Global Precipitation Measurement (GPM) Project

Performance Specification Star Trackers

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

CM FOREWORD

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CHANGE RECORD PAGE

Version	Mod No.	Mod issue date	CCR No.	CCR approval date	Sections Affected	Description
Rev -			105	10/15/08	All	Baseline

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1 SCOPE

This specification describes the electrical, mechanical, operating environment, and verification testing requirements for space-qualified, Star Trackers (ST) for a Goddard Space Flight Center (GSFC) payload, the Global Precipitation Measurement (GPM).

2 DOCUMENTATION AND DEFINITIONS

2.1 APPLICABLE DOCUMENTS

The following documents and drawings in effect on the day this specification was signed shall apply to the fabrication and to the electrical, mechanical, and environmental requirements of the Star Trackers to the extent specified herein. In the event of conflict between this specification and any referenced document, this specification will govern, with the exception of the Statement of Work, GPM-GN&C-SOW-009, in which case the SOW takes precedence.

The following is a list of the applicable specifications and publications.

Table 2-1 List of Documents

DOCUMENT NUMBER	TITLE	Revision/Date
GPM-GN&C-SOW-009	Statement of Work for Global Precipitation Measurement (GPM) Project Star Trackers	
MIL-STD-462	Measurement of Electromagnetic Interference Characteristics	
NASA-HDBK-4002	Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging	
MIL-STD-1246C	Product Cleanliness Levels and Contamination Control	Revision C/ April 1994
NASA-HDBK-7005	Dynamic Environment Criteria	BASE/ 3/13/2001
NASA-STD-7001	Payload Vibroacoustic Test Criteria	BASE/ 6/21/1996
GSFC-STD-7000	General Environmental Verification Standards (GEVS)	April 2005

2.2 DEFINITIONS

2.2.1 Flight Unit

Flight Unit is hardware that will be used operationally in space. It includes the following:

2.2.1.1 Protoflight Unit

Flight hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and flight acceptance test durations.

3 REQUIREMENTS

All of the written requirements in this document must apply at the end of spacecraft (SC) life (EOL), as defined in section 3.5.

3.1 DESCRIPTION

ST-60 The star tracker and appropriate shade is an electro-optic device that is capable of acquiring and tracking multiple stars in its field of view. The tracker shall provide software and a star catalog to be hosted in either the spacecraft or the star trackers. The software and star catalog shall provide an inertial attitude quaternion solution corrected for systematic errors relative to the tracker axes and the star magnitude. No external calibration shall be required for the tracker to meet its accuracy requirements.

ST-61 Star simulator GSE and all unique software required to operate the star tracker shall also be provided to GPM for integration and testing of the star trackers.

3.2 COMPONENT-SPECIFIC FUNCTIONAL/PERFORMANCE REQUIREMENTS

3.2.1 Lifetime

ST-64 The star tracker shall operate within specification during the component mission life as defined in Section 3.5.1.

3.2.2 Rates

ST-66 The star tracker shall operate full performance with slew rate magnitudes ranging from 0.0 deg/sec to 0.3 deg/sec. For slew rate magnitudes ranging from 0.3 deg/sec to 2.0 deg/sec, the star tracker shall operate at reduced performance.

3.2.3 Exclusion and Interference Angles

ST-68 The sun shade shall allow the ST to meet all of the performance requirements herein when:

- the boresight is within 30 degrees of the sun, and/or
- the boresight is within 30 degrees of the earth, and/or
- the boresight is within 15 degrees of the moon

3.2.4 Acquisition Time

ST-73 The star tracker, with no prior attitude knowledge, shall survey the star field and output a correct quaternion output within 120 seconds.

3.2.5 Update Rate

ST-75 When tracking stars, the ST shall provide quaternion solutions at a 1 Hz rate minimum.

3.2.6 Transverse and Boresight Error

3.2.6.1 Boresight Error (Bias + Systematic)

ST-78 The Boresight Error (Bias + Systematic) about the roll (star tracker boresight) axes shall be less than or equal to 36 arcsec, 3σ, for slew rate magnitudes 0.0 deg/sec to 0.3 deg/sec.

3.2.6.2 Random Boresight Error (NEA)

ST-80 The Random Boresight Error (NEA) about the roll (star tracker boresight) axes shall be less then or equal to 108 arcsec, 3σ, for slew rate magnitudes 0.0 deg/sec to 0.3 deg/sec.

3.2.6.3 Transverse Error (Bias + Systematic)

ST-82 The Transverse Error (Bias + Systematic) across the pitch/yaw (star tracker transverse) axes shall be less then or equal to 36 arcsec, 3σ, for slew rate magnitudes 0.0 deg/sec to 0.3 deg/sec.

3.2.6.4 Random Transverse Error (NEA)

ST-84 The Random Transverse Error (NEA) across the pitch/yaw (star tracker transverse) axes shall be less then or equal to 36 arcsec, 3σ, for slew rate magnitudes 0.0 deg/sec to 0.3 deg/sec.

3.2.7 Warm-Up Time

ST-86 The ST shall meet performance requirements within 15 minutes of the application of power, for any of the specified environmental conditions, to the end of life.

3.2.8 Sky Coverage

ST-88 Full performance shall be met over 99% of the sky as long as the spacecraft environment is maintained to within the star trackers' operational requirements.

3.2.9 Bright Source Protection

ST-90 The ST shall be capable of sustaining continuous direct exposure to the sun within its FOV, without permanent degradation. The star tracker shall meet its performance requirements within 10 minutes after return to angles specified in section 3.2.3.

3.2.10 Maintainability

ST-92 The ST shall meet all performance requirements over its operational life without maintenance of any kind including calibration. No maintenance shall be required for up to five years of storage under conditions specified below:

Temperature: 25 °C +/- 15 °C

Humidity: 0 to 70%

Pressure: Sea Level to Vacuum

3.3 PHYSICAL CHARACTERISTICS

3.3.1 Mass

ST-98 The total as delivered ST mass shall be less than or equal to 4 kg.

3.3.2 Center of Mass

ST-100 The Contractor shall define the center of mass. The center of mass shall be determined to within ±2.5 mm relative to an external reference.

3.3.3 Envelope

ST-102 The Star Tracker (including sun shade) shall not exceed the thermal and mechanical volume envelope of 41.0 cm length X 22.5 cm diameter

3.3.4 Demise

ST-104 In order to limit debris re-entry survival, the Star Tracker design should limit use of all parts satisfying either of the following two conditions: (1) Individual parts with a melting point exceeding 1000°C and any linear dimension exceeding 0.20 m. (2) Individual parts with a mass greater than 3.0 kg of stainless steel alloys, 1.0 kg of titanium alloys, 1.0 kg of beryllium alloys, 10.0 kg of aluminum alloys, or 1.0 kg of any material with a melting point greater than 1000°C. All parts exceeding the required thresholds shall be identified.

3.3.5 Minimum Resonant Frequency

ST-106 The unit shall have a minimum structural fundamental frequency of 50 Hz at fixed base. Flexures, if used, are considered as part of the Star Tracker package. This requirement shall be verified by test during structural sine sweep testing.

3.3.6 Mounting and Flatness

ST-108 The ST package will be hard-mounted on a mechanical surface of the spacecraft structure. The Star Trackers shall have an interface flatness of 0.05 mm per 100 mm (0.006 inch per 12 inches) or better. Proper fit/alignment of the ST to the structure shall be inherent in its design, fabrication, and assembly to the structure, through the use of close dimensional control in the location of mounting holes and the use of correct mounting hardware. The mounting interface shall be defined in the Interface Control Document.

3.3.7 External Adjustment

ST-110 The ST shall be designed so that no external adjustments are required after start of acceptance or qualification testing.

3.3.8 Finish

ST-112 All parts should be passivated and external surfaces on externally mounted components shall be conductive as defined in paragraph 3.4.6 (surface conductivity.) Aluminum parts shall be finished with iridite per MIL-DTL-5541F. Titanium surfaces shall be finished per SAE-AMS 2488D. Minor deviations in the material finish may be approved on a case-by-case basis by the COTR.

3.3.9 Identification and Marking

ST-114 Each unit shall be permanently marked with the part number and a unique sequential serial number in the area designated on the interface control drawing in a manner to be approved by the GSFC COTR.

3.3.10 Optical Reference

ST-116 Permanent optical reference surfaces that permit alignment on the spacecraft to the mechanical coordinate frame shall be provided on the star tracker. Knowledge of the star tracker electrical axes alignment to the optical reference shall be to 10 arc seconds or better in each axis. Knowledge of the star tracker electrical axes alignment to the mechanical reference frame shall be to 10 arc seconds or better in each axis.

ST-117 Throughout environments, the electrical axes shall not shift with respect to the optical reference by more than 30 arcsec in each axis. Throughout environments, the electrical axes shall not shift with respect to the mechanical reference by more than 30 arcsec in each axis.

ST-118 Two adjacent surfaces of the optical reference shall be available for alignment measurements without affecting the basic integrity of the ST. Optical reference surfaces shall be at least 0.6 x 0.6 inches and shall be capable of producing an autocollimation indication.

ABSOLUTE ALIGNMENT:

ST-120 The electrical axes shall be aligned to the mechanical axes within 10 arcminutes.

3.4 ELECTRICAL CHARACTERISTICS

ST-122 The electrical interface configuration shall meet the overall requirements of this specification.

