Interim Report

Summary of AXAF Calibration Requirements

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Introduction

This document has been used by the Project for planning the calibration timeline at the XRCF and for a variety of other purposes. It has been referenced many times. It does not appear to be in a position to be superceded by anything for quite a while. Since it has achieved such status, it is being published as a SAO-AXAF, DR-3, Interim Report.

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Items to be added

- Runs with SSS to provide data for correcting the HSI runs for the change in the mirror's energy spectrum with distance away from the center of the image
- ACIS runs to look at the spectral changes of the PRF off axis. Probably needs to be done in 2 steps: one with center of PRF on the ACIS, and another with it off the edge of the ACIS field of view to get the low surface brightness part.

Introduction

The following summarizes requirements on HRMA and HRMA/SI calibration. The following lists of calibration measurements assume that the HRMA meets the CTT requirement that the XRCF test environment shall have not more than a 10% effect on the encircled energy in 1 arcsec raw data, and that it can be calibrated to 1%. This implies that the offloading scheme has been implemented in the HRMA.

It should be remembered that there are additional calibrations needed for

- aspect system
- Tracking
- gyros
- other parts of the PCAS
- spacecraft timing, and checks on timing accuracy for all SIs after integration in the spacecraft
- ficucial lights & periscope
- ~~HRMA actuators~~
- alignments
- optical metrology data: lengths and diameters with errors on mirror elements, optical interferometer data on surface figure
- throughput and imaging stability test: an end-to-end test that can be used after the XRCF to verify that the x-ray throughput and imaging quality have not been degraded.

The tables on the following pages give a summary of the integration times for HRMA and HRMA/SI calibration. We are in the process of adding the overhead times to give the total time needed.

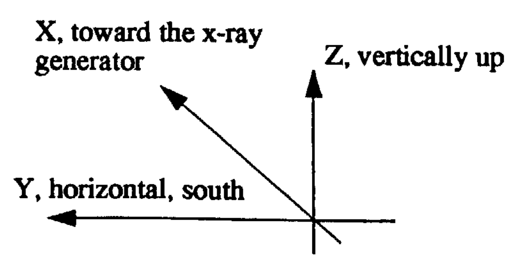
Total data acquisition time for all configurations

Table Number	Configuration	Data Acquisition Time Estimate[a]
Table 2	HRMA PRF/Encircled Energy/Effective Area	36.5 days
Table 3	HRMA/LETG/HXDS	1.1 days
Table 4	HRMA/HETG/HXDS	1.1 days
Table 5	HRMA/HRC-I	8.5 days
Table 6	HRMA/ACIS	21.3 days
Table 7	HRMA/LETG/HRC	2.9 days
Table 8	HRMA/LETG/ ACIS	1.2 days
Table 9	HRMA/HETG/ACIS	4.9 days
	Total Integration Time	**77.5 days**

a. Includes any overhead: computer setup, motor motion, source change, instrument temperature change. We have assumed that the times required for collecting data by the HRC and the ACIS and the times to move the SIM are the same as for the comparable HXDS instruments.

Coordinate Systems

We use the XRCF facility coordinate system, which has the same general orientation and sense as the spacecraft coordinate system. The following illustrates it:



Definition of Telescope Properties Measured

This quantity referred to later in the tables, **PRF/Encircled Energy/Effective Area**, is more rigorously defined as $\left[\frac{dA}{d\Omega dE}(\theta, \varphi, \xi, \chi, E, \Pi f_x, x, \ldots)\right]$, the differential effective area per unit solid angle in the back hemisphere as function of

θ, ϕ: incident angles of x-rays hitting HRMA
ξ, χ: emerging angles from HRMA to focal plane
Π: polarization
E: energy
f_x : x-ray intensity
x: position of detector along telescope axis (i.e. focus)
Also a function of filter inserted, aging effects, radiation damage, magnetic fields, microphonics, calibration source leakage, etc.

For the gratings, this quantity as a function of position along the dispersed spectrum, together with the limit on spectral resolution imposed by the pixel size of the readout device, be it the HRC, the ACIS or the internal detector of the BCS, tells how well energy resolution can be measured. For example, with the LETG, the first order spectrum covers about 10mm on the HRC, going from 0 to 140A wavelength.

Therefore, The dispersion is 1.4 A/mm, or 0.0175 A per 12.5 µm tube diameter along the dispersion direction. The expected resolution at 70 A is 0.047 A, so there are 2.67 independent measurements within the spectral PRF. As the spatial sampling frequency is 2 or 3 times greater than the resolution, we can measure the width of the resolution to about TBD.

We need a model to be able to interpolate between measured data points. We will use a relatively sparse matrix of data points, and use the model to calculate the properties of AXAF for values of the parameters θ, φ, ξ, χ, E, Πf_x, x, ...

Algorithms for Calculating Data Acquisition Time[1]

Assumptions:

- Off-axis rotation of the HRMA plus SIM = 10 min = 600 sec
- Source energy change = 900 sec = 15 min. This includes setting up detector gains and high voltages.
- Motor motion (see footnote [2]): $t_m = (4.5 \text{ sec} + 1.6 \text{ sec mm}^{-1})$
- Time to come to thermal equilibrium = 1 day (=86,400 sec) for measurements vs. T.
  We assume this overhead is incurred only for the encircled energy measurements, because a later shuffling of the schedule will permit us to do all measurements at each T, only requiring change of T once. **This will require that the SIM and HXDS/XDA be mounted together and we can switch between them without breaking vacuum.**
- Times to acquire data for HRC and ACIS and to move the SIM are the same as for comparable HXDS equipment. This one should be checked.

1. See "Notes on HRMA Timeline", R. Brissenden, SAO, 6/3/92. All XDACS times were reduced by 1/2 to model the speedup of the HXDS over the VXDS.
2. J. Roll, SAO, private communication, 7/2/92.

Algorithms:

1. Motor motion
   - $t_m(d) = 4.5 + 1.6d$ sec
     (d in mm)
2. Centering the aperture on the beam; necessary each time we change apertures, off-axis angles, temperatures and energies
   - **beamcen**$(t_i) = 127+6t_i$ sec, or if a move is done as well,
   - **beamcen**$(d, t_i) = t_m(d)+127+6t_i$ sec
     where t_i is integration time
3. Alignment
   - **hsialign**$(t_i) = 268 + 4t_i$ sec
   - **mcaalign**$(n_z, n_y, t_i) = 235 + 14\, n_z + n_z\, n_y \times (97 + 2t_i)$ sec
     where n_z = number of z positions and n_y = number of y positions
4. Simple proportional counter data acquisition with nomove
   - **mcadata**$(t_i) = t_i + 15$ sec
5. Simple proportional counter data acquisition with a move of d
   - **mcadata**$(d, t_i) = t_m(d) + t_i + 15 = 19.5 + 1.6d + t_i$ sec, or
   - **mcadata**$(d, t_{i1}{:}n_1, t_{i2}{:}n_2 \ldots t_{ij}{:}n_j) = m \times t_m(d) + n_j \times \text{mcadata}(d, t_{ij})$
6. 2D scans: **mcascan**$(n_z, n_y, t_i) = 215 + 14\, n_z + n_z\, n_y \times (22 + t_i)$ sec
7. 1D Scans: **beamceny**$(n_y, t_i) = 64 + 3.5\, n_y\, t_i$
   beamcenz$(n_z, t_i) = 64 + 3.5\, n_z\, t_i$
8. Encircled energy or effective area exposure
   - **EE**$(t_i, t_{i1}{:}n_1, t_{i2}{:}n_2, \ldots t_{im}{:}n_m) = \times\, \text{beamcen}(t_i) + \sum_{j=1}^{m} \text{mcadata}(200,\ t_{i1}{:}n_1, t_{i2}{:}n_2 \ldots t_{ij}{:}n_j)$, where t_{ij} is the integration time for the j-th pinhole

