ACIS Verification Summary Report

36-01510.102

Specification:	ACIS Contract End Item Specification
Requirement Number/Title:	3.2.5.6 Meteoroid and Orbital Debris Impact (VRSD 3.2.5.6-2)

Requirement Statement: The probability of SI functional capability shall be at least 0.92 for 5 years.

Verification Method:	Analysis

Procedure Number:

Configuration:

Cycle Time:

Verification Discussion/Results:

This requirement verification was satisfied by submittal of the Power and Thermal Control Structure Meteoroid Analysis Report. Analytical results state a probability of no failure of any critical item due to meteoroid/debris impact of 0.975.

6/3/97

ACIS Cognizant Engineer Date

36-01510, 102

AXAF-I CCD Imaging Spectrometer (ACIS)

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

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<u>**CHANGE/REVISION RECORD**</u>

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			Rev.	Added
New	1 May, 1997	Initial Release	All	

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 analytical data to support the verification of specific PTS Specification requirements. These requirements were assessed to be best verified by a analysis. The method selected in the verification of each specific requirement is the method which provides the assurance to the program that compliance with 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

NASA Documents

SP-8042	Meteoroid Damage Assessment - NASA Space Vehicle Design Criteria (Structures), May 1970

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 and the ACIS Power and Thermal-Control Structure Specification, 36-02101. 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.

3. ANALYSIS

3.1 Applicable Requirements

The following requirements were extracted from AXAF Program Specifications. The fundamental requirement is to ensure micrometeoroids do not significantly degrade ACIS-PTS performance. Compliance with the requirements will be demonstrated by analyses showing that damage to exposed surfaces are within lifecycle degradation budget levels and that the probability of not penetrating a critical component is better than the requirement specified herein.

1. 3.2.7.1.7 Meteoroid and Orbital Debris Protection
   When exposed to the Meteoroid and Orbital Debris environment specified in the AXAF-I Environment Document, EV1-8, exposed ACIS thermal control surfaces shall meet the requirements specified herein with a probability of 96% for 5 years.

NOTE: Per EV1-8, AXAF-I Environment Document

3.1.4.3 Meteoroid Impact
AXAF-I shall provide protection against loss of functional capability when subjected to the meteoroid flux model as defined in SSP 30425, Space Station Program Natural Environment Definition for Design.

The probability of no failure of any critical item due to meteoroids/debris impact shall be at least 0.96 for five years.

3.2 Analytical Discussion

Two analysis are performed to determine the impact the micrometeoroid environment has on the PTS critical surfaces. One, to determine probability of critical components housings being penetrated and, two, the amount of surface damage expected from the micrometeoroid environment to the thermal control surfaces.

The Power and Thermal-Control Structure design critical components relevant to penetration of micrometeoroids are 1) a Detector Housing (DH), 2) a Venting Subsystem (VS), 3) the Power Supply and Mechanism Controller (PSMC) and 4) PTS Wiring Harness. The components sensitive to surface damage due to micrometeoroid impacts consist of the radiator and shades surfaces of the Thermal Control System (TCS).

3.2.1 Critical Component Penetration Analysis

Penetrations of micrometeoroid to the DH, VS, PSMC, or Harness can critically degrade ACIS performance. Analysis has been performed to show the probability of no failure of any critical item due to meteoroids/debris impact is better than 98% which complies with the requirement to be at least 0.96 for five years. Failure is considered to occur if any critical component housing is penetrated.

ACIS Configuration Parameters of Significance to the Analysis

The critical components are housed in the Science Interface Module (SIM). SIM walls are honeycomb panels with .030" composite facesheets. The two .030" facesheets are modeled as a single .036" aluminum panel.

The DH is surrounded by electronic boxes and proton shields to limit stray x-rays from entering through the housing walls. An equivalent of 200 mils of aluminum is assumed for these sources of shielding.