3.4.1 Inputs

ST-124 The presence or absence of any combination of the input signals applied in any sequence shall not damage the ST, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not. No sequence of command shall damage the ST, reduce its life expectancy, or cause any malfunction.

3.4.1.1 Reset

ST-126 There shall be a reset command that causes the processor to start over at the beginning as if power had been cycled off and on. All parameters shall be reinitialized when this command is executed.

3.4.1.2 Upload

ST-128 The ST shall allow either executable code or data to be uploaded into star tracker memory if desired. This mechanism can be used to upload special diagnostic test routines, software patches, and calibration data to the star tracker during flight. The upload command would normally only be used for diagnostic purposes.

3.4.1.3 Timing

External timing requirements will be defined in the Interface Control Document. Nominally, designs should not assume external timing to be provided.

3.4.1.4 Power Input Configuration

ST-132 Power to the ST component will be remotely switched using properly derated lines. The dc power and return will be routed to the ST as twisted pairs and will be shielded as required. The power inputs and their associated returns shall not use adjacent pins on the connector. The ST shall provide an interface for redundant power sources and shall diode isolate power inputs from independent power sources.

3.4.1.5 Power Consumption

ST-134 Maximum Steady State Power shall not exceed 14.2 Watts. Maximum Peak Power shall not exceed 16 Watts.

3.4.1.6 Input Voltage Level

Input voltage will be +28V +/- 7V nominal.

3.4.1.7 Input Noise and Ripple

ST-138 The component shall operate while in the presence of a 500 mVolts rms ripple superimposed on the steady-state voltage over the frequency range of 1 Hz to 10MHz

3.4.1.8 Source Impedance

ST-140 The ST shall meet all performance requirements given the following source impedence information:

The impedance of the supplied power bus is a combination of the power distribution harness, the battery, the battery to PSE power bus impedance, switching devices, bus wiring, and connectors. For the purposes of modeling, the Power subsystem impedance is less than 100 milliOhm resistor in series with 2 microHenrys of inductance on each power and return line. The impedance of the power distribution harness must be added to this model to approximate the impedance of the power bus as seen at any given component power input. The wiring between the power subsystem and any component is application specific, but may be modeled at between 3 to 6 meters of wire gauge (AWG) 12, 20 and 22 depending on the subsystem power service.

3.4.1.9 Input Power Transients

ST-143 Normal Transients: Operational transients shall not exceed 125 percent of the maximum current drawn during peak power operation (25 percent higher than peak operational current) with the maximum duration not to exceed 50 ms and the rate of change of current during the transients not to exceed 20 mA/µs. Transients that exceed this specification may cause the GPM observatory to enter low power mode due to an over-current condition.

ST-144 Abnormal Transients: All GPM Core Spacecraft Subsystems and Components shall be designed to not be damaged by any voltage in the range of 0 to +40 Vdc for an indefinite time period applied to the power input during anomalistic operations. Verification is recommended to be by analysis or test on an engineering test unit (ETU) or a board level.

3.4.1.10 Induced Transients

ST-146 The ST's induced transients shall not exceed the following:

ST-147 Turn-On Transients: Transient turn-on currents drawn by the ST shall not exceed the following limits:

ST-148 (a) The initial inrush current due to distributed capacitance, EMI filters, etc., shall not exceed a slope of 1A/µsec.

ST-149 (b) The rate of change of inrush current after the initial surge shall not exceed 20 mA/µsec.

ST-150 (c) The transient current shall not exceed 300 % of the maximum steady state current at any time.

ST-151 (d) The in-rush shall be reduced to steady-state within 100 msec after turn-on.

ST-152 Turn-Off Transients: When the service is switched off, the peak voltage transient induced on the power service shall not exceed +40 Vdc nor drop below -2 Vdc (no more than two silicon diodes in series) with respect to ground.

ST-153 Operational Transients: Operational transients, those occurring after initial turn-on, shall not exceed 90% of the rated current for the switched service. For the component, the rated maximum current is 2A. The rate of change of current during the transients shall not exceed 20 mA/µsec.

3.4.1.11 Internal Fusing/Over-Current Protection

ST-155 There shall be no internal fusing in the ST. If required, components may use resetable solid-state switches for over-current protection.

3.4.1.12 External Commands

ST-157 External commands as needed by the ST shall be defined in the Interface Control Document.

3.4.1.13 Test Inputs

ST-159 Component test interfaces shall follow the test signal rules below.

a. The component may include test signals at test connectors that are not directly wired to a flight circuit (not isolated) and that are used for ground test operations.

ST-161 b. Test connectors shall meet the same specifications as any flight connector on the component.

ST-162 c. The Contractor shall provide flight-approved RF, static control covers, connector savers, and mating connectors for all connectors.

ST-163 d. Circuits wired to the test connectors shall be designed to prevent damage due to an external short, test equipment malfunction, or ESD.

ST-164 Component power shall not be applied or accessed at or through a test connector

3.4.2 Outputs

3.4.2.1 Telemetry

ST-167 Communications with the star tracker shall be via a redundant transformer coupled 1553B data bus per MIL-STD-1553B. Each tracker shall be cd to have a unique RT address via external jumpers at the interface connector. The output format shall be either a quaternion or an input to a vendor supplied algorithm which will generate a quaternion.

3.4.2.2 Data Bus Topology

ST-169 The transformer-coupled (long stub) interface shall be implemented for the GPM 1553B data bus, as specified in MIL-STD-1553B. A typical subsystem RT will interface to the data bus with an isolation transformer and a coupling transformer. The complete 1553 data bus will be assembled as shown in the figure below.

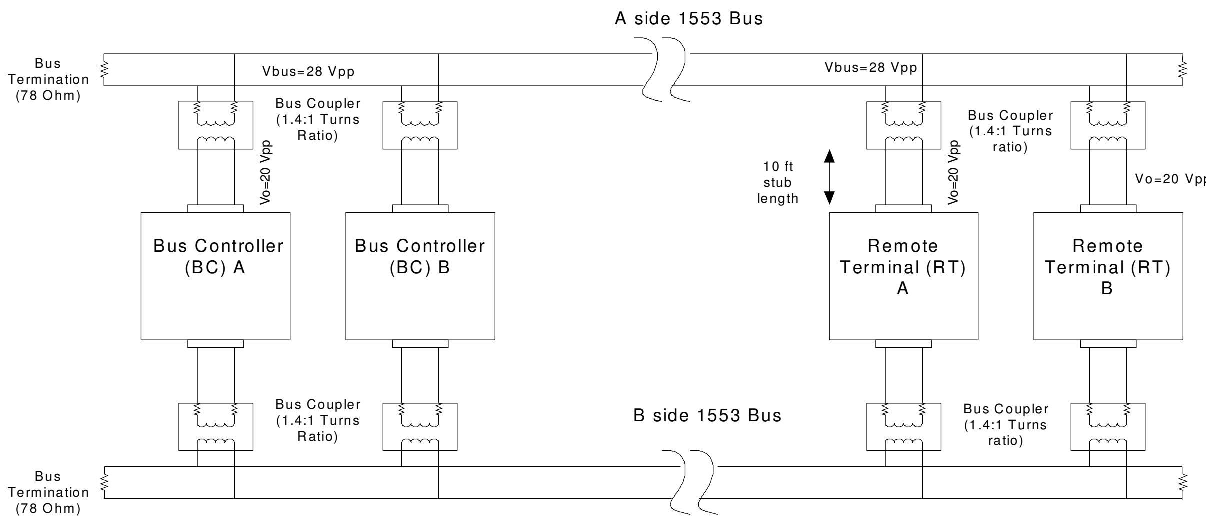


Figure 3-1 1553 Data Bus Subsystem Diagram

3.4.3 Connectors

ST-173 External box connectors shall be chosen from those in the EEE-INST-0002. If the component requirements cannot be met using one of these connectors, equivalent alternates may be used if it meets the derating criteria of EEE-INST-0002, or after successful completion of a qualification program based upon the guidelines contained therein.

3.4.4 Wiring

ST-175 Conventional wire used in the spacecraft harness or any of the subsystem harnesses shall conform to the following requirements.

a. Minimum allowable wire size for power is 22 AWG. Minimum wire size for signals is 24 AWG.

b. All harnessing must be fabricated from low outgassing material that is non-flammable or self-extinguishing. (per EEE-INST-002)

c. All current carrying power wires must be derated in accordance with GSFC EEE-INST-0002

ST-179 d. Wire shields shall not be used for power or power return.

3.4.4.1 Wire Sizing and Number

ST-181 The ST shall provide two power and two return inputs, each sized appropriately, to accommodate the peak operating current draw from the power system and remain within derating guidelines of EEE-INST-0002 for wire in a bundle. This requirement must still remain after one wire is in an open circuit condition.

3.4.4.2 Cable and Signal Shielding

ST-183 All signal lines shall be shielded. Power wires shall be shielded on a case by case basis, if it is determined to be necessary by the EMC tests performed before ST delivery. All shields shall be grounded to the chassis of the ST and not brought through the connectors unless approved by the COTR.

3.4.5 Grounding

ST-185 Unregulated 28V power and return shall be isolated from signal and chassis ground by greater than 1 Mohms. Internal to the ST, signal and chassis ground will be directly connected to each other. Secondary power and ground shall also be isolated from unregulated 28V power and return by greater than 10 Mohms. The secondary ground of power converter circuits shall also be directly connected to chassis ground. Other circuits within the system shall be referenced to signal ground except where otherwise specified. Redundant signal, power and chassis ground contacts shall be provided at the flight connectors. Chassis ground contacts shall take the shortest possible route to chassis. The design of the ST ground layout shall minimize current flow (per 3.4.9.5 Common Mode Noise requirements).

