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AXAF-I CCD Imaging Spectrometer (ACIS)

Verification Assessment Report -Power and Thermal-Control Structure- -Operational Analysis Report-

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1. INTRODUCTION

1.1 Scope

This document provides a collection of information which results from the implementation of the ACIS Verification Plan, 36-01203. It is intended to show that the delivered instrument meets a specific set of requirements from the ACIS Power and Thermal-Control Structure (PTS) Specification, ACIS-36-02101.

In particular, this report provides the operational analysis data to support the verification of specific PTS Specification requirements. These requirements were assessed to be best verified by an operations analysis. The method selected in the verification of each specific requirement is the method which provides the assurance to the program that the requirements have been verified.

The Verification Cross Reference Matrix contained in the ACIS PTS Specification shows how each contractual requirement will be verified. The requirements documented herein have been designated to be verified by analysis and/or a combination of other verification methods.

1.2 Applicable Documents

ACIS Project Documents

36-02101	ACIS Power and Thermal-Control Structure (PTS) Specification
36-01203	ACIS Verification and Calibration Plan

2. METHODOLOGY

2.1 Requirements & Specifications

Verification methods to be used are defined in the verification matrix, compiled as an appendix to the ACIS Power and Thermal-Control Structure Specification, 36-02101.

2.2 Verification Descriptions

Summary level descriptions of each verification activity are located in the ACIS Verification Plan, 36-01203. The specific definitions for this report are as follows:

2.2.1 Analysis Definition

Analysis is a method of verification, taking the form of the processing and accumulated results and conclusions, intended to provide proof that verification of a requirement(s) has been accomplished. The analytical results may be based on engineering study, compilation or interpretation of existing information, similarity to previously verified requirements, or derived from lower level examinations, tests, demonstrations, or analyses. Verification by analysis is a process used in lieu of or in addition to testing to verify compliance with specification requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analytical techniques may be used in lieu of tests for such things as life, storage, failure analysis, safety, interchangability, and some other performance requirements which cannot be verified by test.

2.2.2 Operational Analysis Definition

This topic covers analyses required to verify that operations related requirements have been met by the PTS. This involves the review of ACIS and PTS documentation to ensure that all operational capabilities/constraints are correct and have been incorporated into the appropriate mission definition documentation. In many instances, this may simply show documentation describing an operational sequence or process.

3. ANALYSIS

3.1 Applicable Requirements

Requirement Reference — Requirement

1. 3.2.1.5.3.2c Detector Housing Hermeticity and Venting
The Power and Thermal-Control Structure Detector Housing shall: Be compatible with evacuation of the camera body at the launch pad.

2. 3.2.2.4 Orientation
The Power and Thermal-Control Structure shall operate as specified herein in any orientation specified in Table 3.2.2.4-1 (below), which shows the orientation of the observatory and of ACIS at various stages of assembly, integration and test.

Activity	Orientation
SI installation in SIM	Vertical, +X down
SIM shipping	Vertical, +X down
SI calibration	Horizontal, +Z up
SI integration, test* †	Vertical, +X (HRMA) down
AXAF handling	Vertical, +X (HRMA) down
AXAF test (ambient functional)*	Vertical, +X (HRMA) down
AXAF test (Thermal/Vacuum)* †	Vertical, +X (HRMA) down
AXAF test (acoustic)* †	Vertical, +X (HRMA) down
AXAF shipping	Horizontal, +Z up
AXAF payload processing at KSC*	Vertical, +X (HRMA) down
AXAF on launch pad	Vertical, +X (HRMA) down
Launch	Quasi-vertical, +X (HRMA) down translating to , +Z downward

*All Science Instruments will be operating sequentially during these activities

† Door Operations limited to Detector Housing Temperature of ≥0°C in this orientation

3. 3.2.5a Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum operating, and assembly life of 1 year, beginning with the initial application of power to individual circuits, circuit cards, subassemblies or the Power and Thermal-Control Structure component.

4. 3.2.5b Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum operating, ground checkout, and pre-launch life of 1 year, beginning with application of electrical power to the integrated instrument, and includes instrument test, calibration and verification, SIM integration and test, AXAF-I test and verification.

5. 3.2.5c Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum, non-operating, ground life of 4 years, including fabrication, assembly, integration and test periods, ground transportation, storage and handling.

6. 3.2.5d Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum non-operating launch and ascent life of 30 minutes, including transition from earth to Space Transportation System park orbit insertion.

7. 3.2.5e Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum non-operating transfer orbit duration of 48 hours, including transition from Space Transportation System park orbit to mission orbit insertion.

8. 3.2.5f Operational Availability
The Power and Thermal-Control Structure shall be designed for a minimum orbital operating life of 5 years.