Analytical Approach

The approach used to demonstrate compliance to the requirement is to account for known quantities of shielding from the SIM, housing walls and masses surrounding the critical component being analyzed and use this data to predict the probability of penetration of a critical component. The analysis does not attempt to account for all sources of shielding, once adequate levels of shielding have been identified, additional shielding is not considered. Thus, the results of the analysis should be considered conservative. The steps used in the analysis follows:

- The analysis uses the penetration equations from NASA SP-8042 for thin plate materials.

- Depth of penetration calculations are performed for each micrometeoroid size.

- Shielding calculations are then performed to determine the amount of shielding protecting each critical component.

- The probability of penetration is then determined by multiplying the fluence of the micrometeoroids with mass capable of penetration times the area of the component.

- Probability of penetration for all components are then arithmetically summed (which is conservative) to determine the probability of penetration occurring.

- The probability of no penetrations occurring is then calculated by the equation:

  Probability of No Penetration = 1 - Probability of Penetration

Micrometeoroid Environment

The meteoroid integrated impact fluence is given in Table 3-1 and were obtained from EV1-8. Initial analysis indicated that the coarseness of the data resulted in overly conservative prediction of penetration probabilities. Hence, interpolations were performed to obtain fluences at intermediate micrometeoroid masses.

Review of the provided data suggested that a linear relationship existed between the Log(mass) and Log(fluence) for the masses of interest. Therefore, the intermediate data points used in the analysis were obtained by linearly interpolating using the logs of the data. The expanded fluence spectra data used to calculate penetration probabilities is presented in Table 3-2.

Analytical Results

Results of the analysis, presented in Table 3-3, indicates that the probability of penetrating a critical component with a micrometeoroid is 2.5%. Thus, the probability of no failure of any critical item due to meteoroids/debris impact is 1-0.025 = 0.975 which satisfies the requirement which is the of probability of no failure of any critical item shall be at least 0.96 for five years.

3.2.2 Exposed Surfaces Damage Analysis

Micrometeoroid impacts to thermal control surfaces can damage the surfaces degrading the performance of these surfaces. Analysis has been performed that show no significant degradation in thermal control surfaces performance occurs due to micrometeoroid impacts. Analysis results show that less than 0.68% of the surfaces are obscured due to micrometeoroids, which is accounted for in the lifecycle TCS degradation budgets.

ACIS Configuration Parameters of Significance to the Analysis

The Thermal Control System is attached to the Integrated Science Instrument Module (ISIM) and also surrounded on one side by the entire ISIM (-Z). The telescope and sun shades are open to free space. The shades can withstand numerous impacts and perforations without compromising instrument operation. The warm and cold radiator are mounted to the +Z side of the ISIM. These too can withstand numerous impacts and perforations without compromising instrument operation.

Analytical Approach

The analysis uses the surface damage equations from NASA SP-8042 for thin plate materials. Depth of penetration is calculated for each size particle analyzed, the crater assumed to be hemispherical in shape and the damaged area to have 2 times the diameter of the crater. The damage area per particle is multiplied by the particle areal density to obtain the damage density, reported in terms of the percent of the surface damaged.

Micrometeoroid Environment

The meteoroid integrated impact fluence is given in Table 3-1 and were obtained from EV1-8.

Analytical Results

Results of the analysis are presented in Table 3-4. The percent of the surface damaged is less than 0.68 % which is within the lifecycle degradation budget of 1.0%.

3.3 Conclusion

The PTS hardware has been designed to survive the micrometeoroid environment specified. This report verifies compliance with paragraph 3.2.7.1.7 of the PTS Specification. No further action is required.

