R. GOEKE'S COPY

REVISIONS

Letter	ECO No.	Description	Checked	Approved	Date
A	36-470	Initial Release	DK	RFG	2/1/96

NAME	DATE
Drawn: Mark Bautz	12 Jan. '96
Checked: Brian Klatt	1/31/96
Approved: R. Goeke	1/31/96
Released: D. Gage	2/01/96

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CENTER FOR SPACE RESEARCH

CCD Subassembly Calibration Plan

CSR

Size	Code Identification No.	Drawing No.	Rev.
T	80230	36-01323	A

Scale: NONE | Sheet: 1 of 11

ACIS CCD Subassembly Calibration Plan

MIT Center for Space Research
Drawing Number 36-01323
Rev. A

12 January 1996

Contents

List of Tables

1 Introduction

This document describes the objectives, measurements, and required measurement accuracies for ACIS CCD subassembly calibration to be performed at the MIT Center for Space Research. These calibration measurements will be performed on each flight candidate detector before it is assembled into a flight focal plane. Only detectors which meet the requirements established in the ACIS CCD Screening plan (ACIS memo PS-77) will be calibrated.

The CCD subassembly measurements described here are the first phase of ACIS calibration. Additional ACIS calibration will occur during ACIS integrated instrument testing, as part of AXAF system level calibration at the X-ray Calibration Facility at Marshall Space Flight Center, and through on-orbit calibration measurements performed after launch. Requirements for calibration at XRCF are described in MSFC Spec. 2229.

This document refers to a number of MIT ACIS Project Science Memoranda. These are listed in Table 1.

Memo Number	Title	Author	Date of Current Version
PS-69	High-Resolution Erect-Field Spectrometer Results	G. Prigozhin	19 April 1995
PS-71	ACIS Data Analysis and Database	J. Woo	4 May 1995
PS-72	Quantum Efficiency Energy Choice	T. Isobe	4 May 1995
PS-73	Response Matrices for ACIS	A. Rasmussen	5 May 1995
PS-75	High Energy X-ray Tube	S. Jones	24 May 1995
PS-76	Tritium X-ray Source	S. Jones	4 May 1995
PS-77	ACIS CCD Screening Requirements and Measurement Plan	M. Bautz	9 May 1995
PS-79	X-ray CCD Simulations	A. Rasmussen	26 June 1995
PS-81	CCD Tuning Procedure	G. Prighozhin	24 July 1995

Table 1: MIT ACIS Memoranda Relevant to Sub-assembly Calibration

2 CCD Subassembly Calibration Requirements

The CCD subassembly calibration measurements specified in this document have been selected via the following two-step process. First, scientific investigations which are most sensitive to ACIS calibration accuracy are identified. The corresponding AXAF observations are simulated using a parametric CCD response model, together with models of other components of AXAF. The parameters of the CCD response model are varied to determine the sensitivity of the scientific results to errors in the assumed CCD model parameters. The result of this first step is thus a set of constraints on the accuracy with which CCD model parameters must be determined.

The second step in the measurement selection process determines the accuracy with which various proposed laboratory measurements can constrain CCD response model parameters. This step requires some straightforward analyses and some simulation of feasible laboratory measurements. In principle, the product of this step is a suite of laboratory measurements that calibrates ACIS CCDs with accuracy adequate to meet scientific objectives.

The parametric CCD response model clearly plays a central role in the selection of calibration measurements. The CCD response model used to derive the CCD subassembly calibration measurements specified here is described in ACIS memos PS-73 and PS-79 (Rasmussen).

Practical considerations complicate the selection of calibration measurements. Specific, readily identifiable scientific measurement requirements do not provide a complete specification of calibration accuracy requirements. More fundamentally, one could not, even in principle, anticipate all measurements that will be made with AXAF. For these reasons, it is useful to have a clear, if somewhat arbitrary, set of calibration objectives with which to guide calibration planning. The objectives adopted to plan the CCD subassembly calibration measurements described here are therefore stated, though not justified, as part of each measurement description. These objectives are consistent with the calibration goals identified in MSFC-2229; the justification of the objectives is beyond the scope of this document.

The complexities of laboratory measurements and the oversimplifications inherent in feasible simulations of those measurements must also be accounted for in calibration planning. To allow for these uncertainties, this plan calls for more measurements than the absolute minimum number that simulations suggest is necessary. For example, simulations show that the required accuracy in quantum efficiency can be achieved with measurements at as few as four energies (see ACIS memo PS-72 (Isobe)); this plan calls for measurements at seven energies (see section 6 below.) The additional measurements allow for the evaluation of systematic errors in both the models and the measurements.