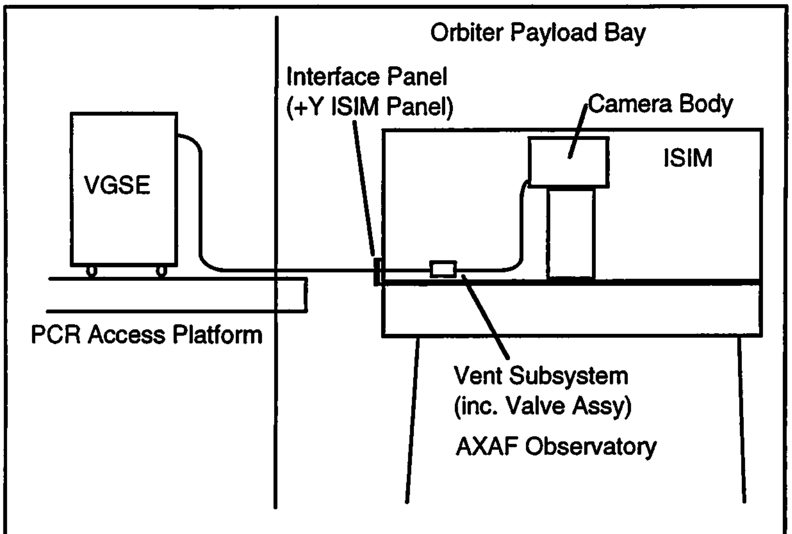
9. 3.2.9e Storage
The Power and Thermal-Control Structure shall be capable of storage in the SIM and the AXAF-I system.

3.2 Analytical Discussion

Requirement Reference | Requirement

1. 3.2.1.5.3.2c Detector Housing Hermeticity and Venting
The Power and Thermal-Control Structure Detector Housing shall: Be compatible with evacuation of the camera body at the launch pad.

DISCUSSION
Provisions are made for the evacuation and maintenance of the Detector Housing via the Venting Subsystem which directs the venting evacuation path to a port on the Integrated Science Instrument Module. This port is located on the +Y panel of the ISIM. There are two vacuum connections, one each for the high conductance and low conductance vent paths, and an electrical interface to drive the internal venting subsystem valving to allow evacuation or purging and pressurization. The evacuation/purge function is performed by the Vacuum Ground Support Equipment, VGSE, LMA Drawing 849AC710000. The VGSE is a self contained vacuum pump, associated plumbing, and valving in a cabinet mounted unit on casters for ease of transport and use in an ambient laboratory environment. The VGSE unit includes two seven foot long hoses (can be connected together for a total length of 14 feet) for connecting up to the ISIM interface. The VGSE uses commercial/facility 120 Volt AC power and bottled GN2 to perform the evacuation function. As illustrated below the VGSE will connect to the camera body to maintain the vacuum for ground processing and to establish a hard vacuum 10^{-7} torr) prior to launch.



Launch Pad Vacuum/Pressurization Configuration

For operations at the launch pad the VGSE will be located on a work platform in the Payload Change-Out Room (PCR) of the Rotating Service Structure (RSS). The Vent Subsystem Interface Panel will be located at approximately Orbiter Station X_o=638 inches and the VGSE on PCR Level 5 (station X_o=681.76 inches (Retracted) and X_o=701.5 inches (Furhtest Extended Platform)). A fact finding trip to KSC by MGSE PIE Scot Anderson (LMA/ACIS) has confirmed that adequate clearance, access, and facility services required exist to establish the required configuration. All necessary hardware and operations to perform this requirement have been performed as part of Detector Housing/Assembly testing and every confidence exists that evacuation at the launch pad will be possible. This analytical discussion verifies compliance with paragraph 3.2.1.5.3.2c of the PTS Specification, no further action is required.

2. 3.2.2.4 Orientation
The Power and Thermal-Control Structure shall operate as specified herein in any orientation specified in Table 3.2.2.4-1 (below), which shows the orientation of the observatory and of ACIS at various stages of assembly, integration and test.

