VETA-1 X-ray Detection System

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1. ABSTRACT

The alignment and X-ray imaging performance of the Advanced X-ray Astrophysics Facility(AXAF) Verification Engineering Test Article-I(VETA-I) was measured by the VETA-I X-Ray Detection System(VXDS). The VXDS was based on the X-ray detection system utilized in the AXAF Technology Mirror Assembly(TMA) program, upgraded to meet the more stringent requirements of the VETA-I test program. The VXDS includes two types of X-ray detectors; 1) a High Resolution Imager(HRI) which provides X-ray imaging capabilities and 2) sealed and flow proportional counters which, in conjunction with apertures of various types and precision translation stages, provide the most accurate measurement of VETA-I performance. Herein we give an overview of the VXDS hardware including X-ray detectors, translation stages, apertures, proportional counters and flow counter gas supply system and associated electronics. We also describe the installation of the VXDS into the Marshall Space Flight Center(MSFC) X-Ray Calibration Facility(XRCF). We discuss in detail the design and performance of those elements of the VXDS which have not been discussed elsewhere; translation systems, flow counter gas supply system, apertures and thermal monitoring system.

2. INTRODUCTION

The Advanced X-ray Astrophysics Facility(AXAF), will be the third of NASA's Great Observatory series, having been preceded by the Hubble Space Telescope and Gamma Ray Observatory, and to be followed by Space Infra Red Telescope Facility. The AXAF, managed by NASA's Marshall Space Flight Center(MSFC), will be the largest imaging x-ray telescope flown in this century, will have the best angular resolution and will have response to higher energy, 10 keV, than any prior high resolution imaging telescope. A more complete description of the AXAF may be found in references 1 and 2.

A major technical challenge of the AXAF program is the fabrication of the AXAF Wolter Type 1 X-ray optics to tolerances never before having been achieved in such large X-ray optics. Fabrication of smaller optics to the required tolerances was demonstrated in the TMA program. However, it was decided that the fabrication technology for large optics should be demonstrated by test prior to proceeding with the full AXAF program. The VETA-I test program was thus instituted. In this program the largest pair of AXAF optics was to be fabricated to final tolerances, mounted in a test mount and tested in X-rays to demonstrate conclusively that the performance requirements had been met.

An X-ray test of the 10 meter focal length AXAF optics would require a new test facility, the X-ray Calibration Facility(XRCF), built at MSFC in place of the existing XRCF which had been used for calibration of the Einstein Observatory(HEAO-B) and testing of the TMA.

Testing of the VETA-I to the required levels would also require more accurate X-ray test equipment than had been previously available. An X-ray Detector Assembly(XDA) had been developed by the Smithsonian Astrophysical Observatory(SAO) for testing of the TMA. It had been utilized at MSFC in the HEAO-B XRCF for two TMA tests and a number of other tests of various X-ray systems. It was decided to upgrade the XDA for testing of the VETA-I.

Additions and modifications made to the TMA XDA to make it suitable for VETA-I testing included: 1) thin window flow proportional counters for low energy testing and new sealed proportional counters with better performance, 2) new, more accurate four-axis translation system for proportional counter scans, 3) new apertures for the proportional counters, 4) flow counter gas supply system, 5) new supporting structure for beam normalization proportional counters, 6) thermal monitoring system and 7) integrated workstation control and data acquisition system. Retained in the system were the HEAO-B breadboard HRI and its data acquisition system and the basic structure and drive mechanisms which provided instrument

selection, focus adjustment, HRI vertical motion and X-ray shutter control.

An overview of the VXDS and its use in VETA-I testing will be given below. Many elements of the VXDS have been covered in detail in other papers, and these will be mentioned briefly. Several important VXDS subsystems will be discussed in detail, particularly in relation to their as-measured performance.

3. VXDS OVERVIEW

3.1 Requirements

The VXDS was required to measure the mirror pair alignment and imaging performance of the VETA-I. Specifically, the system was required to measure:

1. Mirror pair alignment to within +/-0.14 arcseconds per axis.
2. Full width half maximum(FWHM) to within +/-0.05 arcseconds.
3. Encircled energy to within +/-2% fractional energy error.
4. Effective area to within +/-5%.
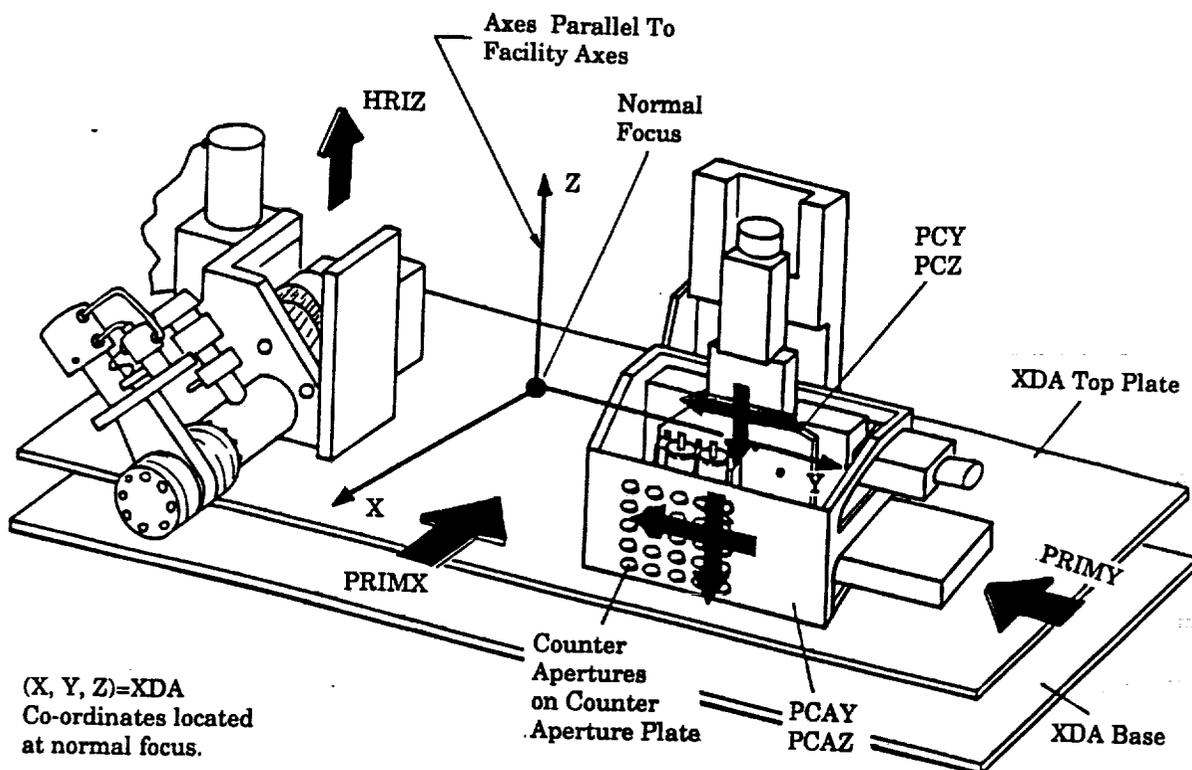
3.2 VETA-I X-ray Detector Assembly