3 Priorities

Because the time available for calibration is severely limited, a priority has been assigned to each measurement described in this plan. Although the current sub-assembly calibration schedule (that of 17 September 1995) allows sufficient time for completion of all measurements described in this plan, the detailed calibration planning will endeavor to ensure that the highest priority measurements are completed first. It should be noted that in some cases, in order to minimize the overhead associated with installing the devices in the calibration chambers, the decision to make priority 2 measurements must be made on a detector-by-detector basis. Therefore, priority 2 measurements may be made on some detectors before priority 1 measurements have been made on others.

As an additional prioritzation measure, it has been recognized that the two outermost detectors in the ACIS-S array will be exposed to a relatively narrow spectral range. Specifically, detectors S0 and S5 (see the AXAF Observatory-to-SI Interface Control Document, MSFC CMa07), which serve the long-wavelength extremes of the grating readout, require the most accurate calibration only at energies below 1 keV. While calibration of these detectors over the full AXAF spectral range is useful because it improves knowledge of all detector model parameters, the low-energy calibration of these devices is of highest priority. Therefore the calibration of devices S0 and S5 have been prioritized separately from those of other devices in the focal plane. The assignment of specific detectors to specific locations in the focal plane will be based on the results of screening measurements (described in PS-77), which will be completed before the calibration measurements descrbied here are begun.

Priorities have been assigned by members of the ACIS science team, in consultation with with representatives of the AXAF Science Center. Measurements have been assigned one of three priority levels. Priority 1 measurements are regarded as the "minimum set" necessary at the sub-assembly level. Priority 2 measurements are regarded as more valuable than those in priority 3, though measurements in both categories are regarded as highly desirable.

4 General Assumptions

Unless otherwise noted, the following assumptions have been made in planning the calibration measurements:

i) It is assumed that each device has passed screening tests specified in the ACIS CCD Screening Plan (ACIS memo PS-77).

ii) The optimum CCD bias and clock levels are assumed to have been established immediately after the screening process, so time for this "tuning" is not allocated in this plan. Tuning measurements have been specified by Prigozhin in ACIS memo PS-81.

iii) Unless otherwise specified, the CCD will be readout in a full-frame mode at the maximum frame rate consistent with 100% exposure duty cycle. The readout time in this mode is assumed to be 2.7 s/frame (100 kpx/s/output node), which is the rate supported by the ACIS flight detector electronics.

iv) The readout format (including, for example, number of overclocks) and timing is assumed to simulate the flight timed exposure mode, with no windowing, as closely as possible.

v) A flux of 6400 counts/CCD/frametime (for a uniform, full-frame exposure) provides acceptably low pileup. At energies below 4 kev, the pileup fraction at this flux is estimated to be less than 4%.

vi) The nominal CCD operating temperature, -120C, will be maintained during calibration measurements unless otherwise specified.

vii) Unless otherwise noted, the measurements specified apply to both front- and back-illuminated devices. The sole exception to this policy is that only the back-illuminated devices require a quantum efficiency measurement at 277 eV.

viii) Data analysis and archiving are an integral part of each measurement. Details of the data formats, required analysis and resulting data products are specified in ACIS memo PS-71 (Woo).

5 Spectral Resolution Measurements (nominal conditions)

5.1 Objectives of spectral resolution measurements

i) Determine energy scale with an error less than 0.1%, and line full-width at half maximum (FWHM) with an error less than 5%.

ii) Determine off-peak features (Si Kesc, Si-K Fl) to 0.3% of total flux.

iii) Determine magnitude of low-energy tail with an accuracy 0.5% of main peak (error in integrated tail area : integrated main peak flux).

5.2 Assumptions for spectral resolution measurements

i) Spectral resolution is effectively independent of position on the CCD. This assumption will be verified at selected energies.

ii) Quantum efficiency measurements will provide spectral resolution data at energies different from those specified here (see next section).

5.3 Spectral Resolution Measurements

Details of spectral resolution measurements are listed in Table 2. Estimated elapsed time for both overhead (see section 8.2) and data acquisition are listed for each measurement group. Note that the time estimates for the High-energy X-ray Source (HEXS) measurements don't include warmup and vent times, since quantum efficiency measurements will be performed immediately after HEXS spectral resolutions measurements without venting.