     $= \sum_{j=1}^{m} n_j\,(6t_i + 342) + \sum_{j=1}^{m} t_{ij} \times n_j$
9. HSI Exposure
   - **hsiimage**$(t_i, d) = (5.5 + t_i + 1.6 \times d)$, sec
     d in mm

10. Compounding of proc(t_i, param.) at various off-axis angles(n_θ), temperatures(n_T) and energies(n_E): in general,

- **Proc(t_i, param., n_θ, n_E, n_T)** $= \{[\mathrm{proc}(t_i, \mathrm{param.}) \times n_\theta + 600 \times (n_\theta - 1)] \times n_E + 900 \times (n_E - 1)\} \times n_T + 86{,}400 \times (n_T - 1)$, sec

so for specific cases

- **EE(t_i, t_{i1}:n_1,t_{i2}:n_2 ...t_{im}:n_m n_θ, n_E, n_T)** $= \{[(\sum_{j=1}^{m} n_j (6t_i + 342) + \sum_{j=1}^{m} t_{ij} \times n_j) \times n_\theta + 600 \times (n_\theta - 1)] \times n_E + 900 \times (n_E - 1)\} \times n_T + 86{,}400 \times (n_T - 1)$, sec
- **hsiimage(t_i, d, n_θ, n_E, n_T)** $= \{[(5.5 + t_i + 1.6 \times d) \times n_\theta + 600 \times (n_\theta - 1)] \times n_E + 900 \times (n_E - 1)\} \times n_T + 86{,}400 \times (n_T - 1)$, sec
- **beamceny(n_y, t_i, n_θ, n_E, n_T)** $= \{[\mathrm{beamceny}(t_i, n_y) \times n_\theta + 600 \times (n_\theta - 1)] \times n_E + 900 \times (n_E - 1)\} \times n_T + 86{,}400 \times (n_T - 1)$, sec

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Table 1: Initial Measurements: Alignment and Focus

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time Estimate	Detector
1. **1.1 X-ray Alignment & Focus** Measure the alignment of P_nH_n. Do hsialign, then beamcen, mcaalign. Accuracy: 0.1 arcsec.	Data needed for verification of HRMA acceptance, and for on-orbit model calculations	0	0.010 mm diam. pinhole	70 ± 2.5 F	Al-K	hsialign(100)+beamcen(5) +mcaalign(9,9,10): {268+4x100+127+6x5+ 235+14x9+[9x9x(97+20)] = 10,663 sec} x 4 mirrors = 11.8 hr	HSI
1.2 2-D scan 19 x 19, beamcen, mcascan	Verification of general image quality	0				beamcen(5)+ mcascan(19,19,10): 127+6x5+215+14x19+19x19x(22+10) = 12190 sec = 3.4 hr	Pinhole Scanner
1.3 Total Data AcquisitionTime for Initial Measurements						15.2 hr	

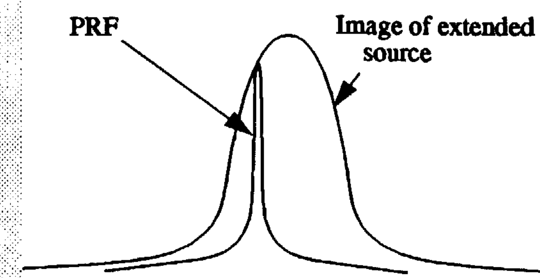
Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector

2.

2.1 Encircled Energy Photometry

This will be used for fitting observed data to a brightness distribution, and to find the absolute flux from an extended region. We need to know the absolute value of the height of the PRF, which is normalized by the pinhole EE measurements.



Encircled energy is defined as flux contained in a circle defined by a mechanical aperture or a region defined in data analysis on an imaging detector.

θ = angle about the Z axis; ϕ = "tilt"angle, an angle about an axis in the horizontal plane that rotates when θ rotates, and is coincident with the Y axis when θ = 0. ψ = roll angle, which will not be varied, but should be set up to be the same as in flight with respect to the SI.

Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

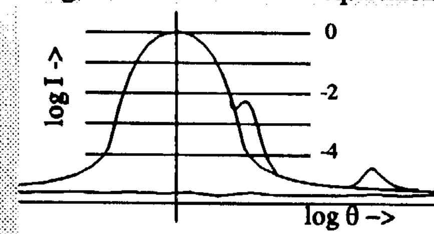
Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector
Encircled energy for each aperture, off-axis angle, temperature and energy. Accuracy: 1%, so we can derive the on-orbit encircled energy to 2%, up to the diameter that encloses 99% of the energy. At larger diameters, we don't care, because the error will be less than 1%.	Sunyaev-Zeldovich, and other experiments where the absolute flux is important. The angular sizes of these objects could be from ≤ 1 arcsec to arc minutes.	$\theta = 0$ arcmin, $\phi = 0$ arcmin, $\psi = 0°$	15 Pinholes[b]: 0.1, 0.16, 0.22, 0.34, 0.6, 0.76, 0.96, 1.1, 1.4, 1.7, 2.8, 13, 40, 200, 800 arcsec.	Templ, nominal, also nominal gradients	20 energies (see Table 12). [c]	2.1.1 EE(20, 100:2,20:13,1,20,1) = {[(15x(6x20+342)+(100x2+20x13))x1+0] x20+900x19}x1+0 = 45.8 hr	pinhole scanner, BND(FPCs, SSS), FMS
			10 Pinholes: 0.1, 0.16, 0.22, 0.34, 0.6, 0.76, 0.96, 1.7, 2.8, 13 arcsec	3 significant sun angle temperatures	4 energies: C K, Al K, Ti K_α, Fe K_α	2.1.2 EE(20,100:2,20:8,1,4,3) ={[(10x(6x20+342)+(100x2+20x8))x1+0] x4+900x3}x3+86400x2 = 66.8 hr	
	Deep survey; cluster and supernova remnant surface brightness mapping	$\theta = 0$ arcmin, $\phi = 1, 2, 3.5, 6, 8, 12, 15, 19, 24, 30$ arcmin	5 Pinholes: 0.96, 1.1, 1.4, 2.8, 13 arcsec	Templ, nominal, also nominal gradients	11 energies: Be K, C K, Cr L, Cu L, Al K, Ag L, Ti K_α, Cr K_α, Fe K_α, CuK_α, Ge K_α	2.1.3 EE(20,20:5,10,11,1) ={[(5x(6x20+342)+(20x5))x10+600x9] x11+900x10}x1+0 = 92.6 hr	
		$\theta = 1, 2, 3.5, 6, 8, 12, 15, 19, 24, 30$ arcmin, $\phi = 0$ arcmin				2.1.4 92.6 hr	
		$\theta = 0, 2, 6, 12, 24, 30$ arcmin, $\phi = 0, 2, 6, 12, 24, 30$ arcmin			4 energies: C K, Al K, Ti K_α, Fe K_α	2.1.5 EE(20,20:5,36,4,1) ={[(5x(6x20+342)+(20x5))x36+600x35] x4+900x3}x1+0= 120.5 hr	
						Subtotal: 17.4 days	

Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector

2.2 Inner Point Response Function Imaging

2D mapping of the details of the inner part of the image, including azimuthal structure. Requirement is based on the need to look at faint objects at small angular



separations from bright ones. Say we want to look for faint objects near a bright source. In Table 11, we see that the requirements on knowing the PRF are less stringent as the bright source gets fainter. Let us assume that we limit ourselves to bright sources no stronger than 0.1 Crab. Then in a 10^5 sec observation, a maximum nominal exposure, we get about 10^2 c s^{-1} in the whole image. About half is in the 1arcsec diameter core, or 50 s^{-1}. The weakest source we can see anywhere in the field of view in that time is about 50 counts, or 5×10^{-4} s^{-1}. The weak source detection sensitivity decreases as the separation between the weak source and the strong source gets smaller, because there is uncertainty in the background of counts from the wings of the point response function coming from the strong source. The requirements on knowledge of the PRF for the following are taken from the column in Table 11 for 0.1 Crab, and % of the PRF value at each angle.

Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector
Accuracy: 1% of the measured value out to 3 arcsec, 2%from 3 to 20 arcsec,. At 100 c s^{-1} $pixel^{-1}$ in the HSI, the XGA can give enough flux to achieve that rate out to 10^{-2} of the peak intensity of the image, 3 arcsec. Therefore, we can run at maximum counting rates to that angle. 2 x 10^4 counts (100 c s^{-1} $pixel^{-1}$) in inner, 5000 in outer. Total time alotted is 1400 sec per exposure, to be broken down later into a series of shorter exposures at different source intensities.	Details of structure of strong near-point sources; detection of faint sources and extended structure near strong point sources (limit: ≤ 0.01 Crab).	θ = 0 arcmin, ϕ = 0 arcmin, ψ = 0°	0.12 arcsec cells within 2 arcsec	Temp1, Temp2, Temp3 (thermal adjustment time not included in time estimate)	25 energies (see Table 12).	2.2.1 hsiimage(1400,200,1,1,3) +hsiimage(1400,0,1,25,3) = {[(5.5+1400+1.6x200)]}x3+{[(5.5+1400)]x25+900x(24-1)}x3 = 48.6 hr	High Speed Imager (HRC or ACIS would be much slower, since this experiment is count rate limited.), BND(FPCs, SSS), FMS
		θ = 0 arcmin, ϕ = 1, 2, 3.5, 6, 8 arcmin			11 energies	2.2.2 hsiimage(1400, 0, 5, 11, 3) = {[(5.5+1400)x5 +600x4]x11+900x10}x3, sec = 93.9 hr	
		θ = 1, 2, 3.5, 6, 8 arcmin, ϕ = 0 arcmin				2.2.3 93.9 hr	
		θ = 0, 2, 6, 8 arcmin, ϕ = 0, 2, 6, 8 arcmin			4 energies	2.2.4 hsiimage(1400, 0, 15, 4,3) ={[(5.5+400)x15+600x14]x4+900x3}x3 = 50.5 hr	
						Subtotal: 12.0 days	

2.3 Outer Point Response Function Imaging

2D mapping of the qualitative features of the outer part of the image.

Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector
Accuracy: 15%of the measured point response from 20 to 60 arc-sec. => 44 cnts/pixel, needs 67 sec/exposure.	For interstellar dust scattering, we need to distinguish between dust on the mirror and dust between us and the source.	$\theta = 0$ arcmin, $\phi = 0$ arcmin, $\psi = 0°$	8 arc sec cells from 16-60 arcsec; 30 arc sec cells from 1-6 arcmin;12 azimuth locations	Temp1, Temp2, Temp3 (thermal adjustment time not included in time estimate)	25 energies (see Table 12).	2.3.1 hsiimage(67,0,1,25,3) = {[5.5+67]x25+900x24}x3 = 19.5 hr	High Speed Imager with occulting disc, BND(FPCs, SSS), FMS
		$\theta = 0$ arcmin, $\phi = 4, 8, 12, 20, 30$ arcmin			11 energies (see above)	2.3.2 hsiimage(67, 0, 5, 11, 3) = {[(5.5 +67)x5 +600x4]x11+900x10}x3 = 32.8 hr	
	Details of structure of strong, extended sources. Limit: ≤0.01 Crab).	$\theta = 4, 8, 12, 20, 30$ arcmin, $\phi = 0$ arcmin				2.3.3 32.8 hr	
		$\theta = 4, 8, 12, 20, 30$ arcmin, $\phi = 4, 8, 12, 20, 30$ arcmin			4 energies (see above)	2.3.4 hsiimage(67, 0, 25, 4, 3) = {[(5.5 +67)x25 +600x24]x4+900x3}x3 = 56.3 hr	
						Subtotal: 5.9 days	
2.4 Wing Scans							
Record wings of PRF at angles > 6 arcmin off-axis, to edge of detector(HRC). Accuracy: 1% of the measured value, or 10^{-5} of peak intensity, whichever is greater. This may be a null experiment, if the wing flux is low enough	Why do we need this? I presume to be able to confront models of scattering from dust on the mirror, and interstellar scattering	$\theta = 0$, $\phi = 0$	3 arcmin cells from 6-17 arc-min; at large angles, use an annulus 5' x 17' = 4.5e-5 sr	Temp1	10 energies (see Table 12).	2.4.1 hsiimage(350,200,1,1,1) + hsiimage(350,0,1,10,1) = {[(5.5 +350)]}+{[(5.5 +350)]x10+900x9}= 3.3 hr, done during HRMA/HRC calibration, so not counted here.	HRC, image cntr off edge of MCP, BND(FPCs, SSS), FMS
						Subtotal: 0 days	

Table 2: HRMA PRF/Encircled Energy/Effective Area[a]