ST-186 The DC electrical resistance across the ST to mounting interfaces shall not exceed 2.5 mΩ. (Assume bolted to aluminum interface with no interface material). Mating surfaces shall be free from nonconductive finishes and shall maximize contact surface area. Connector shells shall be electrically bonded to the chassis through an electrical resistance not exceeding 5 mΩ. Unless specifically approved by the GSFC COTR, the component's ground connection shall be made through its mounting interface.

3.4.6 Surface/Dielectric Charging Protection

ST-188 The component shall meet the following requirements in order to survive the LEO charging environment.

3.4.6.1 Surface Conductivity/External Discharge Protection

ST-190 External surfaces on externally mounted components shall be conductive with a resistivity of less than 109 ohms/sq. and grounded to the Observatory structure, so that charge can bleed from that surface faster than the charge can build up on that surface.

ST-191 The component shall be designed to prevent discharges on the external surfaces from permanently damaging components or upsetting data collection.

ST-192 The component's electrical system shall be designed to carry discharge currents and to shield from the electric field from the discharge without any permanent damage to the Observatory.

3.4.6.2 Internal Charging

ST-194 The component design shall prevent internal charging/discharging effects that can damage the internal components or disrupt operations. Internal charging effects shall be controlled by shielding all electronics elements with sufficient aluminum equivalent thickness (110 mil Al for bulk dielectrics or to 60 mil Al equivalent for Teflon harness insulation) so that the internal charging rate is benign. (NOTE: The ST is located outside the spacecraft module, and thus can assume 40 mils of equivalent Aluminum shielding from the spacecraft.

ST-195 Internal dielectrics materials with bulk resistivity of >1012 ohm-cm (such as the connectors, thermal isolators, thermistor mounting, and other materials such as Kapton and Teflon insulators) that do not meet the shielding requirement shall be controlled via one of the methods described in the following paragraphs below.

a. Limit the electron flux to insulators by shielding to 10^{10} electrons/cm^2 in 10 hours. (This can be met with plate shielding with 110 mil Al for bulk dielectrics or to 60 mil Al equivalent for Teflon harness insulation.)

b. Filter nearby circuitry to withstand a 5,000-Volt, 20-pf, 10-ohm discharge. Detailed analysis of discharge could result in smaller or larger discharge source than above.

c. Coat the exterior surface of the dielectric with a grounded layer with a resistivity of $<10^9$ ohm/sq.

d. Prevent the discharge from reaching a victim circuit by EMI shielding and or grounded conductive barrier that will safely absorb and dissipate the discharge.

ST-200 If none of above control techniques can be applied, the impacts of the discharge from the dielectric material shall be assessed for an approval.

ST-201 Ungrounded (floating) conductors shall not be allowed in the component. This includes unused wires in harnesses; ground test sensors; unused or unpopulated circuit board traces; ungrounded IC, relay, transistor, or capacitor cases; spare pins in connectors; aluminum or copper tape; ungrounded bracketry for harness or connectors; TC105 harness tie-down clips; harness P-clamps; conductive epoxy; thermostat cases; screws; or nut plates.

ST-202 Leakage impedance of conductive internal parts shall be less than 10,000 ohms. This requirement applies to conductive fittings on dielectric structural parts. Further investigation into these effects and mitigations of internal charging can be found in the NASA document, Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects, NASA-HDBK-4002.

3.4.7 Dielectric Strength

ST-204 Dielectric material between mutually isolated electrical circuits shall withstand a test voltage of at least 100 VAC for 60 seconds without exceeding a current of 1.0 mA.

3.4.8 Insulation Resistance

ST-206 Insulation resistance between mutually isolated electrical circuits shall be at least 100 megaohms at a test voltage of at least 50 Vdc for 60 seconds minimum.

3.4.9 EMI/EMC

ST-208 The components shall be compatible with the EMI/EMC levels described below. Acceptable levels of emissions and susceptibility may differ and will be shown in the applicable figures.

- Component Level: CS01/02, CS06, CE01/CE03, RS03, and RE02

3.4.9.1 Conducted Susceptibility (CS)

ST-211 No undesirable response, malfunction, or degradation of performance shall be produced in the component during CS test when subjected to the tests specified below. Performance deviation is acceptable as long as the unit under test shall survive the component CS test levels and meets all performance requirements with the instrument system CS test levels.

ST-212 The CS01 and CS02 (injection of energy into power lines) shall be performed on all electronics that contain the DC/DC converters or power regulation devices.

ST-213 The CS01 test limits shall be 3.1 V rms at the frequency range of 30 Hz to 1.5 kHz, and ramping in a straight line down to 1.0 volt at 50 kHz.

ST-214 The CS02 limit for the test shall be 1.0 V rms at the frequency range of 50 KHz to 400 MHz. These limits, which are defined by MIL-STD-461C, are shown in the figure below.

ST-215 The CS01 and CS02 (injection of energy into power lines) performance shall be verified at the nominal +28V only.

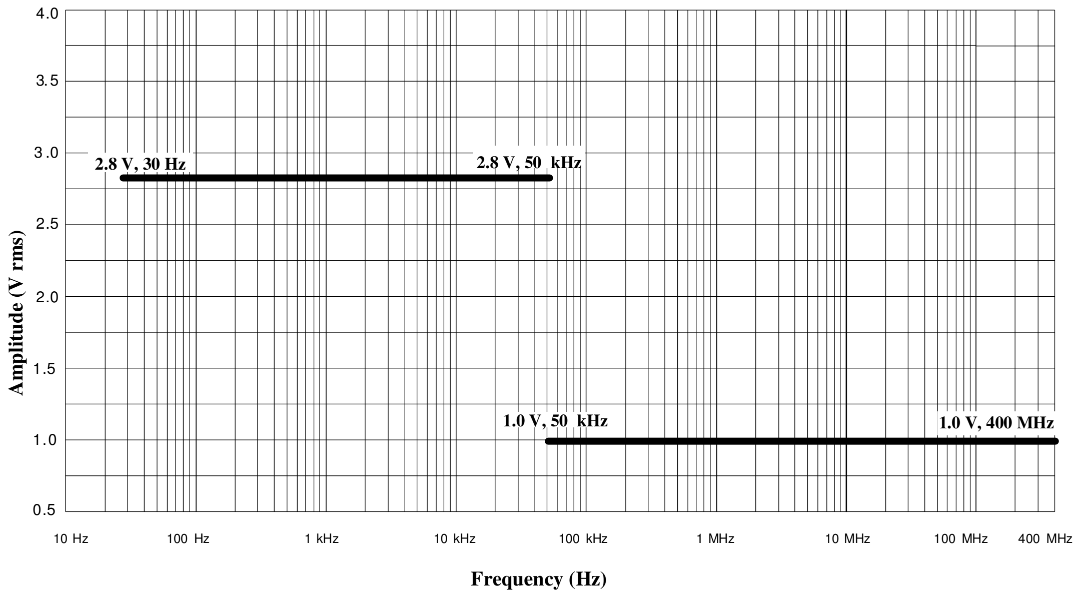


Figure 3-2 CS01/CS02 Limits

ST-218 The CS06 test consists of both a positive transient test and a negative transient test, having an amplitude of 28 V superimposed on the 28 V power bus as in Figure 3.4.9.1. The CS06 test method used shall be as per CS06 as defined in MIL-STD-462. This pulse shall be limited to 56 V peak absolute value and 10 uS from 0.5E (peak) to the 28 V steady-state value crossing point. This pulse width and height are specified per the pulse-generating method as provided in MIL-STD-462.