System	Energy or Band (keV)	Total Counts (/energy/ccd quad.)	No. of Frames	Time(hours) O'head	Data	Total	Priority I0-3, S1-4	S0, S5
HIREFS Spectrometer	0.2-1.5	5×10^5 per band	5000	12	16	28	1	1
HEXS	1.489 (Al-K)	6×10^5 per energy	400 × 4	12	6	18	1	1
	2.622 (Cl-K)						1	2
	6.404 (Fe-K)						1	2
	9.886 (Ge-K)						1	2
	4.952 (V-K)	6×10^5 per energy	400 × 4	0	6	6	2	3
	6.930 (Co-K)						2	3
	7.478 (Ni-K)						2	3
	8.639 (Zn-K)						2	3
Si Edge Spectrometer	1.0-2.2	5×10^5 per band	5000	12	16	28	3	3

Table 2: Spectral Resolution Measurements

6 Quantum Efficiency Measurements (nominal conditions)

6.1 Objective

The objective of these measurements is to determine CCD detection efficiency, as a function of energy, with a statistical accuracy of 1% in each 32-pixel by 32-pixel detector cell.

6.2 Assumptions for quantum efficiency measurments

i) Tritium and HEXS will be used; both sources assumed to be available in each of two chambers.

ii) The nominal flux (6400 ct/CCD/frametime) is available from all sources.

iii) Reference detector will be illuminated by chopping. Reference measurements take same clock time as flight detector measurements

iv) Separate data acquisition systems are available for flight and reference detectors.

v) "Variable voltage" measurements will be made at two energies to confirm depletion depth measurements.

vi) To minimize pumpdown overhead, quantum efficiency measurements will be made immediately after high-energy spectral resolution measurements.

6.3 Quantum Efficiency Measurements

Details of quantum efficiency measurements are listed in Table 3. Note that the time estimates don't include pumpdown and cooldown times, since these measurements are assumed to follow immediately after high-energy spectral resolutions measurements.

System	Energy Range (keV)	Total Counts (/energy/ccd quad.)	No. of Frames	Time(hours) O'head	Data	Total	Priority I0-3, S1-4	S0, S5
Tritium (BI only)	0.277 (C-K)	2.5×10^6	1600	0	8	8	1	1
Tritium	0.525 (O-K)	2.5×10^6	1600×2	0	16	16	1	1
	0.677 (F-K)						1	1
HEXS	1.740 (Si-K)	2.5×10^6	1600×5	0	40	40	1	1
	2.014 (P-K)						1	2
	4.511 (Ti-K)						1	2
	5.899 (Mn-K)						1	1
	8.048 (Cu-K)						1	2
HEXS (var. volt.)	5.899 (Mn-K)	2×10^4/voltage	$200 \times 8 \times 2$	4	12	16	2	3
	8.048 (Cu-K)						3	3

Table 3: Quantum Efficiency Measurements

7 Measurements at "Off-nominal" Conditions

7.1 Objectives

Determine the effects of temperature, clock levels and readout modes on detector performance parameters (noise, dark current, charge transfer efficiency and cosmetics), energy scale, spectral resolution and quantum efficiency.

7.2 Parameters to be varied

7.2.1 CCD Temperature Variations

Measurements are to be made at the following off-nominal CCD temperatures: -130C and -110C.

7.2.2 Clock-level Variations

Aside from the "variable voltage" measurements described in section 5, the following "off-nominal" clock configuration is to be evaluated: minimum dark current mode (reduced levels in the imaging parallel clocks.)

7.2.3 Readout Mode Variations

Calibration data will be obtained in the following readout modes:

i) Continuous readout (no line summation).

ii) Continuous readout, 2 lines summed.

iii) Timed-exposure mode, 2x2 pixel summation.

iv) Timed-exposure mode, windowed readout. Two cases will be calibrated. In both cases, a window of 100 rows will be readout. The starting row numbers for the two cases are rows 1 and 924, respectively. These modes are calibrated because it is expected that they will be used during ACIS instrument calibration at the AXAF X-ray Calibration Facility (XRCF)

v) Frame-mode, AC/BD readouts.

7.3 Off-nominal Measurements

The various device performance, spectral resolution and quantum efficiency measurements to be made, and the associated off-nominal conditions for the measurements, are summarized in Table 4. All measurements referred to in Table 4 will be be performed according to procedures specified in the ACIS CCD Screening Plan (ACIS memo PS-77). As a result, the fundamental CCD parameters described in ACIS PS-77, including noise, dark current, and charge transfer efficiency will be characterized at each "off-nominal" condition referred to in the table.