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Data Acquisition Time	Detector
2.5 X-ray ghost images, Inner							
Imaging detector used for quick survey, 0.006 mm resolution, out to 1.8 mm diameter. Accuracy: 10^{-5} of peak intensity of normal image.	Needed to avoid aliasing of images near strong sources outside the field of view.	θ = 20 arcmin to 5°, in 8 steps ϕ = 10', 20', 30'	field of HSI	Templ	2 energies: Be K, Fe K_α	2.5.1 hsiimage(500,200,24, 2,1) = {[(5.5+500+1.6x200)x24+ 600x(24-1)]x2+900x(2-1)} = 18.9 hr	High Speed Imager, BND(F PCs, SSS), FMS
						Subtotal: 0.8 days	
2.6 Fluorescence							
Spectroscopic measurements of fluorescence from sources outside the field of view.	Needed to avoid contamination of spectra from fluorescence of elements of AXAF by strong sources outside the field of view.	θ = 20',40', 60' ϕ = 2',4', 6'	20 (1 cm diameter of SSS)	Templ	bremsstrahlung continuum	2.6.1 1.6x200 + hsiimage(3600, 0, 9, 1, 1) = 1.6x200+{[(5.5 +3600)x 9+600x8]} = 10.4 hr	SSS, BND(F PCs, SSS), FMS
						Subtotal: 0.4 days	
2.7 Total Data AcquisitionTime for HRMA						36.5 days	

a. From AXAF-203.
b. See predicted encircled energy curve by JPH, 5/29/92.
c. This value should be re-examined to see if it is really necessary.

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Table 3: HRMA/LETG/HXDS

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
3. **3.1 Vignetting**							
X, Y & Z axes. Out of focus x-ray images will be used to measure vignetting due to X, Y and Z axis misalignment. Assume 27 alignment trials, with 10 min alotted for each change of alignment. Accuracy: 0.5 mm for Y,Z, 0.3 mm for X.	Required for alignment	on-axis	3 positions	nominal	Al K	3.1.1 27 [hsiimage(20, 18, 1, 1, 1)] +26[600] = {[(5.5+20+1.6 x18)]}x27+26x 600 = 4.7 hr	HSI, BND(F-PCs, SSS), FMS
3.2 R, PSF							
On-axis response Use beamceny: 20 point 1-D scans. Accuracy: 2%(??)	Fine details of grating PRF not possible with HRC or ACIS	on-axis	6 Pinholes[a]: 0.1 0.22, 0.6, 1.1, 2.8, 13 arc-sec.	nominal	Al IV 131A	3.2.1 $6[t_m(200)$ +beamceny(20 , 50)] = 6[4.5+1.6x200 +64+3.5x20 x50]= 6.5 hr	Scanning photometer, BND(FPCs, SSS), FMS
3.3 Find best focus							
Accuracy: 50 μm in X	Find optimum focus	on-axis	0, $+x_1$, $+x_2$, $-x_1$, $-x_2$	nominal	Al IV 131A	3.3.1 (50x5+4x31) = 0.1 hr	HSI, BND(F-PCs, SSS), FMS
3.4 R, PSF							

Table 3: HRMA/LETG/HXDS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
On-axis response Use beamceny: 20 point 1-D scans. Accuracy: 2%(??)	Fine details of grating PRF not possible with HRC or ACIS	on-axis	6 Pinholes: 0.1 0.22, 0.6, 1.1, 2.8, 13 arc-sec.	nominal	Al IV 131A, C K, Al K	3.4.1 6[t_m(200) +beamceny(20, 50)]x3+900x2 = 6.5x3+0.5 hr = 13.5 hr.	Scanning photometer, BND(FPCs, SSS), FMS
3.5 Survey for strange edges in mirror/grating response							
Accuracy: 1% in 1000 resolution elements.	Molecular contamination search	on-axis	full imager field, 5 fields of 18 mm each covering a total of 100 mm of dispersed spectrum.	nominal	bremsstrahlung continuum 0.1 - 3.5 keV	3.5.1 (50+50+100+500+500)+1x5 +(4.5 +1.6x18)x4 = 0.4 hr[b]	HSI, BND(F-PCs, SSS), FMS
3.6 Total Data Acquisition Time for HRMA/LETG/HXDS						1.1 days	

a. See predicted encircled energy curve by JPH, 5/29/92.
b. See notation on "VETA-I Post Mortem" report by EMK, 7/2/92.

Table 4: HRMA/HETG/HXDS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
4. **4.1 Vignetting**							
X, Y & Z axes. Out of focus x-ray images will be used to measure vignetting due to X, Y and Z axis misalignment. Assume 27 positions. Accuracy: 0.5 mm for Y,Z, 0.3 mm for X.	Required for alignment	on-axis	3 positions	nominal	Al K	4.7 hr (see §3.1.1)	HSI, BND(F-PCs, SSS), FMS

Table 4: HRMA/HETG/HXDS

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
4.2 R, PSF							
On-axis response Use beamceny: 20 point 1-D scans. Accuracy: 2%(??)	Fine details of grating PRF not possible with HRC or ACIS	on-axis	6 Pinholes[a]: 0.1 0.22, 0.6, 1.1, 2.8, 13 arc-sec.	nominal	Al K	4.2.1 6.5 hr (see §3.2.1)	Scanning pho-tometer, BND(FPCs, SSS), FMS
4.3 Find best focus							
Accuracy: 50 μm in X	Find optimum focus	on-axis	0, $+x_1$, $+x_2$, $-x_1$, $-x_2$	nominal	Al K	4.3.1 0.1 hr (see §3.3.1)	HSI, BND(F-PCs, SSS), FMS
4.4 R, PSF							
On-axis response Use beamceny: 20 point 1-D scans. Accuracy: 2%(??)	Fine details of grating PRF not possible with HRC or ACIS	on-axis	6 Pinholes: 0.1 0.22, 0.6, 1.1, 2.8, 13 arc-sec.	nominal	Al IV 131A, C K, Al K	13.5 hr (see §3.4.1)	Scanning pho-tometer, BND(FPCs, SSS), FMS
4.5 Survey for strange edges in mirror/grating response							
Accuracy: 1% in 1000 resolution ele-ments.	Molecular con-tamination search	on-axis	full imager field, 5 fields of 18 mm each covering a total of 100 mm of dispersed spectrum.	nominal	bremsstrahlung continuum 0.35 - 6 keV	4.5.1 0.4 hr[b] (see §3.5.1)	HSI, BND(F-PCs, SSS), FMS
4.6 Total Data Acquisition Time for HRMA/HETG/HXDS						1.1 days	

a. See predicted encircled energy curve by JPH, 5/29/92.
b. See notation on "VETA-I Post Mortem" report by EMK, 7/2/92.