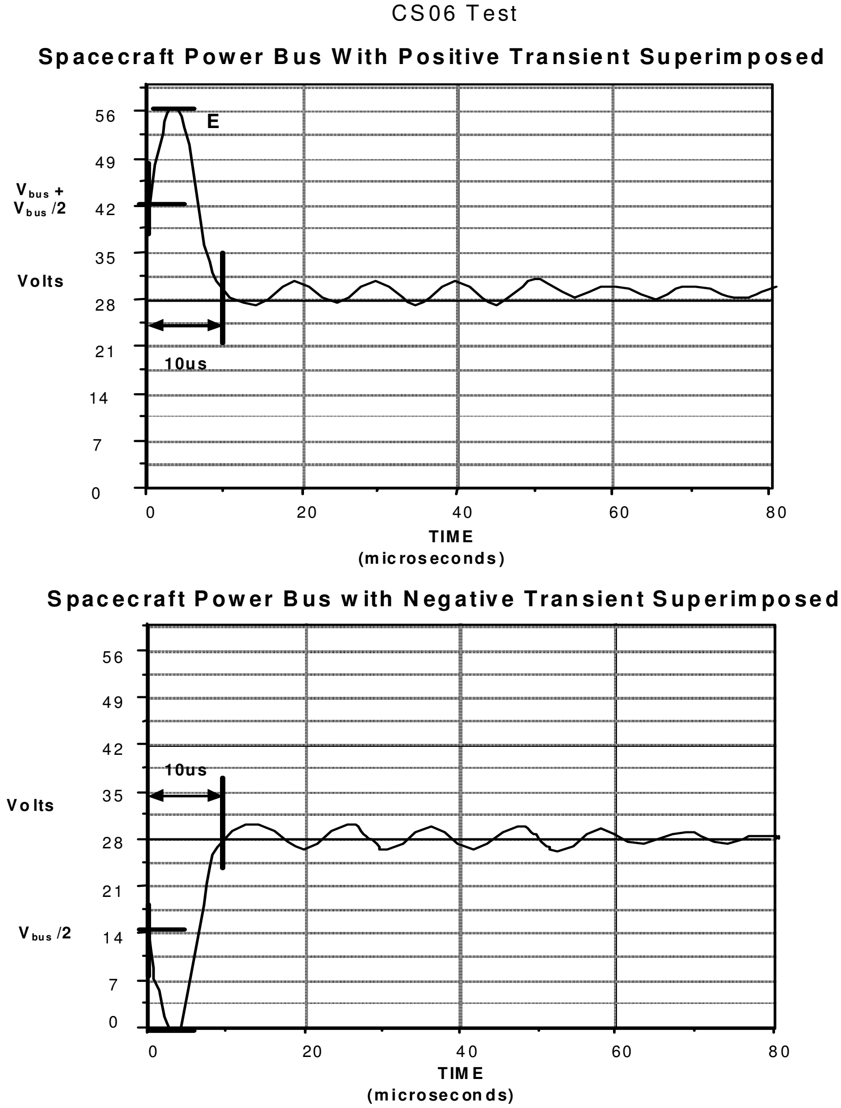


Figure 3-3 CS06 Conducted Susceptibility Test Pulse

3.4.9.2 Conducted Emissions (CE)

ST-222 Conducted emissions shall not exceed the values shown in the figure below when subjected to narrowband testing per CE01 and CE03 as performed per MIL-STD-462. CE01 and CE03 shall be performed on all power and return lines to each component. Transient current pulses, both single event (excluding turn-on) and recurring, shall also be contained within the limits as specified in herein.

Applicable test parameters and limits are as follows for narrowband conducted emissions:

a. Interface lines to be measured are differential mode current lines:

i. +28 V inputs.

ii. 28 V input returns.

b. Interface lines to be measured are common mode current lines:

i. +28 V power inputs with return including heater circuits.

c. Differential mode narrowband test limits are 120 dBµA (1.0 A rms) from 30 Hz to 450 Hz, then decreasing to 50 dBµA (10mA rms) at 20 KHz, then decreasing to 20 dBuA (10µA rms) at 2 MHz, and then continuing at that level to 50 MHz.

Common mode narrowband test limits are 50 dBµA (0.316mA rms) from 30 Hz to 20 KHz, then decreasing to 20 dBuA (10µA rms) at 2 MHz, and then continuing at that level to 50 MHz.

ST-231 Broadband conducted emissions testing shall not be required unless the subsystem/component contains motors with brushes or similar noisy equipment that generates a broadband EMI spectrum.

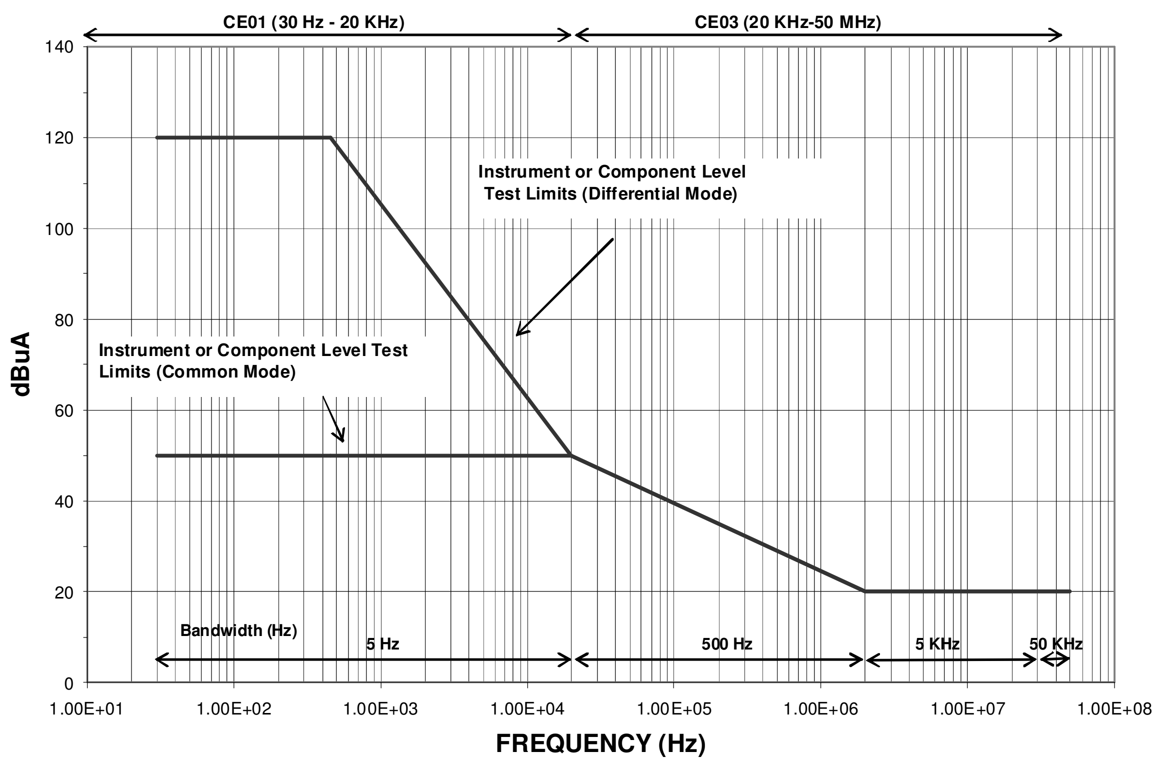


Figure 3-4 Narrowband Conducted Emissions CE01/CE03 Limits

3.4.9.3 Radiated Susceptibility (RS03)

ST-235 Undesirable response, malfunction, or degradation of performance shall not be produced during ST Radiated Susceptibility (RS) testing with the E-field levels shown in the table below.

Table 3-1 GPM Radiated Sources and Levels

Frequency Range	Test Level (Source)
14 KHz-2GHz	2 V/m (GEVS)
2GHz-12GHz	5 V/m (GEVS)
12GHz-18GHz	10 V/m (GEVS)

18GHz-40GHz	20 V/m (GEVS)
2287.5 MHz	10 V/m (TBR) GPM S-B Transmitter
13.6 GHz	1 V/m GPM DPR-Ku radar
35.5 GHz	2 V/m GPM DPR-Ka radar

Table 3-2 Launch Site/Vehicle RS Test Levels

Launch Vehicle - H2-A Transmitter Emission Levels

Frequency Range	Test Level
14 KHz - 30 GHz	0.1 V/m
294 MHz - 297 MHz	0.5 V/m
400 MHz - 500 MHz	1.4 V/m
2.200 GHz - 2.290 GHz	1.3 V/m
2.205 GHz - 2.215 GHz	4.5 V/m
5.23 GHz - 5.786 GHz	30 V/m
14.855 GHz- 14.865GHz	0.4 V/m

ST-289 RS03 shall be performed on all subsystems

Subsystems that are OFF at launch may be powered OFF during Launch Site/Vehicle RS Tests.

3.4.9.4 Radiated Emissions (RE02)

ST-292 Radiated emissions (RE) from the ST shall not exceed the values shown in the figure below when subjected to RE02 narrowband testing.

Table 3-3 GPM Notches for RE02 Testing

	Notch	Notch Center Frequency	Notch Band about Center Frequency	Electric Field Strength[dBuV/m]
A	GPS L2 Receiver	1.227 GHz	1.21 - 1.25 GHz	11.0
B	GPS L1 Receiver	1.575 GHz	1.55 - 1.60 GHz	14.0
C	Spacecraft Receiver	2.106 GHz	2.10 - 2.11 GHz	14.0
D	GMI Channel	10.65 GHz	9.5 - 12 GHz	13.9
E	KuPR Receiver	13.60 GHz	13.5 - 13.70 GHz	80.0
F	GMI Channel	18.7 GHz	16.5 - 27.5 GHz	15.6
G	GMI Channel	23.8 GHz	16.5 - 27.5 GHz	19.0
H	KaPR Receiver	35.5 GHz	34.5 - 39.0 GHz	19.6
I	GMI Channel	36.5 GHz	34.5 - 39.0 GHz	19.6