Table 3-1 Integrated Meteoroid Fluence Spectra

Particle Mass (grams)	Integrated Fluence (#/sq. meter)
1.00E+01	1.76E-08
1.00E+00	3.80E-07
1.00E-01	8.06E-06
1.00E-02	1.66E-04
1.00E-03	3.23E-03
1.00E-04	5.50E-02
1.00E-05	7.90E-01
1.00E-06	8.05E+00
1.00E-07	5.16E+01
1.00E-08	2.02E+02
1.00E-09	5.14E+02
1.00E-10	1.09E+03
1.00E-11	2.55E+03
1.00E-12	5.88E+03
1.00E-13	1.42E+04
1.00E-14	4.31E+04
1.00E-15	1.82E+05

Table 3-2 ACIS Micrometeoroid Penetration to Critical Components - Micrometeoroid Fluence Spectra (with interpolated points) and Depth of Penetration as a Function of Micrometeoroid Mass

Mass	Fluence	Depth of Penetration**	LOG(mass)	Log(fluence)
(gm)	(#/m2)	(mils)		
1.00E-15	1.82E+05	0	-1.50E+01	5.26
1.00E-14	4.31E+04	0	-1.40E+01	4.63
1.00E-13	1.42E+04	0	-1.30E+01	4.15
1.00E-12	5.88E+03	0	-1.20E+01	3.77
1.00E-11	2.55E+03	0	-1.10E+01	3.41
1.00E-10	1.09E+03	1	-1.00E+01	3.04
1.00E-09	5.14E+02	2	-9.00E+00	2.71
1.00E-08	2.02E+02	4	-8.00E+00	2.31
1.00E-07	5.16E+01	9	-7.00E+00	1.71
1.00E-06	8.05E+00	20	-6.00E+00	0.91
1.00E-05	7.90E-01	46	-5.00E+00	-0.10
2.00E-05	*3.54E-01*	*59*	*-4.70E+00*	*-0.45*
3.00E-05	*2.22E-01*	*68*	*-4.52E+00*	*-0.65*
4.00E-05	*1.59E-01*	*75*	*-4.40E+00*	*-0.80*
5.00E-05	*1.23E-01*	*81*	*-4.30E+00*	*-0.91*
6.00E-05	*9.93E-02*	*87*	*-4.22E+00*	*-1.00*
7.00E-05	*8.31E-02*	*91*	*-4.15E+00*	*-1.08*
8.00E-05	*7.12E-02*	*96*	*-4.10E+00*	*-1.15*
9.00E-05	*6.21E-02*	*100*	*-4.05E+00*	*-1.21*
1.00E-04	5.50E-02	104	-4.00E+00	-1.26
2.00E-04	*2.34E-02*	*132*	*-3.70E+00*	*-1.63*
3.00E-04	*1.42E-02*	*152*	*-3.52E+00*	*-1.85*
4.00E-04	*9.98E-03*	*169*	*-3.40E+00*	*-2.00*
5.00E-04	*7.58E-03*	*182*	*-3.30E+00*	*-2.12*
6.00E-04	*6.06E-03*	*195*	*-3.22E+00*	*-2.22*
7.00E-04	*5.01E-03*	*205*	*-3.15E+00*	*-2.30*
8.00E-04	*4.25E-03*	*215*	*-3.10E+00*	*-2.37*
9.00E-04	*3.68E-03*	*224*	*-3.05E+00*	*-2.43*
1.00E-03	3.23E-03	233	-3.00E+00	-2.49
2.00E-03	*1.32E-03*	*297*	*-2.70E+00*	*-2.88*
3.00E-03	*7.84E-04*	*343*	*-2.52E+00*	*-3.11*
4.00E-03	*5.41E-04*	*379*	*-2.40E+00*	*-3.27*
5.00E-03	*4.06E-04*	*410*	*-2.30E+00*	*-3.39*
6.00E-03	*3.21E-04*	*438*	*-2.22E+00*	*-3.49*
7.00E-03	*2.63E-04*	*462*	*-2.15E+00*	*-3.58*
8.00E-03	*2.21E-04*	*484*	*-2.10E+00*	*-3.65*
9.00E-03	*1.90E-04*	*505*	*-2.05E+00*	*-3.72*
1.00E-02	1.66E-04	524	-2.00E+00	-3.78
1.00E-01	8.06E-06	1178	-1.00E+00	-5.09
1.00E+00	3.80E-07	2649	0.00E+00	-6.42
1.00E+01	1.76E-08	5959	1.00E+00	-7.75
Note: fluence from EV1-8				
** Ref. NASA SP8042, Eq 3				