Figure 1. Schematic Diagram of the VETA-I XDA

The VXDS utilized three different types of X-ray detectors; 1) a HEAO-B High Resolution Imager(HRI), 2) flow proportional counters(FPC) and sealed proportional counters(SPC). The HRI, an FPC and an SPC were mounted on a set of translation stages which were located at the focus of the VETA-I. This assembly of detectors and translation stages was

designated as the VETA-I X-ray Detector Assembly(XDA). The VETA-I XDA is illustrated in Figure 1, and is shown pictorially in Figure 2 as it was installed in the MSFC XRCF for the VETA-I test. The VETA-I XDA co-ordinate axes are also shown in Figure 1. The origin of the XDA co-ordinate system is fixed with respect to the XDA base and is nominally located at the focus of the VETA-I when the XDA is properly positioned for testing. The XDA co-ordinates are nominally parallel to the XRCF facility co-ordinates when the XDA has been properly aligned. The XDA X axis is along the VETA-I optical axis, positive towards the VETA-I from the XDA. The XDA Z axis is nominally vertical, positive up, and the Y axis is nominally horizontal, completing a right-handed co-ordinate system.

The XDA structure and the arrangement of the XDA translation axes are shown in Figure 1. The X-ray detectors are mounted on the "XDA Top Plate", which is capable of being translated in the X and Y directions. These translation stage motions are designated as "PRIMX" and "PRIMY', with the stage motion sign convention illustrated in Figure 1(large arrows). The "PRIMX" motion is utilized to adjust the focus position of the XDA such that the detector focal plane is co-incident with the VETA-I focus. The "PRIMY" motion is primarily utilized to select the detector to be used, the HRI or a proportional counter. It is also utilized to adjust the Y position of the XDA such that the selected proportional counter aperture is within reach of the counter translation stages (discussed below). The HRI is mounted on a Z axis translation stage whose motion is designated as "HRIZ", with a positive stage motion being upwards. The XDA FPC and SPC and apertures for these counters are carried by an integrated set of four translation stages, two in the Y direction and two in the Z. The counters and apertures make up a sub-assembly designated as the counter/aperture translation system, or "CAT". This entire sub-assembly mounts on the Top Plate of the XDA.

The translation stage arrangement of the CAT is shown in both Figures 1 and 2. From "ground" on the XDA Top Plate the stage order is PCAY, PCAZ, PCY and PCZ. The proportional counter apertures are carried on structure which is carried by both PCAY and PCAZ. The counters themselves are carried by all four stages. This arrangement allows selection of the counter and aperture combination to use by movement of the PCY and PCZ stages such that the chosen counter is positioned behind the chosen aperture. The counter and aperture together can then be moved relative to the X-ray beam by movement of the PCAY and PCAZ stages.
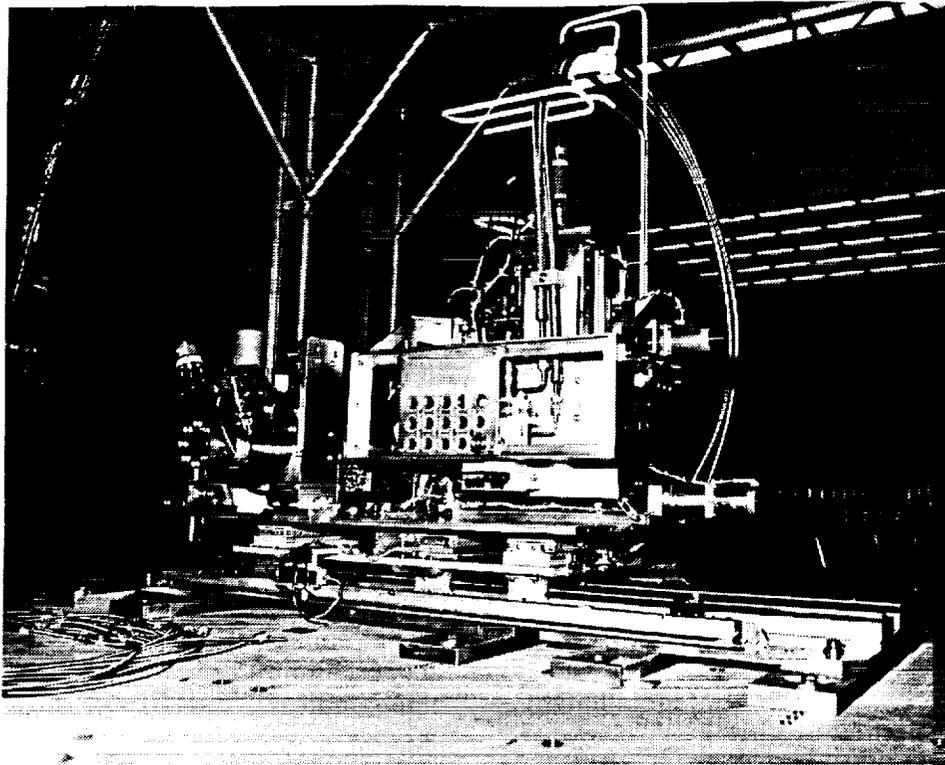

Figure 2. VETA-I XDA Installed in XRCF

3.3 Beam Normalization Detectors

An FPC and an SPC were also located on a structure, shown in Figure 3, just in front of the VETA-I(towards the source from the VETA-I). Their position was such that they intercepted the X-ray beam just outside of the VETA-I aperture annulus and inside the overall beam limits, which were set by the size of the X-ray guide tube. They were used to monitor the X-ray flux incident on the VETA-I and thereby allow normalization of data from the focal plane detectors. These proportional counters were designated as "beam normalization detectors(BND)".

Figure 3. VXDS Beam Normalization Detectors

3.4 Flow Counter Gas Supply System

Operation of the XDA and BND FPC's required a flow counter gas supply system(GSS). The GSS was located outside of the XRCF vacuum chamber and supplied gas through flexible hoses and feed-thrus into the chamber. The GSS is shown in Figure 4. The GSS was capable of supplying either methane or P10(90% argon, 10% methane) at a controlled pressure between 100 and 1000 torr. Safety systems were also incorporated to prevent dumping of flow counter gas into the chamber through a failed flow counter window.