Activity	Orientation
SI installation in SIM	Vertical, +X down
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SI integration, test* †	Vertical, +X (HRMA) down
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AXAF on launch pad	Vertical, +X (HRMA) down
Launch	Quasi-vertical, +X (HRMA) down translating to , +Z downward

*All Science Instruments will be operating sequentially during these activities
† Door Operations limited to Detector Housing Temperature of ≥0°C in this orientation

DISCUSSION

The Power and Thermal-Control Structure components and structure have been designed to accommodate all orientations in a one-g environment. All piece parts are properly connected (i.e., bolted, welded, soldered, potted, conformal coated, tied off, etc.) to adequate structure to accommodate all orientations identified above and as required to operate properly in the on-orbit zero-g environment. Most of the orientations identified above are non-powered shipping, handling, and/or storage operations. For those times the Power and Thermal-Control Structure is energized and being operated, the position will be either Vertical, +X (HRMA) down, or Horizontal, +Z up. The Power and Thermal-Control Structure components and structure will have been tested in these orientations prior to delivery. Pathfinder Power and Thermal-Control Structure components and structure have been handled and operated thru the various orientations defined in this requirement and have met all performance requirements, indifferent to previous or present orientation. Flight hardware will be built and assembled to the pathfinder structural requirements, if not harsher (e.g., flight qualified fasteners versus test hardware). This analytical discussion verifies compliance with paragraph 3.2.2.4 of the PTS Specification, no further action is required.

The mechanisms of the Power and Thermal-Control Structure design is the Detector Housing Door and the Vent Subsystem Valves. The drive unit for the door and the large conductance valve are paraffin actuators manufactured and provided to LMA from Starsys Research Corp.. For Ground, 1-g, operation only (not applicable to zero-g operation, where no constraints apply) the following issues and operational constraints are required.

During door life-cycle testing it was discovered that under certain test conditions (temperature and orientation) and during door closing only, the Starsys actuator shaft did not fully retract to it's nominal position after having closed the door (as documented in LMA Memo ACIS-95-172). The shaft did travel sufficiently to drive the mechanism linkage over-center and actuate the position microswitch to get a closed door indication, but due to 1g and atmospheric convective cooling effects, after heater power was removed, the shaft was not able to fully retract. After the door is closed the shaft is required to retract to its starting position and in so doing, activate a limit switch. Fully retracted, the mechanism is properly configured to perform subsequent door openings, but if the closing shaft is not fully retracted when an open door command is issued the door potentially may not open fully as a result of internal actuator interference.

To ensure full shaft travel the following operational constraints of the actuator, during ground use only, must be performed. Note: To date there have been no problems encountered during door opening.

The steps necessary to achieve proper operation on the ground are as follows:

Door opening:

Before issuing the "enable" and "open door" commands ensure the door closing drive shaft is fully retracted to it's nominal position by verifying a microswitch indication. If not, heat actuator per methodology of item numbers 3, 4 and 5 under Door Closing, below.

Door closing:

1) Issue "enable" and "close door" commands.

2) Once a "door closed" indication is received, heater power will be removed and the shaft will automatically retract via a return spring.

3) If a “full retract” indication is not received after 30 minutes reset the shaft position by applying heater power to the actuator until the actuator case reaches 60° C.**

4) Check for "fully retracted" position indication.

5) If no "fully retracted" indication is received continue heating until shaft has retracted. Monitor temperature during heating. Do not heat above 120° C.

** The capability does exist to monitor the actuator case temperature in real time, via the Test Connector Readout panel. During actuator heating, the actuators can be monitored for an over temperature condition. Power can be manually commanded off.

3-8.Power and Thermal-Control Structure Life Requirements

3.2.5a Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum operating, and assembly life of 1 year, beginning with the initial application of power to individual circuits, circuit cards, subassemblies or the Power and Thermal-Control Structure component.

3.2.5b Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum operating, ground checkout, and pre-launch life of 1 year, beginning with application of electrical power to the integrated instrument, and includes instrument test, calibration and verification, SIM integration and test, AXAF-I test and verification.

3.2.5c Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum, non-operating, ground life of 4 years, including fabrication, assembly, integration and test periods, ground transportation, storage and handling.

3.2.5d Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum non-operating launch and ascent life of 30 minutes, including transition from earth to Space Transportation System park orbit insertion.

3.2.5e Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum non-operating transfer orbit duration of 48 hours, including transition from Space Transportation System park orbit to mission orbit insertion.

3.2.5f Operational Availability

The Power and Thermal-Control Structure shall be designed for a minimum orbital operating life of 5 years.

<u>DISCUSSION</u>

The life of the Power and Thermal-Control Structure as specified above imposes a design life of eleven years, 6 years on the ground and five years in operation on-orbit. Of the six years on the ground the hardware will be operating for one year at the piece part or component level and one year at the integrated instrument level with four years of non-operating time making up the remaining time. The Power and Thermal-Control Structure will meet these life requirements with additional margin.

All electrical and electronic piece parts and components have been adequately sized and operated in a derated mode to assure no overstressing of any one item or system as a whole. These parts are selected in accordance with MIL-STD-975, have been analyzed and will be derated in accordance with MIL-STD-975 or in accordance with Lockheed Martin worst case analysis guidelines WC-001, Revision B, whichever is most restrictive. In addition, where appropriate, materials must meet MSFC-SPEC-1443 and will be certified to MSFC-SPEC-1238 criteria, as modified for AXAF, to assure material compliance and cull out manufacturing imperfections.

