ACIS Verification Summary Report

36-01510.067

Specification:	ACIS Contract End Item Specification
Requirement Number/Title:	3.2.2.7 SI Induced Disturbances (VRSD 3.2.2.7)

Requirement Statement: SI induced disturbances shall meet the requirements of paragraph 3.4.2.1 of the Observatory to Science Instrument ICD.

Verification Method:	Analysis

Procedure Number: Refer to Verification Report ACIS-600-A-03VR

Configuration:

Cycle Time:

Verification Discussion/Results:

ACIS has three moving parts, each of which will be operated only once on orbit and not during the collection of any observation data.

The Venting Subsystem contains a solenoid driven, low conductance, valve which imparts no more mechanical energy than typical latching relays which are common within the observatory. This valve is operated before the Detector Housing Door is opened. The Venting Subsystem also uses a high conductance vent valve which is a slow moving mechanism operated before the Detector Housing door is opened. The Detector Housing Door mechanism uses the same actuator as the high conductance vent valve and again, must be operated before any observations can be made.

Once those three mechanisms have performed their respective functions, ACIS will have completed actuation of all mechanisms and will impart no forces to the observatory.

Refer to ACIS-600-A-03VR for additional information regarding ACIS dynamics characteristics.

[signature] 6/22/97

ACIS Cognizant Engineer Date

36-01510.067

AXAF-I CCD Imaging Spectrometer (ACIS)

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

Document No. ACIS-600-A-03VR

DPD 727 DR SVR04

Contract # NAS8-37716

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

Number	Date	Description	Page	
			Rev.	Added
New	11 June 1997	Initial Release	All	

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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 analytical data to support the verification of specific PTS Specification requirements. These requirements were assessed to be best verified by 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 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, interchangeability, and some other performance requirements which cannot be verified by test.

2.2.2 Dynamic Analysis Definition

Dynamic analysis provides frequencies and a comprehensive set of loads for the low frequency transient, vibro-acoustic, and shock environments for all mission phases.

3. TEST DATA

3.1 Applicable Requirements

Requirement Reference	Requirement

1. 3.2.1.1h General Performance Requirements
   The Power and Thermal-Control Structure Subsystem Shall: Provide structures that comply with mission dynamic and structural loads.

2. 3.2.1.5.4a Power and Thermal-Control Structure Structures
   The Power and Thermal-Control Structure Structures shall: Be compatible with ground operations including, but not limited to, assembly, handling, storage, transportation, and pre-launch operations.

3. 3.2.1.5.4b Power and Thermal-Control Structure Structures
   The Power and Thermal-Control Structure Structures shall: Be compatible with the structural load path during Space Transportation System ascent, on-orbit, and descent mission phases.

4. 3.2.1.5.4c Power and Thermal-Control Structure Structures
   The Power and Thermal-Control Structure Structures shall: Be compliant with the ultimate design load factors for Space Transportation System emergency landing loads without structural failure, however, permanent deformations are acceptable.

5. 3.2.1.5.4d Power and Thermal-Control Structure Structures
   The Power and Thermal-Control Structure Structures shall: Be compatible with the structural load path during Inertial Upper Stage and Integral Propulsion System orbital maneuvering mission phases.

6. 3.2.1.5.4.1 Power and Thermal-Control Structure Structural Modal Frequencies
   The minimum modal frequency of the Thermal Control Subsystem, Detector Assembly (including focal plane), and Power Supply and Mechanism Controller shall be greater than 50 Hz.

7. 3.2.7.2.1a Random Vibration
   The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the protoflight and acceptance random vibration levels defined in Fig. 3.2.7.2.1-1.