Figure 3-5 RE02 Radiated Narrowband Emissions Limits

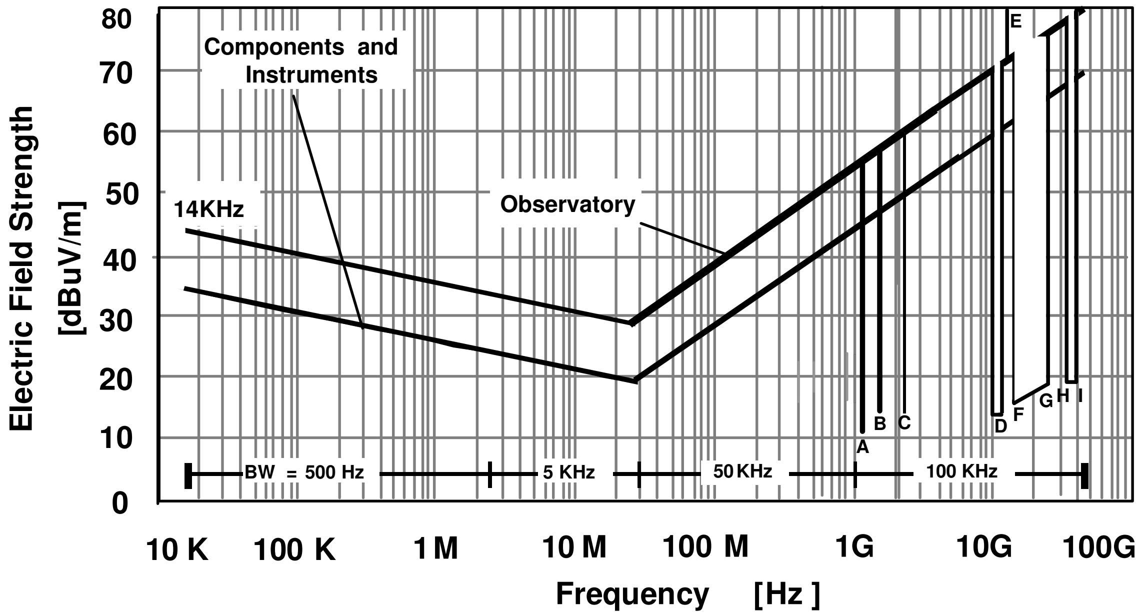


Figure 3-6 RE02 Limits for the Orbiter and STs that are ON from launch to vehicle separation

3.4.9.5 Common Mode Noise

The Common Mode Noise test is as described in section 3.4.9.2 C#01/03

3.4.10 Corona

ST-360 Components with high-voltage circuits shall be immune to corona and arcing while transitioning to the normal orbital vacuum environment.

3.5 LIFE REQUIREMENTS

3.5.1 Mission Life

ST-363 Component orbit life shall be five years as defined herein. The Star Trackers shall meet all performance specifications throughout one year of ground testing and five years of operation in space.

3.5.2 Shelf Life

ST-365 The component shall not suffer any degradation in performance when stored for ten years when packaged using agreed-to procedures.

3.6 ENVIRONMENTAL REQUIREMENTS

ST-367 The component shall be designed to withstand (without degradation of specified performance) the operational and non-operational environments specified in the following section.

3.6.1 Static Loads

ST-369 GPM components shall demonstrate the ability to survive interface limit loads of the table below. This load is based on the GPM mass acceleration for a 4 kg component. If the mass changes by ±0.5 kg, contact the GPM project for a new limit load. Loads are considered to act in any direction, individually. Structural analyses shall be performed to show positive margins of safety using a factor of 1.25X with regard to yield and 1.4X with regard to ultimate material strength for metallic parts except beryllium. Limit loads shall be updated upon completion of GPM Core spacecraft coupled loads analysis.

Table 3-4 Component Limit Load

Component	**Quasi-static limit load (g)**
Star Tracker	31

3.6.2 Vibroacoustic Loads

ST-379 The ST shall be capable of withstanding the random vibration levels and the sine vibration levels shown in the tables below, individually applied to three mutually orthogonal axes.

See Section 4.5.4 for test durations.

Table 3-5 Random Vibration

FREQUENCY (HZ)	Acceptance (Flight) LEVELS (g2/Hz)	Qualification (PROTOFLIGHT and PROTOTYPE) LEVELS (g2/Hz)
20	.013	0.026
20-50	+6dB/oct	+6dB/oct
50-800	.08	0.16
800-2000	-6dB/oct	-6dB/oct
2000	.013	0.026
Overall Grms	10.0 Grms	14.1 Grms

Table 3-6 Sine Sweep Vibration Test Levels

Protoflight/Qualification		**Acceptance Level**	
Frequency (Hz)	**Level**	**Frequency (Hz)**	**Level**
5 - 50 Hz	8 g's	5 - 50	6.4 g's

3.6.3 Acoustic

ST-427 The Star Tracker shall be able to survive acoustic levels at the spacecraft system level testing as defined in the table below and must be capable of withstanding the protoflight acoustic environment. The contractor is not required to verify and test this requirement.

Table 3-7 Limit Level Acoustic Environments for HIIA-202

Full Octave Frequency Band (Hz)	Flight/Acceptance Sound Pressure Level (dB)	Protoflight/Qual Sound Pressure Level (dB)
31.5	125	128
63	126.5	129.5
125	131	134
250	133	136
500	128.5	131.5
1000	125	128
2000	120	123
4000	115	118
8000	113	116
OSPL	**137.5**	**140.5**

The reference point is 20 µPa.

3.6.4 Shock

ST-476 The maximum expected shock environment at the component interface is shown in the figure below. This spectrum is the GEVS shock response spectrum for assessing component test requirements (Figure 2.4-1, GSFC-STD-7001) and is considered benign for electronic devices. All shock testing shall be deferred to the observatory level of assembly and allows for actuation of the actual shock-producing device.

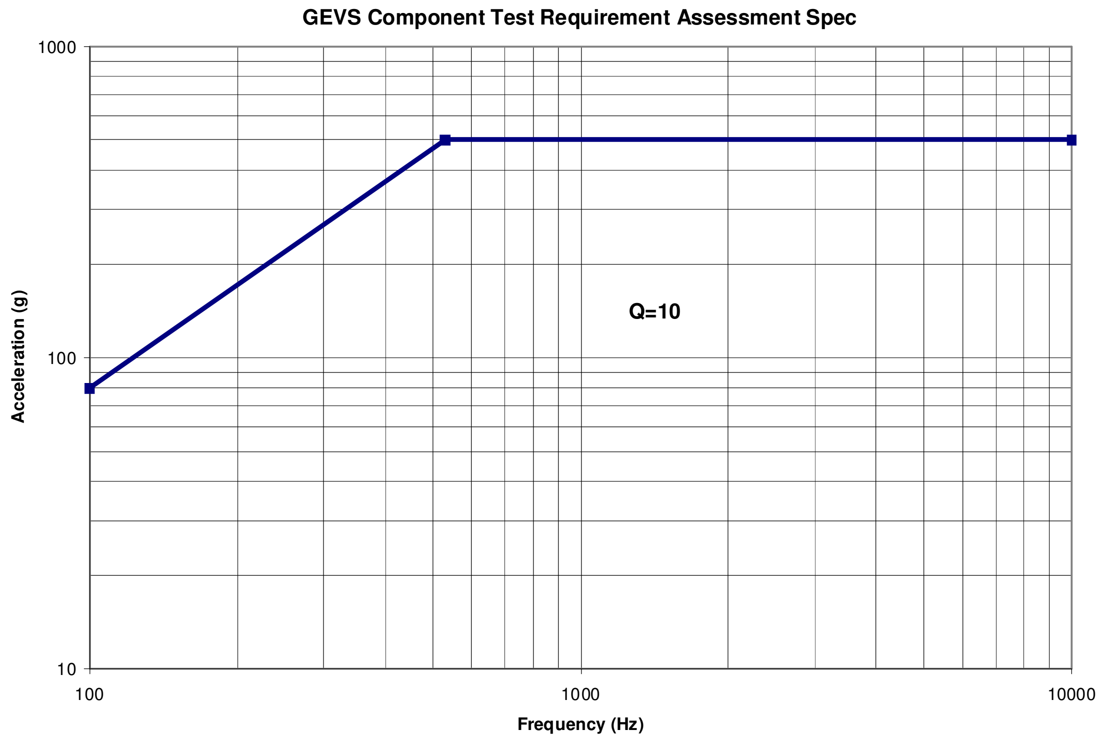


Figure 3-7 Shock Environment

3.6.5 Finite Element Model Requirements

ST-480 If the ST has a predicted first frequency below 100 Hz, the contractor shall provide Finite Element Models (FEMs) for GPM structural analysis. All node, element, material, property and coordinate system numbering shall be approved by the GPM project is the model is to be integrated into the GPM spacecraft model for coupled loads analysis. These FEMs have the following requirements.

3.6.5.1 Finite Element Model Documentation

ST-482 Each formal finite element model submittal shall be submitted with documentation that describes the following:

The version of the model.

A list of element, node, property, and material identification (ID) numbers.

A description of the nonstructural mass represented on each property card.

A description of units.

A description of the local reference coordinate system.

The results of validity checks.

Mass Properties (CG location, Inertias, and total model mass).

Frequencies of the first ten modes while in a free-free boundary condition.

3.6.5.2 Finite Element Model Submittal

ST-492 Formal finite element model submittals shall adhere to the following:

Model submitted as a MacNeal Schwendler Corporation (MSC)/ NASA Structural Analysis (NASTRAN) data deck.

Model file names include the date (YYMMDD) that they were made at the beginning of their name.

All model property and material cards have descriptive names.

Models submission is "full" model with no symmetry assumptions made to reduce model size.

Model includes no "Super Elements".

Model submission includes an explicit Single Point Constraint set.

Until actual hardware mass properties are verified and final, the finite element model is adjusted to the maximum allocated mass for each subsystem and IRU.

Model passes the following validity checks: unit enforced displacement and rotation,free-free dynamics with equilibrium check, and unit gravity loading.

Finite element models used for thermal analysis pass a Star Tracker unit increased temperature (on-orbit worst case predicts) check to verify that the ST does not distort or bend in a way that exceeds the FEM criteria.