3.5 Thermal Monitoring System

A Thermal Monitoring System(THM) was incorporated to measure temperature at 20 locations throughout the VXDS hardware. Thermistors were utilized along with a Hewlett-Packard Model 3852A data acquisition system. Temperatures monitored included each proportional counter, each XDA motor, the GSS accumulator and various points on the XDA structure.

3.6 X-ray Data Acquisition and Control System

The X-ray Data Acquisition and Control System(XDACS) included both the electronics and cabling needed to run the detectors, translation stages and gas supply system as well as the extensive computer control system used to operate the system and to store and analyze the test data. The XDACS is discussed by Brissenden(this volume).
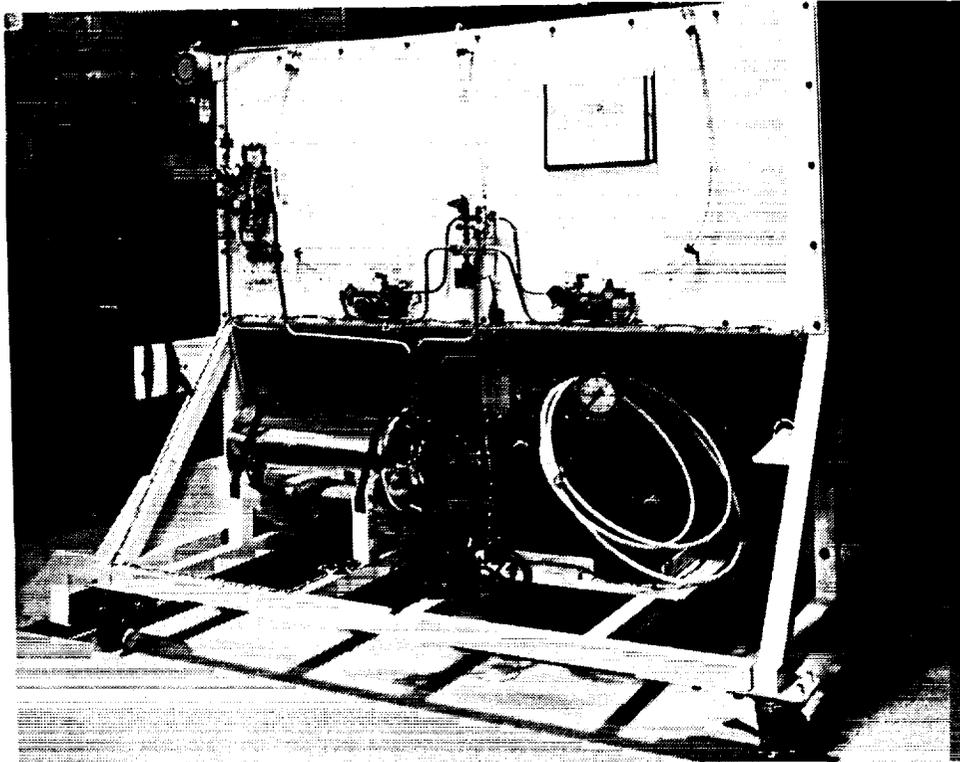

Figure 4. Flow Counter Gas Supply System

4. TRANSLATION STAGE PERFORMANCE

4.1 PRIMX, PRIMY and HRIZ Translation Stages

The translation stage performance requirements varied from stage to stage, depending on the function of the stage and its' heritage. The PRIMX, PRIMY and HRIZ stages were carry-overs from the TMA XDA and had a resolution of 2.5μ. The PRIMX and PRIMY stages incorporated Sony Magnascale linear position sensors which were used for closed loop control of position through the XDACS. The HRIZ stage did not have a position sensor and was controlled in an open loop mode by counting steps. Each of these three stages incorporated an absolute zero indicator and limit switches at the ends of travel.

The absolute accuracies of the PRIMX or HRIZ stages were not critical to the performance of the VXDS. The function of the PRIMX stage was to adjust the focus position of the XDA. The depth of focus of the VETA-I(on the order of 100μ) and the knowledge of the focus position of the apertures(+/-10μ) and HRI focal plane were large when compared with the repeatability of the stage(+/-2.5μ). Also, the focus position was always measured relative to the PRIMX zero reference position. As long as this did not shift we could always move the XDA to the correct focus position for each detector well within the accuracy needed. The HRIZ accuracy was not critical since it was utilized only to position the HRI, an imaging detector with a one inch field-of-view, in the vertical axis.

The PRIMY stage was utilized for large moves to select either the HRI or proportional counters for use and also for small moves to place the chosen proportional counter aperture on-axis. The use of PRIMY for aperture positioning was dictated by the limited travel of the PCAY stage as compared with the extent of the apertures in the Y direction. The XDACS software was developed in such a way that a given aperture could be placed on-axis (that is, the center of the aperture co-located with

the current definition of the X-ray beam center) by any valid combination of PRIMY and PCAY stage positions which yielded the correct sum of the two. The accuracy requirement for PRIMY was therefore driven by the need to repeatably locate the beam with different combinations of PRIMY and PCAY stage postiion. The positioning resolution of the PRIMY stage was 2.5μ(one motor step). The readout resolution was 1μ and the manufacutrers specified accuracy for the readout was better than +/- 10μ over 1 meter of travel).

During the VETA-I test some difficulty was experienced with maintaining accurate beam center positions. The problem was that we could not always return to an aperture in which the beam had been "centered"(that is, located in Y and Z axes) and find the beam still near the center of that aperture(the beam drift was monitored and was not significant). The differences in beam center position were often 30μ to 50μ or sometimes more. In addition, we could not always locate the beam in a new aperture, even though we had carefully centered the beam in a different aperture and had very accurate knowledge of the relative positions of all of the apertures. This did not always occur, however. It was finally determined that the beam center errors occurred when the PRIMY axis had been moved to either reach a new aperture or to come back to the original aperture, but with a different combination of PRIMY and PCAY. The result of the problem was to lengthen the test times somewhat, due to the need to perform "beam centering" procedures each time the aperture was switched. The results of the tests were not compromised, however.