All structure has been designed with positive margins to assure operation after exposure to ground handling, launch, and orbital maneuvering loads.

All materials chosen for Power and Thermal-Control Structure construction are space qualified and/or have been validated to space qualification as part of the hardware qualification effort. This assures that the Power and Thermal-Control Structure piece parts and components will survive exposure to the environments and activities specified above for the periods specified. In addition they must meet MSFC-SPEC-1443, where appropriate, and will be certified to MSFC-SPEC-1238 criteria, as modified for AXAF, to assure material compliance and cull out manufacturing and fabrication imperfections.

All mechanical features, i.e., the Detector Housing Door, and Venting Subsystem valves, utilize polymeric bushings and/or seals between moving metal surfaces. The Door mechanism utilizes Torlon bushings and Viton seals. The large vent valve also uses Torlon for bushings and Viton for the valve seat seal. The low conductance vent valve uses Vespel for bushings and Viton for the valve seat seal.

In operation and on-orbit all mechanism, temperature and the DEA power circuits are redundant, thus the loss of one side still provides for the other side to carry out the mission. There is a concern that the DPA power supply circuit utilizes both paths for nominal operation. If one of the power paths fails the mission will have to be performed in a degrade mode as only half of the necessary power is provided to the DPA. The engineering assessment and circuit worst case analysis substantiate that successful completion of the ground test series on the converters and the derating implemented will guarantee a successful operation of all EEE parts for the entire mission.

The ground test series performed on the Power and Thermal-Control Structure piece parts and components will identify any defective parts, both structural/mechanical and electrical. The present design and construction philosophies and practices, and end-to-end verification of flight hardware assure a successful ground and flight operation. This analytical discussion verifies compliance with paragraphs 3.2.5 a thru f of the PTS Specification, no further action is required.

9. 3.2.9e Storage

The Power and Thermal-Control Structure shall be capable of storage in the SIM and the AXAF-I system.

DISCUSSION

The Power and Thermal-Control Structure has been designed to be integrated onto the Science Instrument Module, which is then integrated with other AXAF components and systems to form the AXAF-I Spacecraft. As such, the Power and Thermal-Control Structure components will have to survive numerous periods of inactivity as the SIM and

AXAF-I spacecraft are shipped, handled, and prepared for launch. From a structural mechanical aspect the Power and Thermal-Control Structure components and piece parts have been designed for these periods of inactivity and adequate end-of-life margins exist in all orientations to support storage in a variety of configurations. From an electrical aspect, since this storage implies being nonpowered, there is no impact and again adequate design and life margins exist in all orientations to support storage in a variety of configurations. Operationally there is the constraint that the integrated Detector Assembly/Camera Body be maintained at a vacuum of less than or equal to 1 x 10^{-5} torr, up to T-172 Hours.

Provisions are made for the evacuation and maintenance of the Detector Housing via the Venting Subsystem which directs the venting evacuation path to a port on the Integrated Science Instrument Module. This port is located on the +Y panel of the ISIM. There are two vacuum connections, one each for the high conductance and low conductance vent paths, and an electrical interface to drive the internal vent subsystem valving to allow evacuation or purging and pressurization. The evacuation/purge function is performed by the Vacuum Ground Support Equipment, VGSE, LMA Drawing 849AC710000. The VGSE is a self contained vacuum pump and associated plumbing and valving cabinet mounted unit on casters for ease of transport and use in a ambient laboratory environment. The VGSE unit includes two 7 foot long hoses (can be connected together for a total length of 14 feet) for connecting up to the ISIM interface. The VGSE uses commercial/facility 120 Volt AC power and bottled GN2 to perform the evacuation function. The VGSE has been designed to operate autonomously to maintain the vacuum. Therefore, storage and maintenance of the Detector Housing are provided.

Per the orientations identified for the program in requirement 3.2.2.4 Orientation (above) the PTS will be handled, transported, tested, and probably stored in either Vertical, +X (HRMA) down, or Horizontal, +Z up. As integrated on the ISIM the Venting Subsystem interface port will be accessible for connection to the VGSE. The ISIM integrator, BASD, will have to assure that the storage facilities have the necessary facility services required to establish the storage configuration. As integrated onto the AXAF-I spacecraft the port will be accessible for connection to the VGSE. The AXAF-I integrator, TRW, will have to assure that the storage facilities have the necessary facility services required to establish the storage configuration.

This analytical discussion verifies compliance with paragraph 3.2.9e of the PTS Specification, no further action is required.