3.6.6 Thermal

ST-503 The ST shall be capable of operation with mounting interface temperatures defined in the table below.

Table 3-8 Temperature Limits at Mounting Interface

Condition	Cold Limit (degrees C)	Hot Limit (degrees C)
Operational Temp (nominal expected orbital range)	-5	+20
Acceptance Temp (test temperatures for flight units) conducted only on flight hardware for which the design has already undergone a Qualification Program.	-10	+25
Qualification Temp (maximum performance limits; test temps for first of multiple flight units if design not previously qualified)	-15	+30
Survival Temp (each unit must continue to function after exposure to these temperatures)	-20	+50

3.6.7 Vacuum

ST-527 The ST shall be capable of meeting all performance requirements of section 4.5.2 at ambient as well as when exposed to a vacuum environment of 1 x 10-5 Torr, or less.

3.6.8 Atomic Oxygen

ST-529 The GPM Core Observatory shall be designed to operate normally for the 3 year lifetime subject to exposure to the atomic oxygen environment consistent with the defined mission orbit. Materials used in the construction of or applied to the GPM Core Observatory shall not generate contamination products resulting from the interaction with an atomic oxygen environment.

ST-530 The atomic oxygen (AO) fluence for GPM Core Observatory surfaces in the velocity vector as a monthly basis is depicted in the figure below. The total AO fluence for the mission lifetime of 3 years plus 2 months is 9.76x1021 atoms/cm2 with no design margin. A minimum design margin of 1.5x shall be applied to account for analysis uncertainties. Applying the 1.5x design margin results in the total AO fluence of 1.464x1022 atoms/cm2 for the mission.

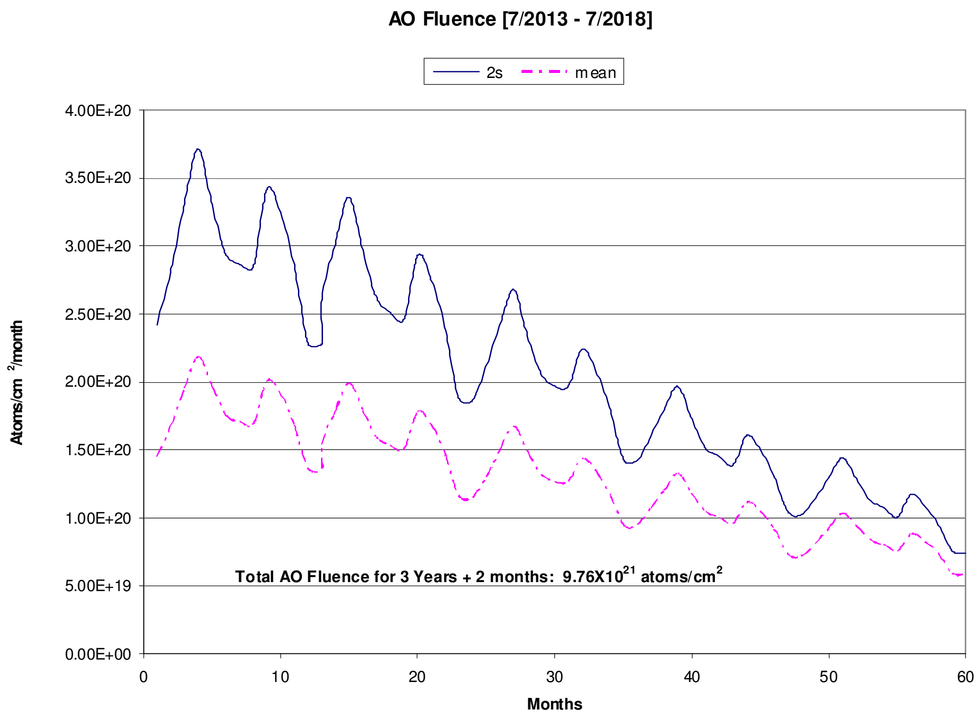


Figure 3-8 Atomic Oxygen Fluence For GPM Mission

3.6.9 Radiation - Total Dose

ST-534 The proposed GPM spacecraft will be positioned in Low Earth Orbit. The total ionizing dose (TID) of radiation is not likely to exceed the values shown in the figure below. Contractor shall assume that there will be NO spacecraft shielding for the star tracker.

ST-535 a) Each component shall be capable of fulfilling their intended application after accumulated exposure based on shielding provided by the Contractor as shown in the figure below. The Contractor must apply a factor of 2 to the values shown in the figure below.

ST-537 b) All linear bipolar components shall be tolerant to the effects of enhanced low dose rates. Linear bipolar components are of special concern for TID degradation, because they may exhibit enhanced degradation when exposed to the low dose rates typical in space environments-a phenomenon called enhanced low dose rate sensitivity.

ST-538 The Contractor shall verify that the performance of devices (for example, bipolar technologies) susceptible to proton displacement damage is unlikely to be compromised by exposure to an equivalent cumulative fluence of 3E11 10 MeV protons.

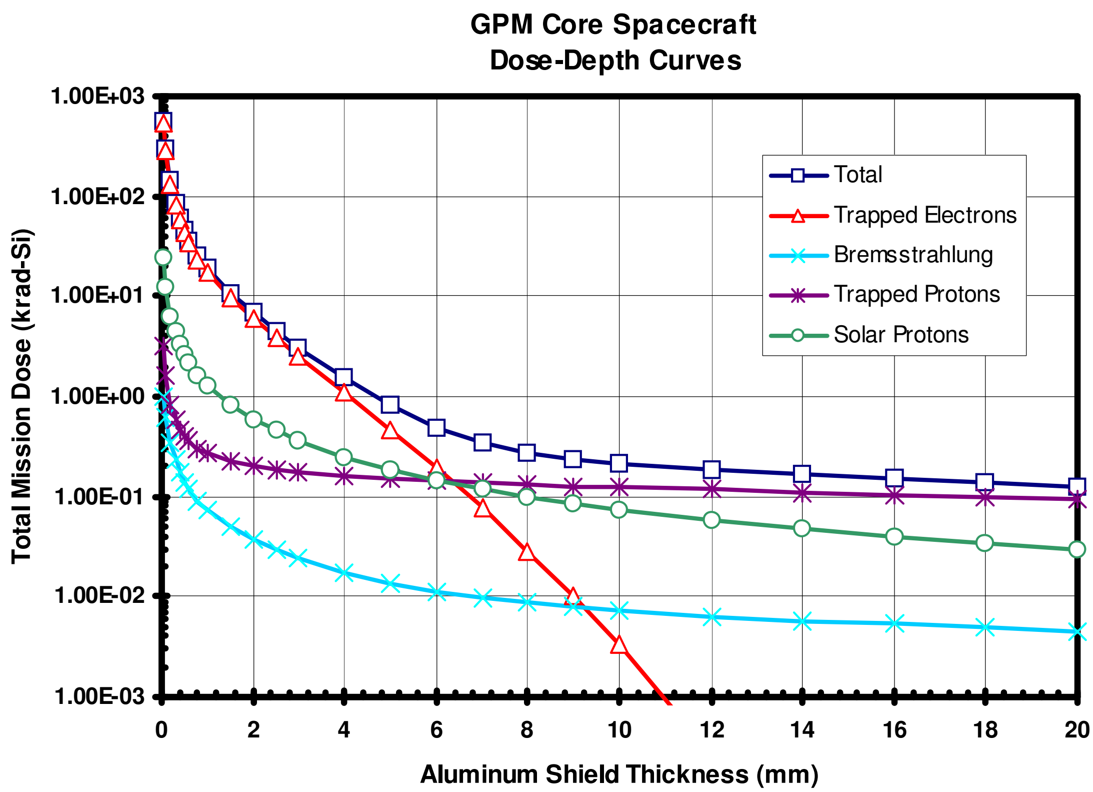


Figure 3-9 GPM Core mission total ionizing dose curves for dose at the center of solid aluminum spheres. Values do not include design margins.

3.6.9.1 Non-Destructive Single Events Effects

ST-542 a) The Contractor shall demonstrate that for non-destructive SEE, such as single event upset (SEU), the minimum LET for each component shall be greater than 37 MeVcm2/mg.

b) The Contractor must consider that there is no geomagnetic shielding for the SDO SC orbit, and so that high LET particles are not considered attenuated.

ST-544 If a device is not immune to SEE's as defined in (a) above, analysis for SEE rates and effects must be performed based on threshold LET of the candidate devices. Effects due to both the galactic cosmic heavy ion and solar heavy ion environment shall be assessed and approved by the GSFC COTR.

ST-545 The Star Tracker shall be capable of maintaining track in the radiation environment of the inclined geosynchronous orbit. Any interruption of track, due to radiation effects, including transient environments such as Coronal Mass Ejections (CME), shall not exceed 10 minutes.

3.6.9.2 Destructive Single Events Effects

ST-547 The Contractor shall demonstrate that for destructive SEE, such as single event latch-up (SEL), the minimum LET for components shall be 100 MeVcm2/mg. Minor deviations in the minimum LET for components may be approved on a case-by-case basis by the COTR

Power MOSFET or bipolar transistors must be derated into their safe operating areas to prevent single-event gate rupture (SEGR) and single-event burnout (SEB).