After the VETA-I test a series of measurements were made to determine the accuracy of the PRIMY stage. These were made using an HP laser position measuring system, and are documented in reference 3. The results are shown in Figure 5, wherein the PRIMY position errors are plotted vs. commanded move distance. The Figure shows PRIMY errors to be on the order of 0.6μ to 0.8μ per millimeter move. The sense of the error is that the true distance moved(measured by the HP laser) is always less than the indicated move (as measured by the Sony Magnascale) on the PRIMY stage. In the next generation of X-ray detection equipment the PRIMX, PRIMY and HRIZ stages will be replaced, thereby correcting this problem.
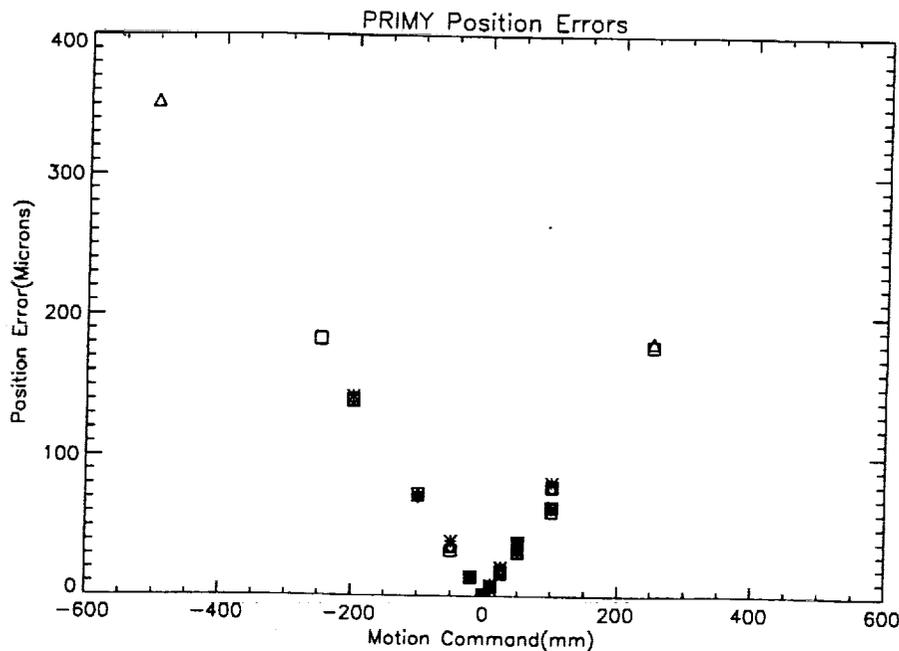

Figure 5. PRIMY Position Errors

4.2 PCY, PCZ, PCAY and PCAZ Translation Stages

As discussed above in Section 3.2 the PCY and PCZ stages on the CAT were used to move the selected proportional counter behind the selected aperture. The required positioning accuracies (including readout inaccuracy) for the PCY and PCZ stages

were +/-5μ over the entire travel range (approximately 200mm) of each stage. Testing using an HP laser position measuring system verified that these accuracies were met.

The PCAY and PCAZ stages were used both to select an aperture for use and to perform various types of scans through the X-ray beam, with the proportional counter held fixed behind the selected aperture. One dimensional scans in either the Y or Z axis and a two dimensional raster scan in both Y and Z were used extensively in the VETA-I test. The accuracy desired for aperture selection was +/-3μ over the entire range of travel(approximately 100mm for PCAY and 150mm for PCAZ), even though the PRIMY stage was not as accurate. The reason for this was to allow very accurate aperture to aperture moves using PCAY and PCAZ alone. Apertures were grouped together such that the smaller apertures could be reached by PCAY and PCAZ moves only. Figures 6 and 7 show acceptance test data for the PCAY and PCAZ stages. Positioning errors are plotted over the entire travel range of each stage. In each case the +/-3μ error limits were met.
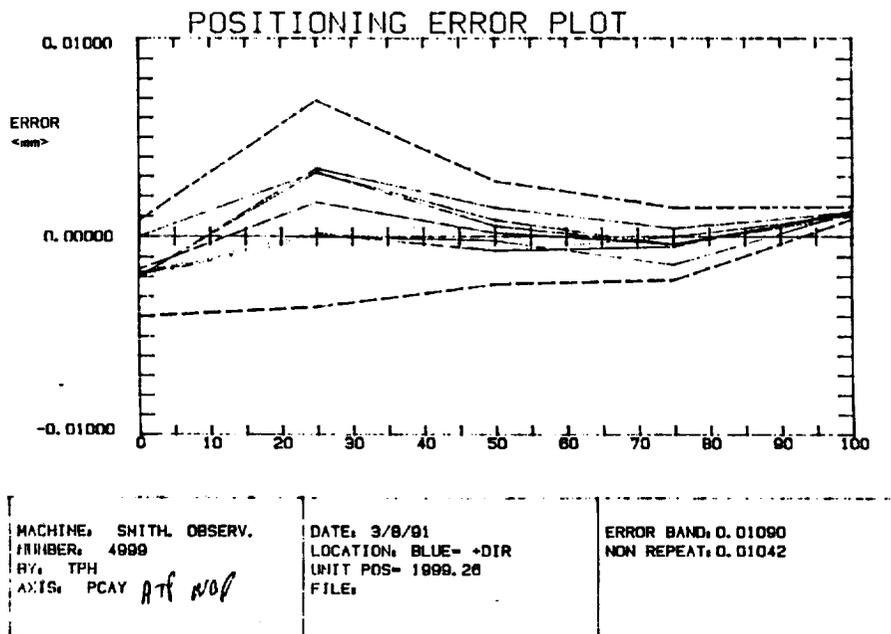

