. Mayer
Date: July 21, 1997
Subject: Verification Report 36-01510.052 (CCD Performance)

In the Verification Summary Report for this topic, submitted about June 1, MIT incorrectly stated the requirement at the top of the report. This error led to the belief that the Front Illuminated CCDs did not meet the CEI requirement for an efficiency of 50% between 0.7 keV and 8 keV. In fact, the actual requirement is stated in the following sentence of the CEI spec.

The exact CCD statement is "The CCD quantum efficiency shall nominally exceed 50% between 0.7 and 8 keV. The CCDs shall be deemed to have met the nominal specification if the specified quantum efficiency is exceeded over at least 75% of the specified passband." Apparently there was much discussion of this topic in the early days of AXAF and this statement was the outcome of long negotiations between Lincoln Labs, MIT, PSU and MSFC. It was well known that the CCDs would not have an efficiency of 50% at 0.7 keV, but the AXAF science team wanted to have a specification over the entire passband. Hence, the qualifier of 75% of the passband (for 50% efficiency) was added.

From the report previously submitted, one can determine the efficiency as a function of energy from Figure 4 of the attached ACIS memo #131. The efficiency exceeds 50 % continuously from 0.87 to 8.8 keV. A simple calculation results in the fact that the FI CCDs exceed an efficiency of 50% for over 97% of the 0.7 to 8 keV passband in the CEI. Since the stated requirement is 75%, ACIS easily exceeds the specification. Therefore, item #2 of Bob Goeke's presentation on Non-Conformances is hereby withdrawn.

We apologize for the confusion over this issue.

From: Mark W. Bautz <mwb@drang>
Subject: waive the CCD QE waiver
To: bk@drang (Brian Klatt), wfm@drang (William F. Mayer)
Date: Wed, 16 Jul 97 9:35:44 EDT
Cc: garmire@astro.psu.edu (Gordon Garmire)
X-Mailer: ELM [version 2.3 PL11]
X-UIDL: 869261741.024

052

Bill and Brian,

I write regarding the waiver request for verification item CEI 3.2.1d-3-1, the ccd quantum efficiency at 0.7 keV. In fact, no waiver is required because ACIS meets the requirement.

The CEI spec does not require that the monochromatic efficiency at 0.7 keV exceed 50%. Instead, it requires that the NOMINAL efficiency exceed 50% over the 0.7-8 keV band. By definition of NOMINAL in the CEI spec., we do meet the requirement, since the ccd efficiency exceeds 50% in at least 35% of the 0.7 to 8 keV passband.

This peculiar formulation was inserted in the CEI spec MSFC's insistence. MIT would never have specified that a front-illuminated CCD be capable of 50% qe at a monochromatic 0.7 keV, since it would require a gate structure that is much thinner than has ever been built at Lincoln.

It is probably also worth noting that over the years Max and Nes have reported annually to the IAR on ACIS performance, and in helping them prepare for these reviews, they and I have always agreed that the low-energy detection efficiency requirements were met because the back-illuminated ccd qe far exceeds 50% at 0.7 keV.

In fact the low-energy performance of the ACIS FI CCDs exceeds our expectations as well.

In any case, no waiver is needed, because ACIS meets the requirement; I must insist that none be submitted. I'd be happy to speak with Tony Lavoie about this.

mark