Table 3-3 ACIS Micrometeoroid Penetration to Critical Components - Penetration Probabilities Analysis Summary

Component	Minimum wall thickness (mils)	Inherent Shielding (SIM walls 36 mil eq al)+others	Box wall + inherent shielding thickness (mils)	Penetration Fluence(#/m2)	Component Area (m2)	Component Probability of Being Penetrated
DH	60.0	286.0	346.0	7.84E-04	0.780	0.061%
VS	60.0	36.0	96.0	7.12E-02	0.002	0.017%
PSMC data	x=.268,y=.214,z=.268 m					
-x wall	100.0	36.0	136.0	2.34E-02	0.057	0.134%
+x wall	100.0	36.0	136.0	2.34E-02	0.057	0.134%
-y wall	60.0	36.0	96.0	7.12E-02	0.072	0.511%
+y wall(conn side)	60.0	36.0	96.0	7.12E-02	0.072	0.511%
-Z face	130.0	36.0	166.0	1.42E-02	0.057	0.082%
+Z face	100.0	36.0	136.0	2.34E-02	0.057	0.134%
P"TS Harness	25.0	36.0	61.0	3.54E-01	0.025	0.886%
Note: DH calculation ignores mm coming down telescope, proton shield credits taken						
Note: VS sued for 1/60 mission time so sees 1/60 of fluence in life, time adjusted in area term						
Arithmetic Sum of Penetration Probabilities						**2.5**

Table 3-4 ACIS Micrometeoroid Induced Degradation to Exposed Surfaces - Analysis Summary

Mass	Integral Fluence	Differential Fluence	Depth of Penetration	Surface Damage Diameter	Surface Obscuration
(gm)	(#/m2)	(#/m2)	(mils)	(cm2)	
1.00E-15	1.82E+05	1.39E+05	1.39E-02	1.41E-04	0.196%
1.00E-14	4.31E+04	2.89E+04	3.13E-02	3.18E-04	0.092%
1.00E-13	1.42E+04	8.32E+03	7.03E-02	7.15E-04	0.059%
1.00E-12	5.88E+03	3.33E+03	1.58E-01	1.61E-03	0.054%
1.00E-11	2.55E+03	1.46E+03	3.56E-01	3.61E-03	0.053%
1.00E-10	1.09E+03	5.76E+02	8.00E-01	8.13E-03	0.047%
1.00E-09	5.14E+02	3.12E+02	1.80E+00	1.83E-02	0.057%
1.00E-08	2.02E+02	1.50E+02	4.05E+00	4.11E-02	0.062%
1.00E-07	5.16E+01	4.36E+01	9.10E+00	9.25E-02	0.040%
1.00E-06	8.05E+00	7.26E+00	2.05E+01	2.08E-01	0.015%
1.00E-05	7.90E-01	7.35E-01	4.60E+01	4.68E-01	0.003%
1.00E-04	5.50E-02	5.18E-02	1.04E+02	1.05E+00	0.001%
1.00E-03	3.23E-03	3.06E-03	2.33E+02	2.37E+00	0.000%
1.00E-02	1.66E-04	1.58E-04	5.24E+02	5.32E+00	0.000%
1.00E-01	8.06E-06	7.68E-06	1.18E+03	1.20E+01	0.000%
1.00E+00	3.80E-07	3.62E-07	2.65E+03	2.69E+01	0.000%
1.00E+01	1.76E-08	1.76E-08	5.96E+03	6.05E+01	0.000%
				Total Surface Obscuration	**0.679%**