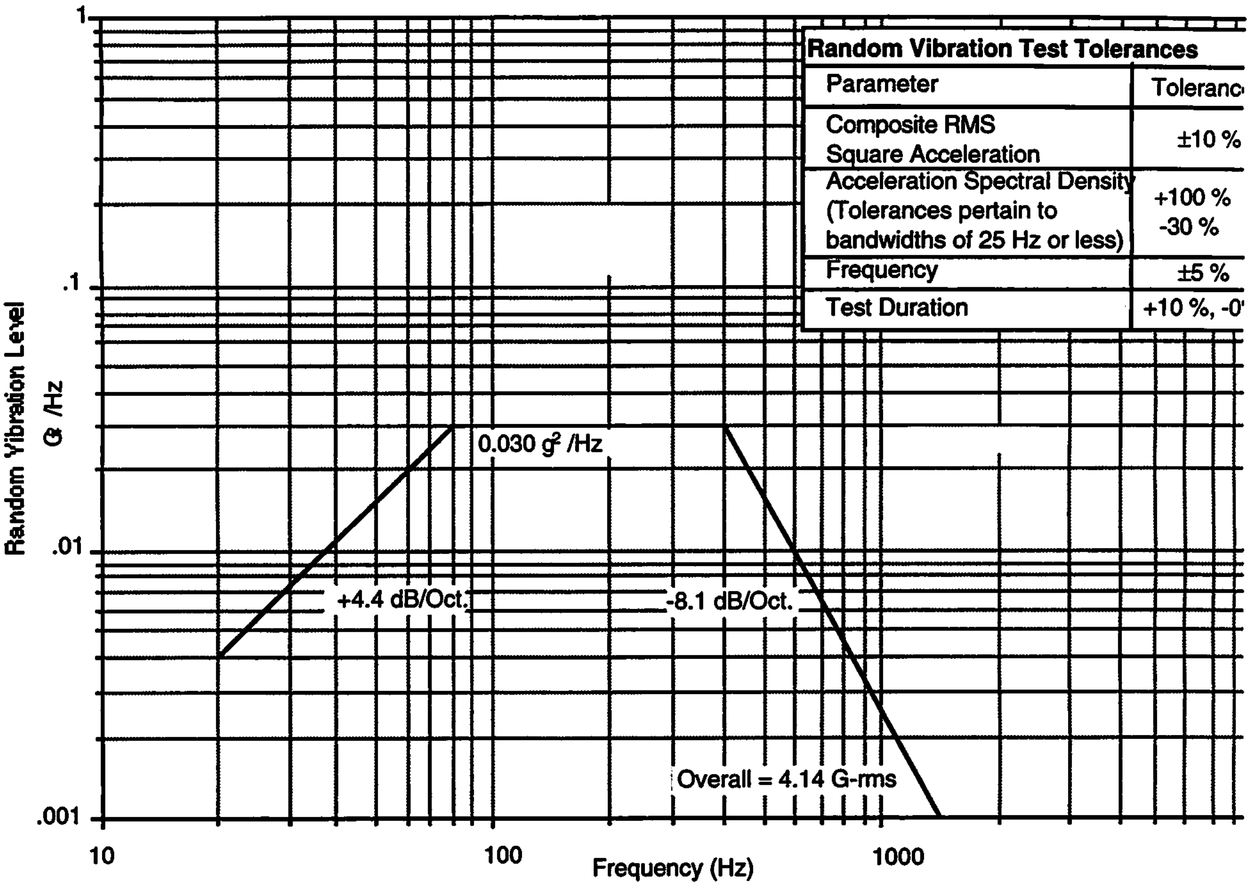

Figure 3.2.7.2.1-1 Random Vibration Requirements.

8. 3.2.7.2.1b Random Vibration
The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the protoflight and acceptance random vibration levels derived from the Miles equation, defined as:

$$3\ G_{rms} = 3 \sqrt{\pi/2 * Q * PSD(f_1) * f_1}$$

9. 3.2.7.2.1c Random Vibration
The Power and Thermal-Control Structure shall be designed to limit disturbances from moving parts to the Observatory to 0.01 g_{rms} levels. One time or other infrequent operations will be excluded.

10. 3.2.7.2.1d Random Vibration
The Power and Thermal-Control Structure shall operate as specified herein while subjected to vibrations of 0.01 g_{rms} over the frequency range from DC to 50 Hz.