Figure 6. PCAY Stage Position Errors - Full Travel

The most demanding use(in terms of accuracy) of the PCAY and PCAZ stages was to perform the one and two dimensional scans. These scans were typically small in extent, with very small scan steps. A typical one dimensional scan would be to scan the 5μ aperture in either Y or Z in steps of 2μ over a range of 200μ. A typical two dimensional scan would utilize the 10μ aperture, scanning in steps of 10μ over a 19 x 19 scan matrix(190μ by 190μ). For these short scans we utilized a "motor incremental mode" of scanning. In this mode the encoder feedback was NOT used, and the movement was made by motor steps alone. In addition, the scans were performed in such a manner as to remove translation stage backlash. For example, when performing a two-dimensional raster scan all rows were scanned in the same direction, and the stage was always moved beyond(to the left of) the first point in the row so that the the backlash was taken out in the righward move to the first scan point in the row. Using this mode the errors were below 1μ at any scan point. This accuracy was demonstrated using the HP laser position measurement system. A typical test run is shown in Figure 8, wherein position error is plotted vs. stage position for a 30μ scan in steps of 5μ. The maximum error in this case was 0.2μ. A 1 μ scan position error was utilized in developing the error budgets of the VXDS. With this error the overall performance requirements were shown to be met.
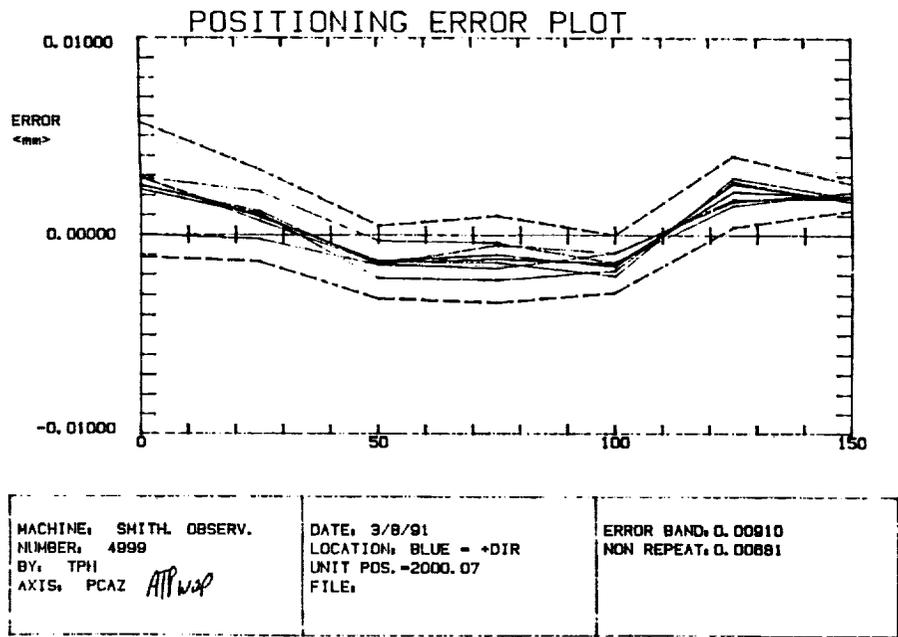
POSITIONING ERROR PLOT

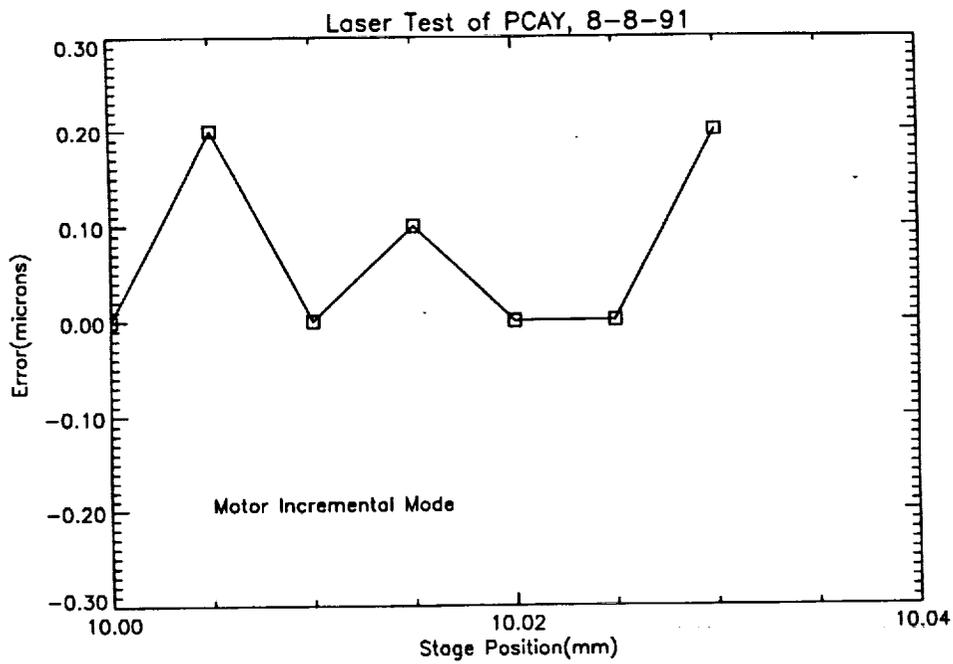| MACHINE: SMITH. OBSERV.
NUMBER: 4999
BY: TPH
AXIS: PCAZ _ATПwдʹ_ | DATE: 3/8/91
LOCATION: BLUE = +DIR
UNIT POS. -2000. 07
FILE: | ERROR BAND: 0. 00910
NON REPEAT: 0. 00681 |

Figure 7. PCAZ Stage Position Errors - Full Travel

Figure 8. PCAY Position Errors - Small Motions

5. PROPORTIONAL COUNTER APERTURES

The most accurate measurement of the performance of the VETA-I was made using proportional counters in conjunction with various types of apertures located in front of the counters. The accuracy of this approach is attributable to the high spatial resolution which can be obtained with small, precision apertures in front of the counters, good energy resolution provided by the counters and the use of the BND counters to normalize the focal plane counters during scans. The general arrangement of counters and apertures on the XDA is shown in Figures 1 and 2. In addition to the counters on the XDA, two counters were utilized for beam normalization, as discussed in Section 3.3 and shown in Figure 3. Precision apertures were also placed in front of each BND counter.

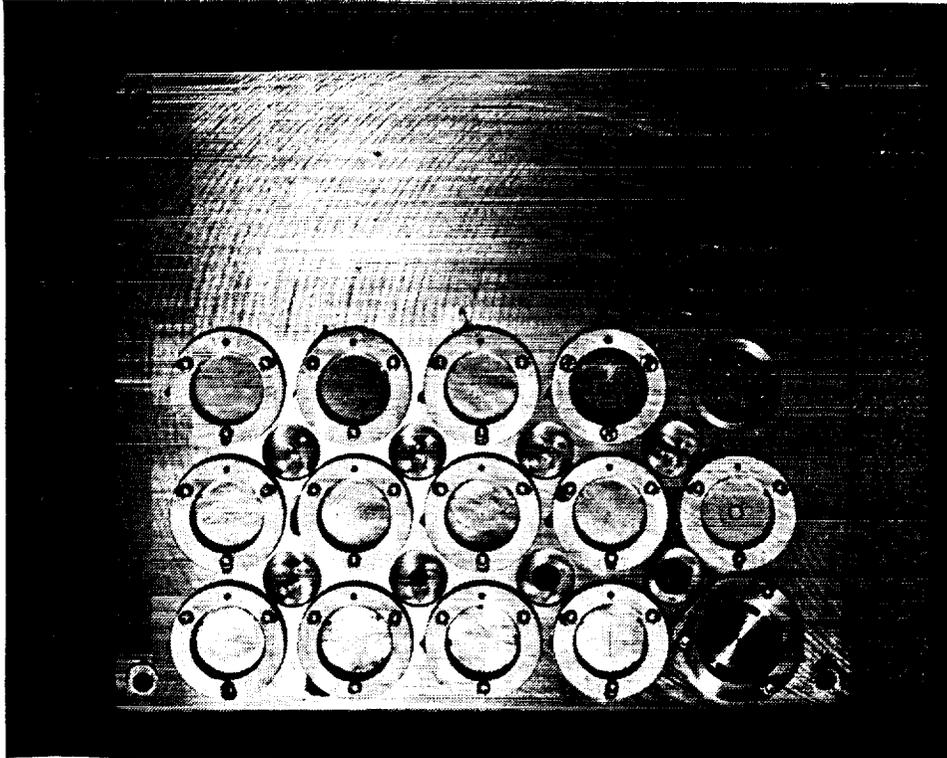The arrangement of apertures on the XDA "aperture plate" is shown in Figure 9.