Table 5: HRMA/HRC-I

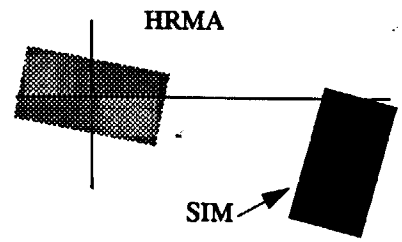
Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
5. **5.1 Knife-Edge Focus**						
Locate focal position along optical axis such that image shift in knife-edge test is < 0.1" . 5 positions along x-axis. hsiimage with 4 shutter settings at each focal setting. **Unresolved issue: how will we coordinate between the XDACS and the HRC to control the acquisition of data and the control of the shutters? What GSE will be used to make the SIM motions?**	maximize sensitivity for point source detection, for example, knots in jets [c]	on-axis	Templ, nominal	4 energies: Cu K, Al K, Ti K, Cu K_{α} (see Table 12).	5.1.1 HRC(5 x positions, 4 shutters, 1 angle, 1 T, 4 E) = [(268+4 x100)x5 +(4.5+1.6 x0.1)x4]x4+900x3= 4.5 hr	HRC-I, BND(FPCs, SSS), FMS
5.2 Focus by Changes in PSF Core						
Use image acquisition capability of HRC. **Overhead times are unknown!!** Accuracy: to ± 0.025 mm (TBR) vs. temperature for 3 temperatures.	maximize point source sensitivity	on-axis	Templ, nominal	4 energies: Cu K, Al K, Ti K, Cu K_{α} (see Table 12).	5.2.1 [(50x5+(4.5+1.6x0.1)x4]x4+900 x3= 1.0 hr	HRC-I, BND(FPCs, SSS), FMS
5.3 Effective Area Confirmation						
Effective area at one image radius Accuracy to 1%. The HRC must be translated & rotated so the images striking it duplicate the conditions in flight. The SIM rotates and trans-  lates to keep the HRC detectors in a rigid body relationship with the HRMA. **XGA turned down to 10^{-4} of max.**	source fluxes and spectra	on-axis	Templ, nominal	25 energies (see Table 12).	5.3.1 4000x25 = 27.8 hr	HRC-I, BND(FPCs, SSS), FMS
		Set1 (6).		6 energies: TBD based on an examination of the predicted curve of effective area of combined HRMA and HRC-I vs. energy, to select critical energies at features in the curve.	5.3.2 4000x6x6 = 40 hr	
					Subtotal: 6.5 hr	

Table 5: HRMA/HRC-I

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
5.4 On-axis HRMA/HRC-I PSF & PSF-Wing Calibration						
1% of the measured value in 1 x 1 arc sec cells within 2 arcsec of image center, 3% of the measured value in 1 x 1 arc sec cells from 2-20 arcsec.	Source structure and detection of extended emission around point sources. (strongest source: 0.01 Crab)	on-axis	Templ, nominal	10 energies: B K, C K, Cr L, Cu L, Al K, Ag L, Ti K_α, Cr K_α, Fe K_α, Ge K_α	5.4.1 (10000+1500)+x10 = 1.3 days	HRC, BND(FPCs, SSS), FMS
		Set1 (6)		4 energies: C K, Al K, Ti K_α, Fe K_α	5.4.2 11500x6x4 =3.2 days	
					Subtotal: 110 hr	
5.5 HRMA/HRC-I Plate Scale and Related Properties						
Relative image positions to 1 arcsec on scales of 5 arcmin to 1 arcsec (?). **Assumes that HRC and XDA are co-mounted to speed up temperature change measurements.**	Identification of sources in deep surveys, source positions.	50 (TBD)	Templ, nominal	4 energies: C K, Al K, Ti K_α, Fe K_α	5.5.1 {[HRC(100sec)x n_θ + 600 x (n_θ - 1)] x n_E + 900 x (n_E - 1)} = 100x50+600x49x4+900x3 = 34.8 hr	HRC, BND(FPCs, SSS), FMS
		10 (TBD)	3 Ts	Al K	5.5.2 [100x10+600x9x1+900x0]x3=5.3 hr	
					Subtotal: 40.1 hr	
5.6 HRMA/HRC-I Count Rate Linearity						
1% for source flux rates of 5, 10, 15, 100 and 200 s^{-1}.	Identification of sources in deep surveys, source positions.	near axis	Templ, nominal	7 energies: ??	5.6.1 4000x7 = 7.5 hr	HRC, BND(FPCs, SSS), FMS

Table 6: HRMA/ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
6. **6.1 Focus Test**						
2 chips, five focus settings		on-axis	nominal	4 energies	6.1.1 flapper, 2 hrs	ACIS-I, BND(FPCs, SSS), FMS
Repeat for ACIS-G					6.1.2 2 hrs	ACIS-G, BND(FPCs, SSS), FMS
					Subtotal = 4 hrs	
6.2 Effective Area Confirmation						
Accuracy: 1% of peak intensity Accumulate images. Several per chip are required, because of ACIS counting rate limits. Also, there are four chips. Four subarray readout modes, covering 4 arcsec, 11 arcsec, 55 arcsec and 4 arcmin will be used to permit acquisition of data at as high counting rates as possible in the inner part of the PRF. See ACIS description for details.	source fluxes and spectra	on-axis	Temp1 (nominal)	11 energies (see Table 12).	6.2.1 (200+1000 +1000+1000)x11 = 9.8 hr	ACIS-I plus occulting disc, BND(FPCs, SSS), FMS
		Set1 (12).	Temp1 (nominal)	6 energies: C K, Cu L, Al K, Cr Kα, Fe Kα, Ge Kα	6.2.2 3200x6x11 = 59 hr	
Repeat for ACIS-G					68.8 hrs	ACIS-G plus occulting disc, BND(FPCs, SSS), FMS
					Subtotal: 137.6 hr	
6.3 ACIS PSF & PSF-Wing Calibration						

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Table 6: HRMA/ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
2% of the measured value in 0.5 arcsec cells within 16 arcsec of image center, and 5% of the measured value in 5 x 5 arcsec cells within 20 arcsec of the image center. Exposures at 3 different frame readout configurations.	Source structure and detection of extended emission around point sources up to 0.01 Crab.	on-axis	Templ, nominal	10 energies: B K, C K, Cr L, Cu L, Al K, Ag L, Ti Kα, Cr Kα, Fe Kα, Ge Kα	6.3.1 2000x3x10+9x900 = 19 hr	ACIS, BND(FPCs, SSS), FMS
		Set1 (8)		4 energies: Al K, Ti Kα, Fe Kα, Ge Kα	6.3.2 [(3200x3x8)+7 x900]x4+3x900 = 93 hr	
Measure the response of the gate structure to the PRF at 9 critical locations in the gate.	Prevent artifacts in the images.	3x3 locations			6.3.3 [(3200x9)+8x900]x 4+3x900 = 40.8 hr	
Repeat §6.3.1 through §6.3.3 for ACIS-G					6.3.4 152.8 hr	
					Subtotal: 306 hr	
6.4 Background Data						
Used for Interpreting XRCF Calibrations. 10% accuracy.	Needed for HRMA data analysis.	N.A.	Templ	N.A.	6.4.1 10000 = 2.8 hr	ACIS-I, BND(FPCs, SSS), FMS
					6.4.2 2.8 hr	ACIS-G, BND(FPCs, SSS), FMS
					Subtotal: 5.6 hr	
6.5 Survey for strange edges in mirror/ACIS response						
Accuracy: 1% in 1000 resolution elements.	Molecular contamination search	N.A.	Templ, nominal	bremsstrahlung continuum	6.5.1 57.6 hr	ACIS-I, BND(FPCs, SSS), FMS
6.6 Total Integration Time for HRMA/ACIS					21.3 days	

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e.LETG response to MSFC Project Scientist inquiry, May 1991.