11. 3.2.7.2.2 Acoustics
The Power and Thermal-Control Structure shall be designed to withstand the maximum expected launch and transonic sound pressure levels shown in Table 3.2.7.2.2-1.

Table 3.2.7.2.2-1 Combined Liftoff/Boost Acoustic Spectrum

1/3 Octave Band Center Frequency (Hz)	Sound Pressure Level (dB relative to 2x20^{-5} N/M) (Acceptance Level)	Sound Pressure Level (dB relative to 2x20^{-5} N/M) (Qualification Level)
20.0	112.0	118.0
25.0	114.0	120.0
31.5	116.0	122.0
40.0	118.0	124.0
50.0	119.5	125.5
63.0	121.0	127.0
80.0	122.0	128.0
100.0	122.5	128.5
125.0	123.0	129.0
160.0	123.5	129.5
200.0	123.5	129.5
250.0	123.0	129.0
315.0	122.5	128.5
400.0	121.5	127.5
500.0	119.0	125.0
630.0	117.0	123.0
800.0	115.0	121.0
1000.0	113.0	119.0
1250.0	111.5	117.5
1600.0	110.0	116.0
2000.0	108.0	114.0
2500.0	106.0	112.0
3150.0	104.5	110.5
4000.0	102.5	108.5
5000.0	100.5	106.5
6300.0	99.0	105.0
8000.0	97.0	103.0
10000.0	95.0	101.0
Overall SPL	133.0	139.0

12. 3.2.7.2.3a Acceleration
The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the lift-off and landing accelerations and loads as shown in table 3.2.7.2.3-1 applied simultaneously for each event.

Table 3.2.7.2.3-1 Limit Load Factors and Angular Accelerations

Flight Event	Load Factors (G's)			Acceleration (Rad/Sec/Sec)		
	X	Y	Z	R_X	R_Y	R_Z
Lift Off	±4.3	±2.4	±2.7	±5.9	±10.9	±8.7
Landing	±1.0	±2.3	±4.6	±8.6	±6.7	±5.5

Notes:
1. The load factors/angular accelerations will be considered in all combinations for each event.
2. Accelerations and loads due to acoustics and random mechanical excitations should be added to the loads above in accordance with NASA TM-86538.
3. The coordinate system for ACIS is the coordinate system defined in Figure 3.3.10-1
4. Thermally induced loads are additive to the above loads.
5. SI load factors & angular accelerations are defined as the total externally applied force/moment on the SI divided by the corresponding SI weight/mass moment of inertia. The design of the SIs shall include appropriate safety factors as defined in MSFC-HDBK-505A.

13. 3.2.7.2.3b Acceleration

The Power and Thermal-Control Structure shall not structurally fail, however, permanent deformations are acceptable, after exposure to the emergency landing accelerations and loads as shown in table 3.2.7.2.3-2 applied simultaneously for each event. The Longitudinal load factors are directed in all aftward azimuths with a cone of 20° half-angle.

Table 3.2.7.2.3-2 Emergency Landing Design Load Factors

Emergency Landing Load Factors (G)		
X	**Y**	**Z**
+4.5 -1.5	+1.5 -1.5	+4.5 -2.0

14. 3.2.8e Handling and Transportation

The Power and Thermal-Control Structure shall meet the specifications herein following exposure to the handling and transportation loads specified in Table 3.2.8-1.