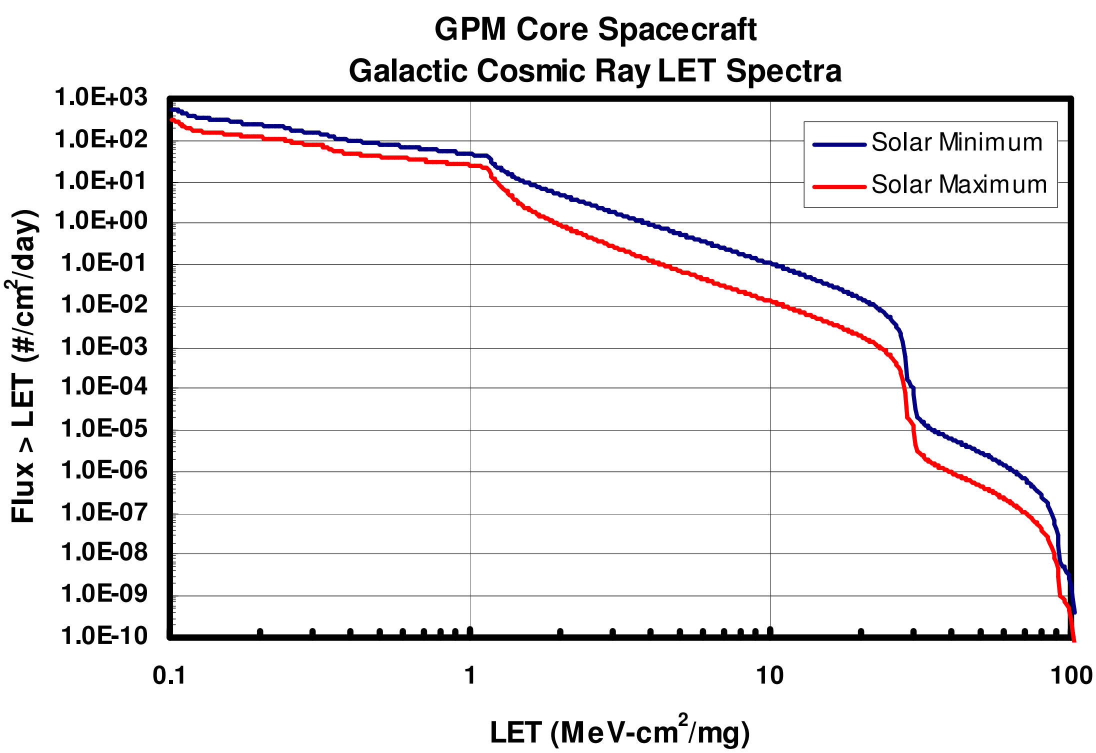


Figure 3-10 Integral LET spectra for galactic cosmic ray ions hydrogen through uranium assuming 100 mils of aluminum shielding

3.6.9.3 Long-Term Displacement Damage

ST-552 The ST shall be capable of meeting requirements over the course of the GPM mission when subjected to radiation environments that cause long-term displacement damage. Appropriate radiation environments are shown in the two figures below. Displacement damage is also caused by secondary neutrons produced by protons interacting with surrounding shielding.

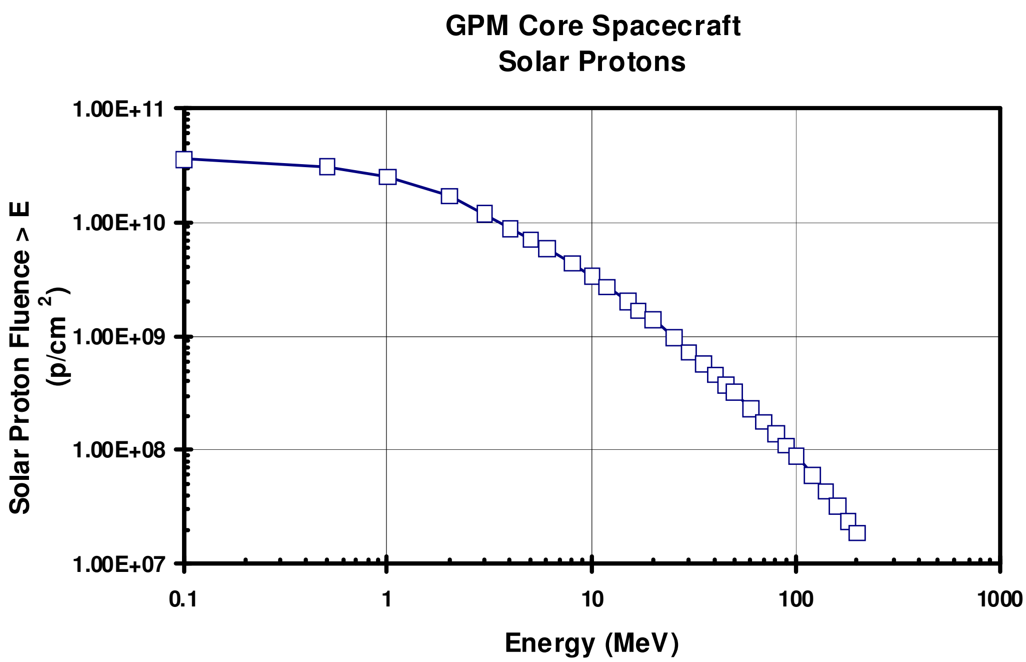


Figure 3-11 Long-Term Proton Levels

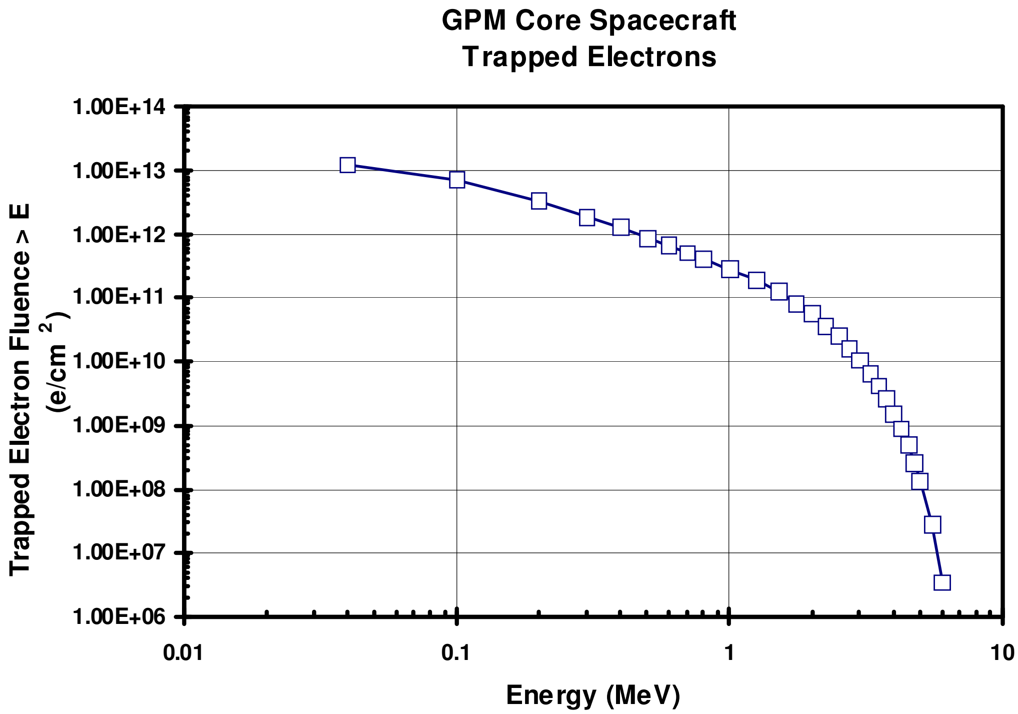


Figure 3-12 Surface incident integral trapped electron fluence for the 5-year GPM Core mission

3.6.9.4 Transient Proton Radiation Flux

ST-558 Particle interference during solar events is of particular concern because it can impact the observation times of CCDs. The elemental composition of a solar particle event consists of about 95% protons, on average. The ST shall be capable of meeting requirements, both during and after, such transient radiation noise events. The maximum proton transient throughout which the ST is expected to meet performance is plotted in the integral energy spectrum in the figures below

Note: Figure below is in terms of protons per square centimeter per second per steradian.

3.6.9.5 Transient Electron Radiation Flux

ST-560 An electron transient that is 20 times that shown in Figure 3-12 above shall be considered to be superimposed on the proton transient.

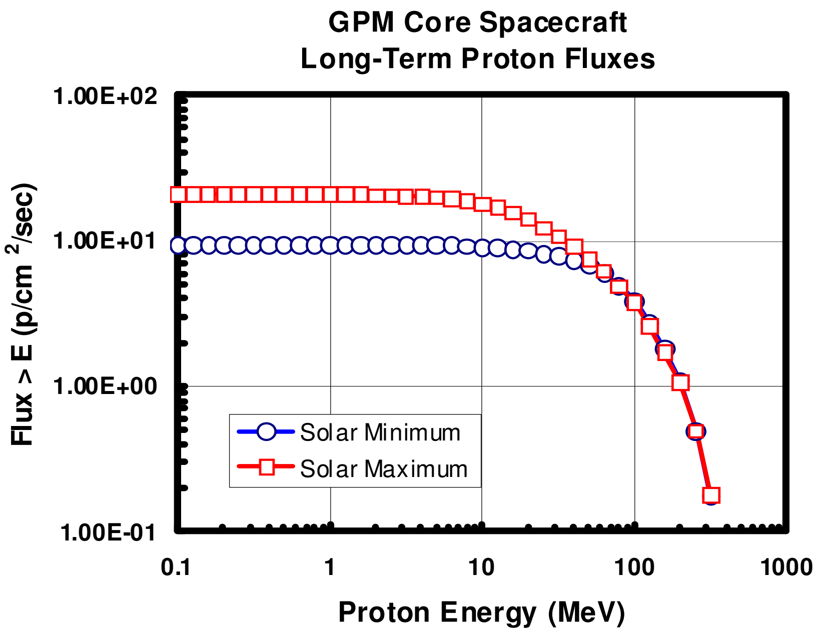


Figure 3-13 Long-term integral proton fluxes for single event effects evaluation. Included are the trapped proton and solar proton fluxes behind 100 mils of aluminum shielding.