Figure 9 Apertures on XDA Aperture Plate

Three rows of aperture holders, each row containing five holders, are located on the plate. In addition, circular apertures are machined directly into the aperture plate. These machined apertures are located between the rows and columns of aperture holders. Three different types of apertures were provided:

1. Circular apertures, commonly referred to as "pinholes", even though the largest was 20mm in diameter.

2. Annular apertures with a variety of nominal diameters and annulus widths, referred to as "annuli".

3. Linear apertures, referred to as "slits", in both horizontal and vertical orientation.

A complete listing of the apertures provided on the XDA is given in Tables 1(pinholes), 2(slits) and 3(annuli). The apertures on the BND are given in Table 4. The tables provide the aperture name, nominal dimensions, open area, equivalent diameter(pinholes), method of manufacture and method of measurement. Three different fabrication techniques were used used for the apertures. The smallest apertures were laser drilled into 12μ gold foil which had been bonded into machined "aperture holders". These aperture holders were then fastened to the aperture plate, using both screws and a locating pin, and tack bonded to the plate. Other apertures were machined directly into special aperture holders and attached to the plate as described above. Finally, a number of circular apertures were machined directly into the aperture plate. Three methods of

measurement of aperture area were also used. The smallest apertures were photographed with a scanning electron microscope(SEM). The boundary curve was then digitized using precision calipers and a SEM photograph of a calibration standard, which provided a grid of lines approximately 0.46μ apart. This calibration photo allowed compensation for SEM scale factor variation. The estimated accuracy in measurement of boundary points was better than 0.01μ in each axis. The boundary data were then entered into the IDEAS CAD system which calculated the open area of the aperture to an accuracy of 0.02% (reference 4).

Mid-size laser drilled apertures were inspected at the laser drilling vendor's facility using an optical microscope and translation stages with an estimated accuracy of +/-0.2μ. The boundary co-ordinates were entered into the IDEAS CAD program and the open area calculated. Larger apertures machined into the aperture plate were inspected using a two-axis video zoom system and translation stages accurate to 1μ. Two orthogonal diameters were determined for these larger circular apertures. The average diameter was used to calculate the open area.

Aperture Name	Area (Sq mm)	Equivalent Diameter	Fabrication Method	Measurement Method
2μ	7.707923X10-6	3.13μ	L	SEM
5μ	28.33479X10-6	6.01μ	L	SEM
10μ	104.96409X10-6	11.56μ	L	SEM
25μ	511.55011X10-6	25.52μ	L	SEM
50μ	1926.3078X10-6	49.52μ	L	M
100μ	7660.07X10-6	98.76μ	L	M
300μ	74155.591X10-6	307.28μ	L	M
500μ	198109.55X10-6	502.24μ	L	M
0.75mm	0.407150	0.720mm	P	V
1.0mm	0.716303	0.955mm	P	V
1.5mm	1.824147	1.524mm	P	V
2.0mm	3.122771	1.994mm	P	V
3.0mm	6.955939	2.976mm	P	V
5.0mm	19.322051	4.960mm	P	V
7.5mm	43.556561	7.447mm	P	V
10.0mm	78.006654	9.966mm	P	V
20.0mm	313.845185	19.990mm	M	V

Fabrication Method:
    L=Laser drilling
    M=Machined
    P=Machined into plate
Inspection Method:
    SEM=Scanning Electron Microscope
    M=Vendor Microscope
    V=Video Camera and Stages				

Table 1. Circular Apertures(Pinholes) on XDA Aperture Plate

The measured open area of the apertures are the geometric areas. Vignetting of the beam occurs due to the fact that the X-ray beam from the VETA-I is a converging cone with a cone angle of approximately 6.8 degrees This factor is significant for the smaller apertures, and is taken into consideration in the test data analysis.
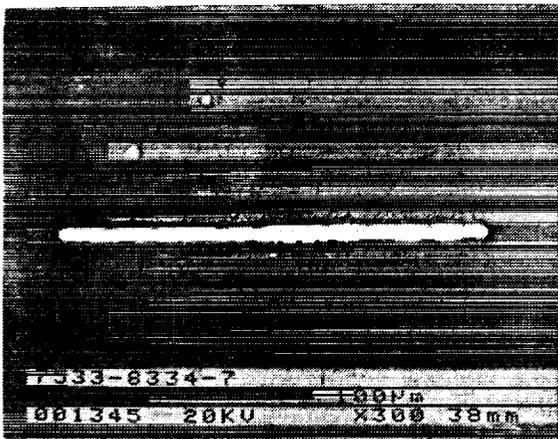
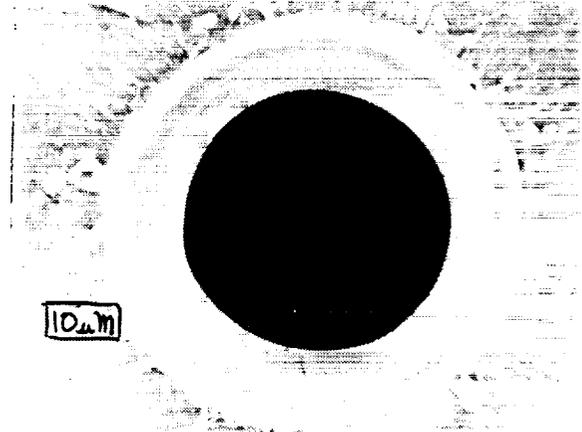Figure 10 shows SEM photographs of several of the VETA-I apertures.
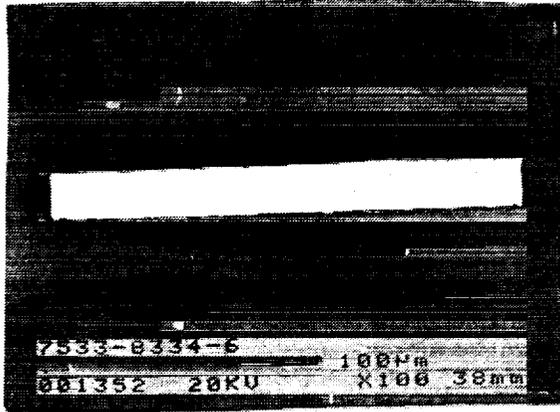
(a) 1mm x 100µ slit   (b) 5µ Pinhole