Table 3.2.8-1 Design Limit Load Factors for GSE and Test Fixtures

Medium/Mode	**Load Factors (Gs)** Fore/Aft	Lateral	Vertical	**Load Apply**	**Safety Yield**	**Factor Ultimate**
Water Barge/Dock Bumping	+0.5 -0.5	+1.0 -1.0	+2.5 -0.5	S S	2 2	3 3
Water Barge in Transient*	±0.09 ± 0.00025h	±0.05 ± 0.0013h	±1.0 ± 0.0025 x ± 0.0013L	S	2	3
Air C5A	+3.0 -3.0	+1.5 -1.5	+3.0 -1.0	S	2	3
Truck-Trailer	+2.0 -2.0	+2.0 -2.0	+3.5 -1.5	I	2	3
Truck-Trailer Air-Ride	+2.0 -2.0	+2.0 -2.0	+3.5 -1.5	I	2	3
Rail Slow Moving No Hump <5 mph	+1.0 -1.0	+0.75 -0.75	+1.5 -0.0	I	2	3
Dolly Slow Moving 30 ft/min max.	+1.0 -1.0	+0.75 -0.75	+1.5 -0.0	I	2	3
Hoisting, Handling Erecting, Lowering			+1.5 -1.5	D	3	5
Fork-Lifting Fork-Lowering	+1.0 -1.0	+0.5 -0.5	+2.0 -0.0	S	2	3
Seismic	+0.5 -0.5	+0.5 -0.5	+1.0 -1.5	S	2	3

15. 3.3.6.1.1 Emergency Landing

The Power and Thermal-Control Structure shall be designed such that it will not create an STS hazard when subjected to the emergency landing loads specified in paragraph 3.2.7.2.3b. Following exposure to these loads, the instrument will not be required to operate satisfactorily. The structure may yield but not fracture.

16. 3.3.6.2a Strength
The Power and Thermal-Control Structure structure shall be designed, using the appropriate factor of safety defined in paragraph 3.3.6.1.b, to have sufficient strength to withstand limit loads with other accompanying environmental phenomena for each design condition, without permanent deformation or rupture.

3.2 Analytical Discussion

The Power and Thermal-Control Structure Structural analyses are provided for review and comment per contractual data requirement SSE03. The dynamic analysis for the various Power and Thermal-Control Structure components and piece parts have been provided via this route (ref. SSE03, Vol. 8).

Requirement Reference — Requirement

1. 3.2.1.1h General Performance Requirements
The Power and Thermal-Control Structure Subsystem Shall: Provide structures that comply with mission dynamic and structural loads.

<u>DISCUSSION</u>
The Power and Thermal-Control Structure structure has been analyzed to the mission structural loads. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. The dynamic and structural analyses have been shown to meet the requirements specified above with positive margins. This discussion verifies compliance with paragraph 3.2.1.1h of the PTS Specification, no further action is required.

2. 3.2.1.5.4a Power and Thermal-Control Structure Structures
The Power and Thermal-Control Structure Structures shall: Be compatible with ground operations including, but not limited to, assembly, handling, storage, transportation, and pre-launch operations.

<u>DISCUSSION</u>
The Power and Thermal-Control Structure structure has been analyzed to the ground operations structural loads. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. Positive margins were shown on all PTS hardware for flight and test operations which envelope all ground operations. This discussion verifies compliance with paragraph 3.2.1.5.4a of the PTS Specification, no further action is required.

3. 3.2.1.5.4b Power and Thermal-Control Structure Structures
The Power and Thermal-Control Structure Structures shall: Be compatible with the structural load path during Space Transportation System ascent, on-orbit, and descent mission phases.

<u>DISCUSSION</u>
The Power and Thermal-Control Structure structure has been analyzed to the required structural load paths during Space Transportation System ascent, on-orbit, and descent mission phases. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. All margins have been shown to be positive for the environments specified. This discussion verifies compliance with paragraph 3.2.1.5.4b of the PTS Specification, no further action is required.

4. 3.2.1.5.4c Power and Thermal-Control Structure Structures
The Power and Thermal-Control Structure Structures shall: Be compliant with the ultimate design load factors for Space Transportation System emergency landing loads without structural failure, however, permanent deformations are acceptable.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to the ultimate design load factors for Space Transportation System emergency landing loads. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. All margins have been shown to be positive for the environments specified. The specified emergency landing loads are enveloped by the flight acoustic and random vibration environments. This discussion verifies compliance with paragraph 3.2.1.5.4c of the PTS Specification, no further action is required.