Table 7: HRMA/LETG/HRC

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
7. 7.1 HRMA/LETG/HRC Focus Test							
Hartmann test flapper) Accuracy: 50 μm in X	Find optimum focus	on-axis	0, $+x_1$, $+x_2$, $-x_1$, $-x_2$	nominal	Al IV 131A	7.1.1 4.5 hr (see §5.1.1)	HRC-G, BND(FPCs, SSS), FMS
						7.1.2 4.5 hr (see §5.1.1)	HRC-I, BND(-FPCs, SSS), FMS
						Subtotal: 9 hr	
7.2 HRMA/LETG/HRC R, PSF[a]							
On & off-axis response, to 10^{-3} of peak		$\theta = 0, \theta_1, \theta_2, \phi = 0, \phi_1, \phi_2, \psi = 0°$	0	nominal	Al IV 131A	7.2.1 (4000x5+4x900) = 6.6 hr	HRC-G, BND(FPCs, SSS), FMS
Temperature gradient sensitivity of PSF		on-axis		nominal 0.04 Ccm^{-1} [b]		7.2.2 4000 = 1.1+12 = 13.1 hr	
Focus at 44 A			0, -TBD	nominal	C K	7.2.3 4000x2+900 = 2.5 hr	
Redo § to §7.2.3 with HRC-I						7.2.4 22.2 hr	HRC-I, BND(-FPCs, SSS), FMS
						Subtotal: 44.4 hr	

Table 7: HRMA/LETG/HRC

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
7.3 Absolute wavelength determination & Efficiency							
On-axis energy response, absolute efficiency Accuracy 0.02 A., 2% relative effic.		on-axis	0	nominal	C K + mono., Al K, Fe K, Cr-K,	7.3.1 (1000)x4+3x900 = 1.9 hr	HRC-G, BND(FPCs, SSS), FMS
Rel. Accuracy 2%. To be done after HRMA/HRC calibration. Angle of incidence is different from HRMA/HRC case.		on-axis	0	nominal	11 energies: B K, Ti L, O K, Cu L, Si K, Zr L, Ag L, Sn L, Ti K, Cu K, +continuum	7.3.2 200x11+10x900 = 3.1 hr	
Higher order efficiency					3 energies	7.3.3 200x3+2x900 = 0.7 hr	
Repeat §7.3.1 to §7.3.3 with HRC-I						7.3.4 5.7 hr	HRC-I, BND(-FPCs, SSS), FMS
						Subtotal: 11.4 hr	
7.4 Survey for strange edges in mirror/grating response							
Accuracy: 1% in 1000 resolution elements.	Molecular contamination search	N.A.	0	nominal	bremsstrahlung continuum	7.4.1 10,000x1000/500 = 5.6 hr	HRC-G, BND(FPCs, SSS), FMS
7.5 Total Integration Time for HRMA/LETG/HRC						2.9 days	

a. Table I from 28/11 '88 fax from astro nl

b. thermal adjustment time not included in time estimate f.MIT response to MSFC Project Scientist inquiry, Oct 7, 1991.

Table 8: HRMA/LETG/ ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
8. **8.1 Focus**							
Flapper test		on-axis	2	nom.	Al IV 131A	8.1.1 3 hr	ACIS-G, BND(FPCs, SSS), FMS
Repeat for ACIS-I						8.1.2 3 hr	ACIS-I, BND(FPCs, SSS), FMS
						Subtotal: 6 hr	
8.2 HRMA/LETG/ACIS Resolution, PSF[a]							
On-axis energy response		on-axis		nominal	Al K	8.2.1 3000x3 = 1.4 hr	ACIS-G, BND(FPCs, SSS), FMS
						8.2.2 1.4 hr	ACIS-I, BND(FPCs, SSS), FMS
						Subtotal: 2.8 hr	
8.3 Absolute wavelength determination & Absolute efficiency							
On-axis energy response, absolute efficiency Accuracy 0.02 A., 10% effic.		on-axis	0	nominal	C K + mono., Al K, Fe K, Cr-K,	8.3.1 4000x4+3x900=5.2 hr	ACIS-G, BND(FPCs, SSS), FMS
						8.3.2 5.2 hr	ACIS-I, BND(FPCs, SSS), FMS
						Subtotal: 10.4 hr	
8.4 Relative Efficiency							

Table 8: HRMA/LETG/ ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Detector
Accuracy 2%. Includes separation of higher orders by pulse height analysis.		on-axis	0	nominal	13 energies: C K, Ti L, O K, Cu L, Al K, Si K, Zr L, Ag L, Sn L, Ti K, Cr K, Fe K, Cu K, +continuum	8.4.1 400x13+12x900 = 4.4 hr	ACIS-G, BND(FPCs, SSS), FMS
						8.4.2 4.4 hr	ACIS-I, BND(FPCs, SSS), FMS
						Subtotal: 8.8 hr	
8.5 Total Integration Time for LETG/ACIS						1.2 days	

a. Table I from 28/11 '88 fax from astro nl

Table 9: HRMA/HETG/ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	Energy	Estimated Integration Time	Detector
9.						
9.1 PRF/Encircled Energy/Effective Area[a]						
Efficiency. Relative from one energy to another, 3%, Absolute efficiency 10%.	SNR plasma T to 5% accuracy and ionization age to 10% requires 3% relative calibration of efficiency.	$\theta = 0$ arcmin, $\phi = 0$ arcmin, $\psi = 0°$; two off-axis angles, TBD	0	7 energies from 0.4 to 8 keV: Ti L_α, Ni L_α, Na K_α, Al K_α, Ti K_α, Fe K_α, Cu K_α.	9.1.1 (200x3+2x900)x7+6x900 = 21000 = 5.8 hr	ACIS-G, BND(F-PCs, SSS), FMS
Point Spread Function, vs. focus to 10^{-3} of peak.	Measure 200 km s^{-1} doppler broadening with signal-to-noise ratio >3.		0, x_1, x_2	3 energies (TBD) from 0.4 to 8 keV.	9.1.2 ((4000x3+2x900)x3+2x900)x3+2x900 = 36.5 hr	
Background.	validates other calibration data	N.A.			9.1.3 20000 = 5.6 hr	