(c) 300µ x 10µ slit   (d) 10µ Pinhole

Figure 10 SEM Photographs of Aperuures

Type	Nominal Dimensions Length x Width	Area (Sq mm)	Fabrication Method	Measurement Method
Horizontal slit	300µ x 10µ	0.00266520	L	SEM
Horizontal slit	1000µ x 100µ	0.09730713	L	SEM
Vertical slit	300µ x 10µ	0.00263928	L	SEM
Vertical slit	1000µ x 100µ	0.09480202	L	SEM

Fabrication Method:
   L=Laser drilling
   M=Machined
   P=Machined into plate
Inspection Method:
   SEM=Scanning Electron Microscope
   M=Vendor Microscope
   V=Video Camera and Stages				

Table 2. Slit Apertures on XDA Aperture Plate

Aperture Name	Nominal Dimensions Diameter x Width	Area (Sq mm)	Fabrication Diameter	Measurement Method
100μ Annulus	100μ x 10μ	0.00204820	L	M
300μ Annulus	300μ x 30μ	0.01869377	L	M
600μ Annulus	600μ x 60μ	0.07951131	L	M
1.0mm Annulus	1.0mmμ x 100μ	0.27067390	L	M
4.0mm Annulus	4.0mmμ x 400μ	4.1978070	L	M
20mm Annulus				

Fabrication Method:
   L=Laser drilling
   M=Machined
   P=Machined into plate
Inspection Method:
   SEM=Scanning Electron Microscope
   M=Vendor Microscope
   V=Video Camera and Stages

Table 3. Annular Apertures on XDA Aperture Plate

Part Number	Aperture Name	Area (Sq mm)	Equivalent Diameter
7533-8362 S/N 1	BND Flow Counter	314.158	20.000mm
7533-8362 S/N 2	BND Sealed Counter	315.356	20.038mm

Table 4. BND Apertures

6. FLOW COUNTER GAS SUPPLY SYSTEM

The flow counter gas supply system provided either methane or P10(90% argon, 10% methane) at a controlled pressure. Gas from the selected supply bottle was regulated to a pressure of approximately 5 psig and then fed into an accumulator via an electronically controlled "pulsing" valve. This valve would activate for a set time period whenever the measured pressure in the accumulator would drop below a computer controlled pressure setpoint. Gas from the accumulator would flow through gas lines into the XRCF vacuum chamber and to the XDA and BND flow counters, then return to the gas supply system(see Figure 4). The gas would then flow across a manually adjustable needle valve into a vacuum pump on the gas supply system. The exhaust gas from the vacuum pump was routed out of the XRCF building via an exhaust line.

Important performance characteristics for the gas supply system were its' stability about a setpoint(+/-0.5 torr), absolute accuracy of pressure regulation(+/-2 torr) and pressure repeatability(+/-1 torr). The absolute accuracy and repeatability were functions of the pressure transduced used. A pressure transducer was selected which met the accuracy and repeatability requirements. The stability requirement was met be providing a large accumulator to minimize the pressure rise caused by each gas pulse and minimizing the flow rate to the extent practical. Plots of pressure vs. time over long and short time periods are shown in Figures 11 and 12. The data show short term stability to be on the order of +/-0.2 torr.
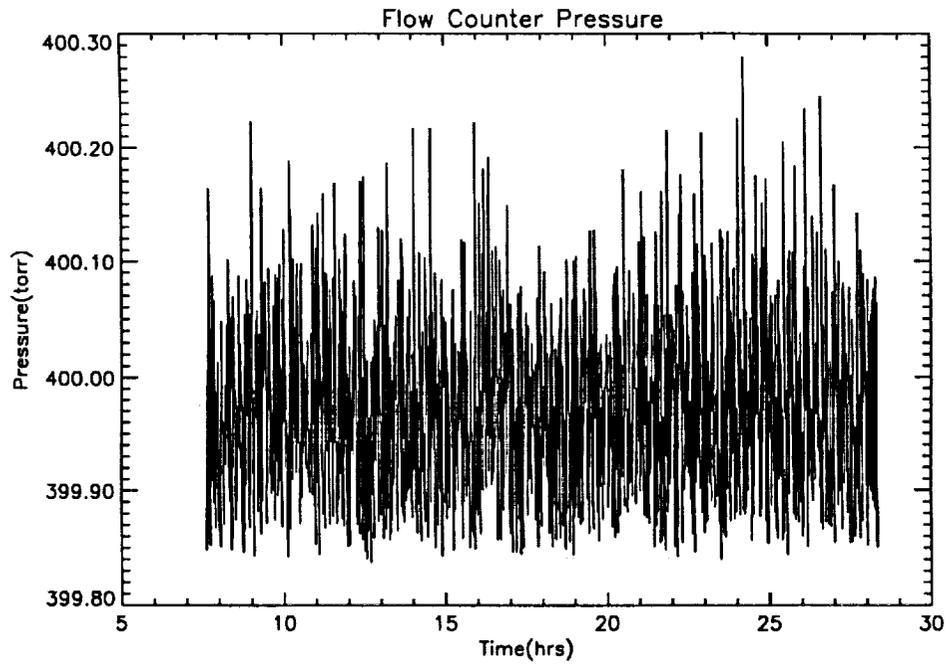
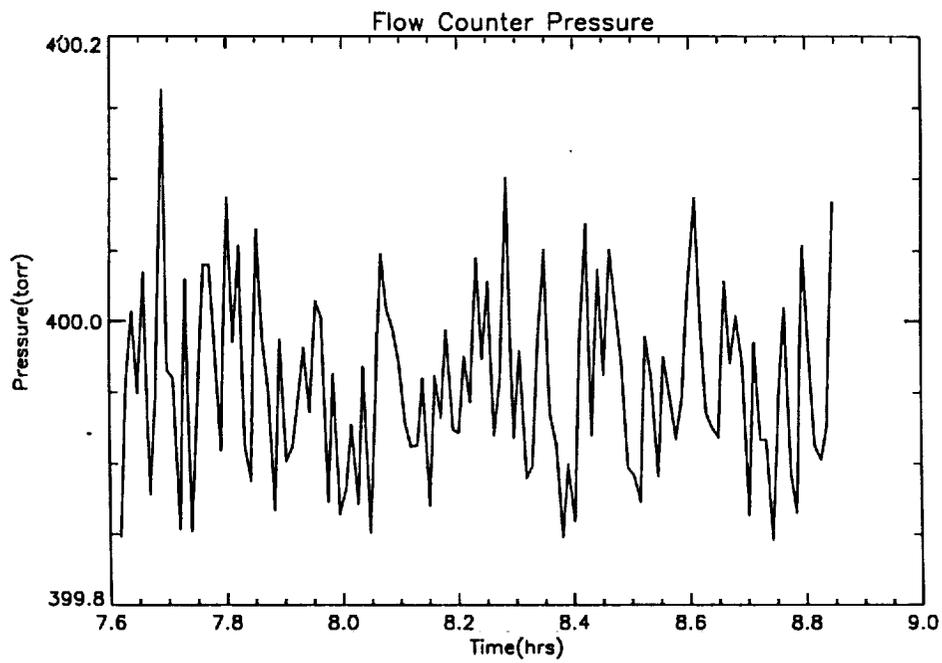Figure 11. Flow counter gas pressure stability - long term