5. 3.2.1.5.4d Power and Thermal-Control Structure Structures
The Power and Thermal-Control Structure Structures shall: Be compatible with the structural load path during Inertial Upper Stage and Integral Propulsion System orbital maneuvering mission phases.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to the structural load path for Inertial Upper Stage and Integral Propulsion System orbital maneuvering mission phases. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. All margins have been shown to be positive for the environments specified. The specified IUS and IPS orbital maneuvering loads are enveloped by the flight acoustic and random vibration environments. This discussion verifies compliance with paragraph 3.2.1.5.4d of the PTS Specification, no further action is required.

6. 3.2.1.5.4.1 Power and Thermal-Control Structure Structural Modal Frequencies
The minimum modal frequency of the Thermal Control Subsystem, Detector Assembly (including focal plane), and Power Supply and Mechanism Controller shall be greater than 50 Hz.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine the structural modal frequencies. This information has been provided previously per the SSE03, Volume 8 data submittal. All resonant frequencies have been shown by both analysis and test to be higher than 50 hertz as required. This discussion verifies compliance with paragraph 3.2.1.5.4.1 of the PTS Specification, no further action is required.

7. 3.2.7.2.1a Random Vibration
The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the protoflight and acceptance random vibration levels defined in Fig. 3.2.7.2.1-1.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine the effects of exposure to the specified random vibration levels defined. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. All margins have been shown to be positive for the environments specified. The specified random vibration environments were used in the acceptance tests for the hardware. The Detector Housing, Venting subsystem, Power Supply and Mechanism Controller, and components of the Thermal Control System have been analyzed and tested to the above spectra. The

Thermal Control System shades and radiators, and attachment hardware, have only been analyzed to the specified spectra and all margins are positive as shown in the SSE03 submittals. These components were acoustic tested which a more stressing environment for this hardware. This discussion verifies compliance with paragraph 3.2.7.2.1a of the PTS Specification, no further action is required.

8. 3.2.7.2.1b Random Vibration
The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the protoflight and acceptance random vibration levels derived from the Miles equation.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine successful operation after exposure to the random vibration levels derived from the Miles equation. This information has been provided previously per SSE03 Volumes, 2,3, and 8 data submittals. With the load factors calculated per Miles equation, all margins have been shown to be positive. This discussion verifies compliance with paragraph 3.2.7.2.1b of the PTS Specification, no further action is required.

9. 3.2.7.2.1c Random Vibration
The Power and Thermal-Control Structure shall be designed to limit disturbances from moving parts to the Observatory to 0.01 g_{rms} levels. One time or other infrequent operations will be excluded.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine disturbances from moving parts to the Observatory. There are only a few moving parts within the ACIS and they will only be operated one time on orbit. The low conductance vent valves are operated only once after the AXAF is on orbit. They are a solenoid powered valve similar to a mag-latching relay. The mechanical energy imparted into the rest of the ISIM is no more than a typical latching relay which are common within the ISIM and AXAF. The High Conductance Vent Valve Actuator Assembly and Door Aperture Mechanism Assembly are both slow moving mechanisms which will not cause any significant disturbances and the actuations occur in less than 20 minutes. This discussion verifies compliance with paragraph 3.2.7.2.1c of the PTS Specification, no further action is required.

10. 3.2.7.2.1d Random Vibration
The Power and Thermal-Control Structure shall operate as specified herein while subjected to vibrations of 0.01 g_{rms} over the frequency range from DC to 50 Hz.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine compatibility with Observatory induced disturbances. This information has been provided previously per SSE03 Volumes 2,3, and 8 data submittals. All components will operate as specified with up to 1G DC in any axis. None of the active components within the PTS are sensitive to low level vibrations of .01 g_{rms} at frequencies between DC and 50 hertz and will operate as specified. All other components are passive and have been tested and analyzed at significantly higher levels than those required. This discussion verifies compliance with paragraph 3.2.7.2.1d of the PTS Specification, no further action is required.

11. 3.2.7.2.2 Acoustics

The Power and Thermal-Control Structure shall be designed to withstand the maximum expected launch and transonic sound pressure levels shown in Table 3.2.7.2.2-1.