Table 9: HRMA/HETG/ACIS

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Location	Energy	Estimated Integration Time	Detector
Repeat §9.1.1 to §9.1.3 for ACIS-I					47.9 hr	ACIS-I, BND(F-PCs, SSS), FMS
					Subtotal: 95.8 hr	
9.2 Survey for strange edges in mirror/grating response						
Accuracy: 1% in 1000 resolution elements.	Molecular contamination search	N.A.			9.2.1 22.2 hr	ACIS-G, BND(F-PCs, SSS), FMS
9.3 Total Integration Time for HETG/ACIS					4.9 days	

g.ACIS response to MSFC Project Scientist inquiry, Apr 30, 1991

Table 10: HRMA Off-line measurements[a]

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)
10. **10.1 Absolute Reflection Efficiency**					
Adequate data to permit empirical evaluation of the x-ray optical constants as a continuous function of energy. Must reveal all spectral features, their energies, discontinuities, and energy widths. There is no sufficiently accurate information available on the reflectivity of the AXAF mirror surfaces without these measurements. A source with the required energy resolution could not be conceived for the XRCF. The off-line nature of this experiment, done at the synchrotron, removes it from the AXAF critical path. In fact, if necessary, some of the work can be done after launch.	Accurate determination of absolute source spectra.	Every grazing angle pertinent to the HRMA. Angle intervals to be variable, with coarse spacing away from the critical angle, and fine spacing near the critical angle. Choose angle steps so the reflection efficiency changes by 5% for each step.	N.A.	Templ, ± 5 °C.	10 eV
10.2 Image distribution from surface scattering					

Table 10: HRMA Off-line measurements[a]

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)
Microroughness.	Interpretation of extended source structure.	N.A.	N.A.	Templ, ± 5 °C.	TBD
10.3 Contamination vs. time					
Effects of contamination as a function of time and event between completion of HRMA and launch.	Estimation of changes to reflection efficiency and scattering between XRCF calibration and on-orbit operation.	N.A.		Templ, ± 5 °C.	N.A.
10.4 Detector Cross-calibrations					
Measure efficiency of a photometric detector at NIST	Improve confidence in absolute calibrations	N.A.		Templ, ± 5 °C.	Fe-K, Al-K

a. From AXAF-203.

Table 11: SI Off-line measurements[a]

Test Name, Description and Accuracy Requirement (± 1σ)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time
11.			
11.1 Flat Field			
HRC-I	Templ,	30, see Table 13	
HRC-G			
ACIS-I			
ACIS-G			

Table 11: SI Off-line measurements[a]

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time
11.2 Image distribution from surface scattering			
Microroughness.	Templ, ± 5 °C.	TBD	
11.3 Contamination vs. time			
Effects of contamination as a function of time and event between completion of HRMA and launch.	Templ, ± 5 °C.	N.A.	
11.4 Detector Cross-calibrations			
Measure efficiency of a photometric detector at NIST	Templ, ± 5 °C.	Fe-K, Al-K	

a. From AXAF-203.

Table 12: Facility Characterizations

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Total Time Including Overheads	Instrumentation
12. **12.1 Beam Uniformity**								
2D map of beam at entrance to HRMA. Accuracy: 5%.	Needed to make accurate measurement of effective area	N.A.			25 energies	100x(1400/5)x25 = 194 hrs		2D beam mapper on HXDS, XGA
12.2 Guide Tube Scattering								

Table 12: Facility Characterizations

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Total Time Including Overheads	Instrumentation
Measure angular distribution and spectrum of x-rays that hit the HRMA after scattering from the walls and/or baffles of the guide tube. Accuracy:		N.A.			2 energies	TBD		High Speed Imager & an x-ray optical system such as TMA or S056.
12.3 Filter Absorption								
Measure the x-ray absorption of 27 filters in the XGA (see Table 12). Need beam monitor in front of filter. Accuracy: 0.5%	Needed for correct fitting of spectral shapes in x-ray detector data.	N.A.			3 energies	TBD		BND solid state spectrometer
12.4 X-ray source properties								
12.4.1 Anode Voltage Measure accelerating voltage on electron gun, vs. emission current over full range. Accuracy: 100V.	Assure that the electron beam energy is correct and stable.							
12.4.2 Spectrum Measure the spectral shape, from each distinct operational configuration of the XGA Accuracy: 1% per keV	To assure that there is sufficient intensity and energy range coverage	N.A.			25 targets for HEXGA, also for LEXGA	TBD		FMS, BND spectrometer

Table 12: Facility Characterizations

Test Name, Description and Accuracy Requirement (± 1σ)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Total Time Including Overheads	Instrumentation
12.4.3Spectral intensity (including 100:1 dynamic range) from each distinct operational configuration of the XGA. Accuracy: 10%								
12.4.4 Time stability of the flux from each distinct operational configuration of the XGA Accuracy: 5%.								
12.4.5Anode HV stability from each distinct operational configuration of the XGA, to assure that the bremsstrahlung end point remains unchanged. Accuracy: 5%		N.A.			25 targets for HEXGA, also for LEXGA			
12.4.6Brightness distribution Record pinhole camera images of the spot distributions from each distinct operational configuration of the XGA. Accuracy: 0.05 mm on spot size	To assure that the source size is small enough.							High Speed Imager
12.4.7Polarization Measure the polarization of the XGA Accuracy: 5%								FMS
12.5HXDS Properties								
12.5.1Angular Resolution								
12.5.2Data taking speed								

Table 12: Facility Characterizations

Test Name, Description and Accuracy Requirement ($\pm 1\sigma$)	Justification	Off-axis angles	Focal Plane Included Angles (radius)	T, °C	Energy Sampling Interval (ΔE)	Estimated Integration Time	Total Time Including Overheads	Instrumentation
12.5.3Counting Rate Capability Flux measuring accuracy vs. counting rate.								
12.5.4Positioning accuracy								
12.5.5Beam centering accuracy								
12.5.6Encircled Energy accuracy								
12.5.7Absolute Quantum Efficiency accuray								
12.5.8Detector backgrounds								
12.5.9Detector spectral resolution								
12.6Scattered Light Source Properties								
12.6.1UV source								
12.7Stray light from XGA								
Effect of UV on HRC & ACIS, effect of visible on ACIS								

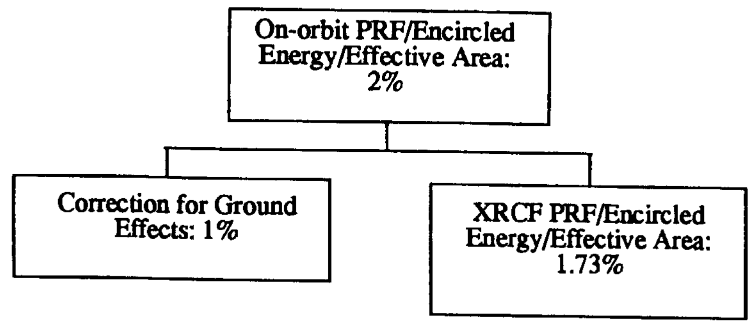
Table 13: Calibration Targets, Filters, Energies and Detectors.