System	Mode Specifications			Energies (keV)		Time(hours)			Priority	
	Temp.	Clock Levels	Readout Mode	Spectral Resolution	QE	O'head	Data	Total	I0-3, S1-4	S0, S5
HIREFS	-130C, -110C	nom.	nom.	0.2-1.5, 5.9	5.9	2	24	26	1	1
HIREFS	-110C	6.2.2	nom.	0.2-1.5, 5.9	5.9	0	12	12	3	3
IFM	nom.	nom.	6.2.3 iv) (windowed)	0.5,1.5,5.9	5.9	12	4	16	1	1
IFM	nom.	nom.	6.2.3 i), ii) (continuous)	0.5,1.5,5.9	5.9	0	8	8	2	2
IFM	nom.	nom.	6.2.3 iii) (2x2 sum)	0.5,1.5,5.9	5.9	0	4	4	3	3

Table 4: Off-nominal Calibration Measurements

8 Facilities and Scheduling Considerations

8.1 Facilities

The calibration will be performed using 5 source/detector systems at MIT Center for Space Research. These are described in Table 5. The High-Resolution Erect-Field Spectrometer and its capabilities are described in ACIS memo PS-69 (Prigozhin). The High-Energy X-ray Source (HEXS) and the tritium source are described in ACIS memos PS-75 and PS-76 (Jones).

Name	Source Type	Energy Range (keV)	Chamber Type	Detector Translation	Reference Detector	Remarks
HIREFS	Spectrometer+Fe^{55}	0.1-1.5	1 CCD	1-d trans.	none	BI CCD Ref?
IFM	Monochromator+Fe^{55}	0.1-1.5	1 CCD	none	none	
SES	Monochromator	0.5-2.2	1 CCD	none	none	
HEXS A	photon fluorescent+H^3	0.3 - 10	2 CCD	2-d trans.	CCD	
HEXS B	photon fluorescent+H^3	0.3 - 10	2 CCD	2-d trans.	CCD	

Table 5: Calibration Facility Characteristics

8.2 Overhead Time Estimates

Overhead time estimates are listed in Table 6 (CCD installation time estimates) and Table 7 (Data Acquisition/analysis time estimates). The data acquisition time estimates are based on the following assumptions:

i) It is assumed that data backup can proceed in parallel with either data acquisition or data analysis, but not in parallel with both.

ii) It is assumed that two DAT drives operate on each of the three machines supporting HIREFS, SES and IFM, respectively.

iii) It is assumed that two data acquisition systems (one for the device being calibrated and one for the reference detector) are available for each of the two HEXS systems.

iv) The data analysis required immediately after each measurement is that currently specified in ACIS memo PS-71 and implemented in the scripts acisanal1 and acisanal2.

Operation/Step	Time Required (hours)	Remarks
Install CCD in chamber	0.5	
Pumpdown/bakeout	8	
Cool CCD (to -120)	3	
Warmup	3	
Vent/Remove CCD	0.5	
Change CCD Temperature 5C	1	

Table 6: CCD Installation/Removal Operation Time Estimates

Operation/Step	Time Required (hours)	Remarks
Setup source	1	
Setup acquisition	0.5	log, header setup, bias acq.
Acquire data	2.7 s/frame	
Analyze data	2.7 s/frame	acisanal1 and acisanal2
Backup	3 hr/partition/tape drive	See text; 1 partition=1.8Gbyte

Table 7: Data Acquisiton and Analysis Time Estimates

9 Data Management

The large volume of data produced by the ACIS CCD subassembly calibration must be managed carefully. The ACIS subassembly calibration data will be managed according to the following principles.

vi) Measurement conditions, including the identity and configuration of X-ray sources, detectors and supporting electronics, as well as time of measurement and identity of operator, will be recorded and stored electronically with the data. In most cases, the relevant information will be stored in FITS headers as an integral part of the raw data. For technical reasons, some information will be stored in ancillary files which will be kept with the raw data.

vi) Raw data from each measurement will be subjected to preliminary analysis within 24 hours of acquisition. The analysis will include the steps outlined in ACIS memo PS-71 to extract events and evaluate the resulting event lists. The purpose of the analysis is to verify that the measurement was of sufficient quality to meet the objectives specified in this calibration plan.

vi) All data, including the raw data and the products of the preliminary analysis, will be archived. The raw data will be archived to tape within 24 hours of acquisition; a single copy of the data will be written to tape. Upon completion of the analysis and tape archiving, and verification that the measurement was successful, the raw data will be removed from the data acquistion computer storage. The analysis products, including event lists from each measurement, will be archived in a separate database computer system. The organization of the online database is described in ACIS memo PS-71.

vi) The tape archive will be managed with the aid of an on-line database that allows efficient location of any raw data set.

vi) As soon as possible after each archive tape is written, the AXAF Science Center will duplicate the tape. The tape duplication will serve to verify the integrity of the data on the original tape, and to provide a backup.