DISCUSSION

The Power and Thermal-Control Structure structure has been analyzed to determine the effects of exposure to the specified acoustic levels defined. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. The Detector Housing, Venting Subsystem, Power Supply and Mechanism Controller, and components of the Thermal Control System have been formally and successfully tested to the required random vibration spectrum which was derived from the specified acoustic environment. The components of the Thermal Control System, consisting of the telescope and sun shades, the cold and warm straps, the radiators and attachment hardware have been tested and analyzed to the specified acoustic environment. The analysis shows that all margins are positive and all components passed the required tests without damage . This discussion verifies compliance with paragraph 3.2.7.2.2 of the PTS Specification, no further action is required.

12. 3.2.7.2.3a Acceleration

The Power and Thermal-Control Structure shall meet the requirements stated herein after exposure to the lift-off and landing accelerations and loads as shown in table 3.2.7.2.3-1 applied simultaneously for each event.

DISCUSSION

The Power and Thermal-Control Structure structure has been analyzed to determine successful operation after exposure to the accelerations levels specified. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. The analysis shows that all margins are positive using the required lift-off and landing load factors. This discussion verifies compliance with paragraph 3.2.7.2.3.a of the PTS Specification, no further action is required.

13. 3.2.7.2.3b Acceleration

The Power and Thermal-Control Structure shall not structurally fail, however, permanent deformations are acceptable, after exposure to the emergency landing accelerations and loads as shown in table 3.2.7.2.3-2 applied simultaneously for each event. The Longitudinal load factors are directed in all aftward azimuths with a cone of 20° half-angle.

DISCUSSION

The Power and Thermal-Control Structure structure has been analyzed to determine structural integrity after exposure to the emergency landing accelerations and load levels specified. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. The analysis shows that all margins are positive using the required emergency landing acceleration and load factors. This discussion verifies compliance with paragraph 3.2.7.2.3.b of the PTS Specification, no further action is required.

14. 3.2.8e Handling and Transportation

The Power and Thermal-Control Structure shall meet the specifications herein following exposure to the handling and transportation loads specified in Table 3.2.8-1.

DISCUSSION

The Power and Thermal-Control Structure structure has been analyzed to the ground operations structural loads specified. This information has been provided previously per SSE03 Volumes 2 and 8 data submittals. The analysis shows that all margins are positive using the required handling and transportation load factors. These loads are enveloped by flight acoustic and random vibration loads and thus do not require detailed analysis. This discussion verifies compliance with paragraph 3.2.8e of the PTS Specification, no further action is required.

15. 3.3.6.1.1 Emergency Landing
The Power and Thermal-Control Structure shall be designed such that it will not create an STS hazard when subjected to the emergency landing loads specified in paragraph 3.2.7.2.3b. Following exposure to these loads, the instrument will not be required to operate satisfactorily. The structure may yield but not fracture.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to determine structural integrity after exposure to the emergency landing accelerations and loads levels specified. This information has been provided previously per SSE03 Volumes 2, 3, and 8 data submittals. The analysis shows that all margins are positive using the required emergency landing load factors. These loads are enveloped by flight acoustic and random vibrations requirements and thus do not require detailed analysis. This discussion verifies compliance with paragraph 3.3.6.1.1 of the PTS Specification, no further action is required.

16. 3.3.6.2a Strength
The Power and Thermal-Control Structure structure shall be designed, using the appropriate factors of safety defined in paragraph 3.3.6.1.b, to have sufficient strength to withstand limit loads with other accompanying environmental phenomena for each design condition, without permanent deformation or rupture.

DISCUSSION
The Power and Thermal-Control Structure structure has been analyzed to the appropriate factors of safety. This information has been provided previously per SSE03 Volume 2 data submittal. All margins are positive to prevent permanent deformation or rupture with the required factors of safety. This discussion verifies compliance with paragraph 3.3.6.2a of the PTS Specification, no further action is required.