13.	Line	Energy keV	Wavelength A	Tentative Filters	Photometric Detectors		Imaging Detectors		Spectroscopic Detectors	
					Flow proportional	solid anode MCP	Hi Speed Imager (HSI)	IPC	SSS	avalanche
13.1	Al IV-V discharge	0.095	131					??		
13.2	Be K	0.099	125							
13.3	B K	0.185	67.02							no response
13.4	C K	0.282	43.96							
13.5	C K + monochr.			0.05 A monochromator						
13.6	Ti $L\alpha_{12}$, $L\beta_1$	0.4522, 0.4584	27.06, 27.42							
13.7	O $K\alpha_1$	0.523	23.7	O_2 gas cell ?						
13.8	Cr L	0.581	21.3							
13.9	Fe L	0.705	17.6							
13.10	Co L	0.790	15.7							
13.11	Ne K edge		14.6							
13.12	Ni L	0.866	14.3	Ne cell, 14.6 A						
13.13	Cu L	0.928	13.4							
13.14	Zn L	1.032								
13.15	Na $K\alpha_{12}$, $K\beta_1$	1.041, 1.071	11.58, 11.91							
13.16	Mg $K\alpha_{12}$, $K\beta_1$	1.254, 1.302	9.52, 9.89							

Table 13: Calibration Targets, Filters, Energies and Detectors.

13.	Line	Energy keV	Wavelength A	Tentative Filters	Photometric Detectors		Imaging Detectors		Spectroscopic Detectors	
					Flow proportional	solid anode MCP	Hi Speed Imager (HSI)	IPC	SSS	avalanche
13.17	Al K	1.487								
13.18	Si K	1.740								
13.19	Zr L	2.042								
13.20	Mo L	2.293								
13.21	Ag L	2.984								
13.22	Sn L	3.444								
13.23	^{22}Ti K_α, Z-1 filter	4.510		^{21}Sc ?, or ^{22}Ti ?						
13.24	^{22}Ti K_β, Z-1 filter	4.931		^{21}Sc						
13.25	^{24}Cr K_α, Z-1 filter	5.415		^{24}Cr ? or ^{23}V ?						
13.26	^{26}Fe K_α, Z-1 filter	6.404		^{25}Mn ? or ^{26}Fe ?						
13.27	Cu K_α, Z-1 filter	8.408								
13.28	Ga K	9.25								
13.29	Ge K_α	9.885								
13.30	Au L	10.00								

Top level Error Budget. The following diagram illustrates one possible allocation of errors. Various projections of the PRF/Encircled Energy/Effective Area from



its hyperspace of independent variables, such as the Encircled Energy, the integral of dA... from 0 out to angle θ_1 and over a band of energies:

$$EE = \left[\int_0^{\theta_1} \int_{E_1}^{E_2} \frac{dA}{d\Omega dE} (\theta, \varphi, \xi, \chi, E, \Pi f_x, x, \ldots)\, dE d\theta \right]$$

and the Point Response Function within a specific energy band $E_1 < E < E_2$ and angular range $0 < \theta < \theta_2$ may experience differing errors from correction of ground

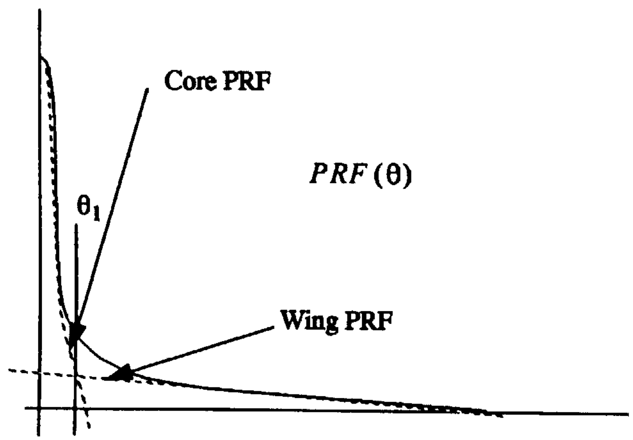
$$PRF(\theta \le \theta_2) = \left[\int_{E_1}^{E_2} \frac{dA}{d\Omega dE} (\theta, \varphi, \xi, \chi, E, \Pi f_x, x, \ldots)\, dE d\theta \right]$$

effects.

The Effective Area is the integral over an energy band $E_1 < E < E_2$ and over angles $0 < \theta < \pi/2$. One useful approximation is to assume a core PRF $f_c(\theta)$ and a wing PRF with a radial distribution, $f_w(\theta) = \frac{k}{\theta^2}$ so the integral flux out to $\pi/2$ is

$$EffectiveArea = Core(\theta_1) + Wing(\theta_1) = \int_0^{\theta_1} f_c(\theta)\, \theta d\theta + 2\pi f_c \theta_1 \int_{\theta_1}^{\pi/2} \left(\frac{\theta_1}{\theta}^2\right) \theta d\theta$$

where θ_1 is the angle at which the core and wing intensities are equal. The Wing is then $Wing(\theta_1) = 2\pi\theta_1^2 f_c(\theta_1) \ln\theta\Big|_{\theta=\theta_1}^{\pi/2} = 2\pi\theta_1^2 f_c(\theta_1) \ln\left(\frac{\pi}{2\theta_1}\right)$. so $EffectiveArea = EE(\theta_1) + 2\pi\theta_1^2 f_c(\theta_1) \ln\left(\frac{\pi}{2\theta_1}\right)$



We can find $EE(\theta_1)$ from the measured Encircled energy curve vs. angle. We can find θ_1 and $f_c(\theta_1)$ from the HSI encircled energy curve in which we have fit wing and core PRF curves as in the above figure.

Table 15: Required PRF Accuracy for Four Strong Source Strengths

Angular Separation Radius, arcsec	PRF Accuracy, 1σ							
	1 Crab		0.1 Crab		0.01 Crab		0.001 Crab	
	Fraction of PRF Peak	% of measured point response value	Fraction of PRF Peak	% of measured point response value	Fraction of PRF Peak	% of measured point response value	Fraction of PRF Peak	% of measured point response value
10	4e-6	0.9	5e-6	2.3	3e-5	14	3e-4	> 100
45	5e-7	1.4	3e-6	14	3e-5	> 100	3e-4	> 100
135	3e-7	7	3e-6	> 100	3e-5	> 100	3e-4	> 100

were made. Some of them are

- The duration of an observation is 10^5 sec
- The PRF measured at HRMA calibration is identical to the VETA-I result obtained with the HSI at Zr-L
- There are 3 sources of error: counting statistics in the on-orbit observation, a 1% error in EE at 1 arcsec radius in correcting for XRCF effects in measuring the PRF, and the accuracy of measuring the PRF at the XRCF. The latter is that quoted in Table 12
- The PRF fits a power law vs. radius for the purpose of accounting for the 1% EE error
- The smallest number of counts that constitutes a detected source on-orbit is 50 counts
- The counting rate from the Crab is 1000 s^{-1}.

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