Figure 12. Flow counter gas pressure stability - short term

7. SYSTEM TEMPERATURES

Twenty thermistors were placed at critical points on the VXDS. These thermistors were read by the XDACS via the HP 3852A data acquisition system and logged in the test data files. Temperatures monitored included proportional counters, motors, various structural components and the gas supply system accumulator. The flow proportional counter temperatures were of particular importance since the counter efficiency is related to gas density. The gas supply system maintained the pressure constant in both the XDA and BND flow counters, but the density would vary, and hence the efficiency, if the gas temperatures were different. The logged temperatures were used to compensate for this effect and therefore ensure that the BND counter would properly normalize the XDA flow counter. A plot of counter temperature vs. time is shown in Figure 13.
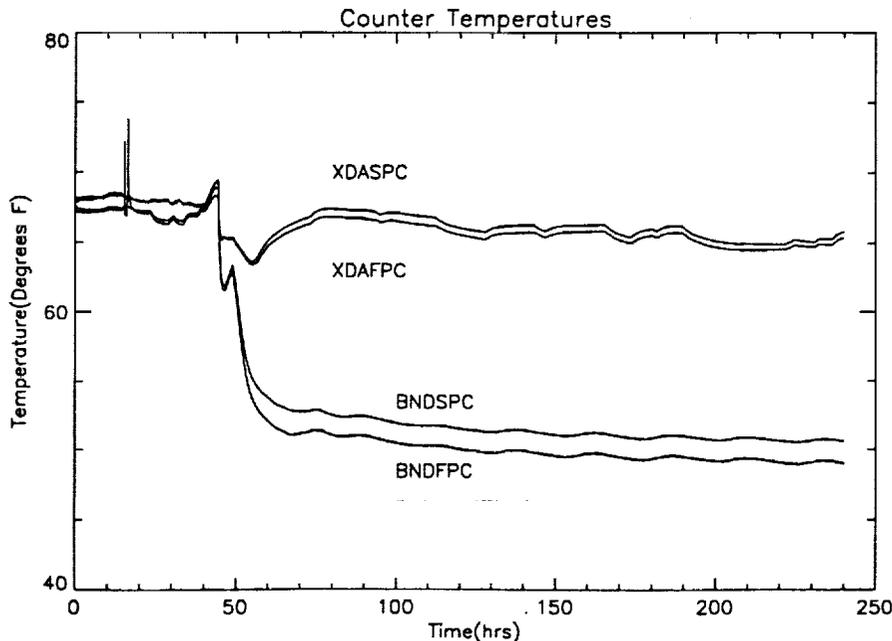

Figure 13. Proportional counter temperatures vs. time

The time duration of the plot is approximately 250 hrs, commencing near the start of the VETA-I test. A key feature shown on the plots is the large decrease in temperature of the BND counters(BNDSPC and BNDFPC) as compared with the counters on the XDA(XDASPC and XDAFPC). This was due to a cold condition which developed in the front of the XRCF vacuum chamber, near the BND. The large difference in counter(and therefore gas) temperatures made the density correction important in the data analysis.

8. CONCLUSIONS AND FUTURE WORK

The TMA XDA, an existing set of test equipment, was significantly upgraded to perform the testing on the VETA-I. The upgrades were necessary to support low energy testing(flow counters), provide enhanced accuracy(CAT & apertures), greatly improve the test efficiency and data analysis capabilities(XDACS) and to adapt the system to the new XRCF. The system was developed between mid-1989 and mid-1991 and was installed in the XRCF in June, 1991. VETA-I testing commenced in late August, 1991 and continued through late October, 1991. Additional tests were performed on the VXDS itself from December, 1991 through May, 1992.

The VXDS performed well throughout the test series, with no major failures which stopped the testing. The most significant technical problems were the failure of the XDA sealed counter and a higher than expected level of electrical noise in the XDA proportional counters. We were able to find work-arounds to both problems. Another significant issue was the effect of the flow proportional counter window mesh, which is discussed in detail in Reference 5.

The architecture of the VXDS, particularly the integrated and networked computer control system, discussed in Reference 6, was a major success. The data acquisition and analysis capabilities of the VXDS were crucial to the success of the VETA-I test.

An X-ray detection system for the AXAF High Resolution Mirror Assembly(HRMA) calibration is now being developed at SAO. The system, the HXDS, will utilize major elements of the VXDS. The dated TMA equipment will be replaced and improvements will be made to other elements where necessary. The overall control architecture of the VXDS will be carried forward to the HXDS.

REFERENCES

1. M. Weisskopf, "The Advanced X-ray Astrophysics Facility: An Overview," Astrophysical Letters & Communications., vol. 26, pp. 1-6, 1987.

2 E. Kellogg, R. Brissenden, K. Flanagan, M. Freeman, M. Jones, M. Ljungberg, P. McKinnon, W. Podgorski, D. Schwartz, M. Zombeck, "Calibration of the Verification Engineering Test Article-I(VETA-I) using the VETA-I X-ray Detection System," SPIE Volume 1546, pp. 2-12, 1991.

3. T. Norton Internal Memorandum TJN-FY92-003, "VETA-I Test Setup Verification", December 26, 1991

4. R. Goddard Internal Memorandum RG92-02, "VETA-I Aperture Area Determination Summary", June 1, 1992

5. P. Zhao, M. D. Freeman, E. M. Kellogg, D. T. Nguyen, "VETA-I Encircled Energy and Data Reduction" SPIE 1742-08

6. R. J. V. Brissenden, M. T. Jones, M. Ljungberg, D. T. Nguyen, J. B. Roll, "VETA X-ray Data Acquisition and Control System", SPIE 1742-06.