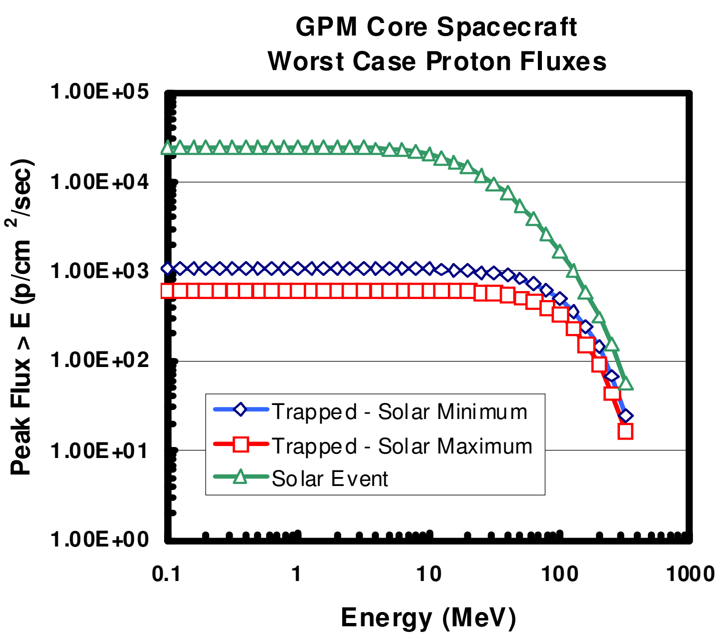


Figure 3-14 Worst case integral proton fluxes for single event effects evaluation. Included are the peak trapped proton fluxes averaged over a 1-minute interval during solar

3.6.10 Humidity

ST-566 The ST shall be capable of meeting the requirements herein during and after exposure to 20 to 70% relative humidity for 2 years.

3.6.11 Venting

ST-568 All ST shall be vented to prevent pressure buildup during the ascent phase of launch. The ST shall survive external depressurization from one atm to 10-5 Torr in 30 seconds.

ST-569 GPM components not having a minimum of 0.25 square inches of vent area for each cubic foot volume, shall demonstrate the ability to survive the venting rate. If analysis is required, the venting analysis must indicate a positive structural margin at loads equal to the maximum expected pressure differential during launch, with a Factor of Safety of 2.0 applied to the loads.

ST-570 Location of the vent hole shall be shown in the ST mechanical ICD.

3.6.12 Magnetic Dipole

ST-572 Any component or piece part exceeding 3 Amp m2 dipole moment shall be identified and approved for its use by the GSFC COTR.

4 VERIFICATION REQUIREMENTS

ST-574 The Contractor shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. The Contractor shall provide a verification matrix defining the method of verification for each specific requirement of this document. Verification methods include inspection, analysis, test or a combination of these techniques.

4.1 INSPECTION

Verification by inspection includes visual inspection of the physical hardware, a physical measurement of a property of the hardware, or the documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

4.1.1 Visual Inspection

Visual inspection, up to 7-10X magnification, of the physical hardware by a customer appointed qualified inspector.

4.1.2 Physical Measurement

Physical measurement of hardware property (i.e. mass, dimensions, etc.) demonstrating the hardware meets specific requirement.

4.1.3 Documentation Search

ST-582 Verification of requirements based on similarity shall include supporting rationale and documentation and shall be approved by the GSFC COTR

4.1.4 Exterior Cleanliness Requirements

ST-584 All hardware cleanliness shall be verified to be visibly clean, upon delivery to spacecraft integration. The Star Trackers shall be cleaned to Level 450A.

4.2 ANALYSIS

Verification of performance or function through detailed analysis, using all applicable tools and techniques, is acceptable with GSFC COTR approval.

4.3 TEST

Verification by test represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

ST-589 Performance parameter measurements shall be taken to establish a baseline that can be used to assure that there are no data trends established in successive tests that indicate a degradation of performance trend within specification limits that could result in unacceptable performance in flight.

4.4 TEST RESTRICTIONS

4.4.1 Failure During Tests

ST-592 The test shall be stopped if equipment fails during testing in cases where this failure will result in damage to the equipment. Otherwise, the test shall be completed to obtain as much information as possible. No replacement, adjustment, maintenance, or repairs are authorized during testing. This requirement does not prevent the replacement or adjustment of equipment that has exceeded its design operating life during tests, providing that after such replacement, the equipment is given as many tests as are necessary to assure its proper operation. A complete record of any exceptions taken to this requirement shall be included in the test report.

4.4.2 Modification of Hardware

ST-594 Once the formal acceptance test has started, cleaning, adjustment, or modification of test hardware shall not be permitted.

4.4.3 Re-Test Requirements

If any event, including test failure, requires that a component be disassembled and reassembled, then all tests performed prior to the event must be considered for repeat. If the unit has multiple copies of the same build, then all units must be examined to determine if the problem is common. If all copies require disassembly for repair, then each must receive the same test sequence.

4.5 REQUIRED VERIFICATION METHODS

The following measurements, tests, environments, and inspections are required for each ST to provide assurance that the ST meets specified performance, functional, environmental, and design requirements. Each test or demonstration is described below.

a. Weight and Envelope Measurements

b. Initial Alignment (if necessary), Performance and Functional Tests

c. EMI/EMC Tests

Loads Test (Prototype/Protoflight only)

Sine Vibration

Random Vibration

Thermal Vacuum

Final Alignment, Performance and Functional Tests

4.5.1 Weight and Envelope Measurement

ST-608 Measurement of the weight and envelope of the ST shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program.

4.5.2 Performance Tests

ST-610 The ST shall be tested to demonstrate compliance with performance requirements, including alignment if necessary. Performance Tests are detailed functional tests conducted under conditions of varying internal and external parameters with emphasis on all possible modes of operation for the component. A Performance Test shall be conducted at the beginning and end of each acceptance test.

Functional Tests are abbreviated Performance Tests done periodically during or following the component environmental testing in order to show that changes or degradation to the component have not resulted from environmental exposure, handling, transporting, or faulty installation.

4.5.3 EMI/EMC

ST-612 The tests indicated below shall be performed as noted in section 3.4.9 and below

- First Flight Unit: CS01/02, CS06, CE01/03, RS03, RE02, and Common Mode Noise
- Subsequent Flight Units: CS01/02, CS06, CE01/03, and Common Mode Noise

ST-615 It is encouraged to perform these EMI tests as early as possible in the development. All tests shall be performed with the component in its most sensitive mode for susceptibility testing and in its most noisy mode as appropriate for the EMI emission test.

4.5.4 Loads Tests

ST-617 Structural design loads per the levels in Table 3-4 shall be applied to prototype or protoflight hardware. There is no requirement to strength test flight hardware that has already been strength tested through a prototype or protoflight program (ie, there is no "acceptance level" strength test requirement for flight hardware).

Structural Loads testing can be verified by performing either a fixed frequency Sine Burst test, or a series of static loads pull tests.

No permanent deformation may occur as a result of the loads test, and all applicable alignment requirements must be met following the test. Components that require alignment will have an alignment check following loads testing. A performance test will be conducted to verify that no damage occurred due to the loads test.

Components do not have to be powered during static loads tests.

4.5.4.1 Sine Burst

A simple Sine Burst test following the random vibration test in each axis is a convenient method to conduct a structural loads test. This test applies a ramped sine input at a sufficiently low frequency such that the test item moves as a rigid body. An analysis is required to show that a base drive Sine Burst test will not cause over-test or under-test in some areas of the structure.

Duration: 5 cycles of full level amplitude.

4.5.4.2 Static Pull

Static pull tests are another method to perform loads testing and can be applied at flight interfaces in a static test facility. The loads can be applied either as component loads applied simultaneously, or the single resultant vector load can be applied to the test point. Strain gages are generally positioned around the test point to verify deflection predictions from the analytical model.

Test Duration: 30 seconds

4.5.5 Random Vibration

ST-628 The ST shall be subjected to a random vibration test along each axis to the appropriate levels shown in Section 3.6.2. The test item shall be mounted to the test fixture as it would be mounted to the spacecraft. A functional test shall be performed before the start of testing and after a test in each axis.

Prior to the test, a survey of the test fixture/exciter combination will be performed to evaluate the fixture dynamics and the proposed choice of control accelerometers.

ST-630 The duration for the test shall be 1 minute per axis for Acceptance and Protoflight Test and 2 minutes per axis for Prototype Tests.

4.5.6 Sine Vibration

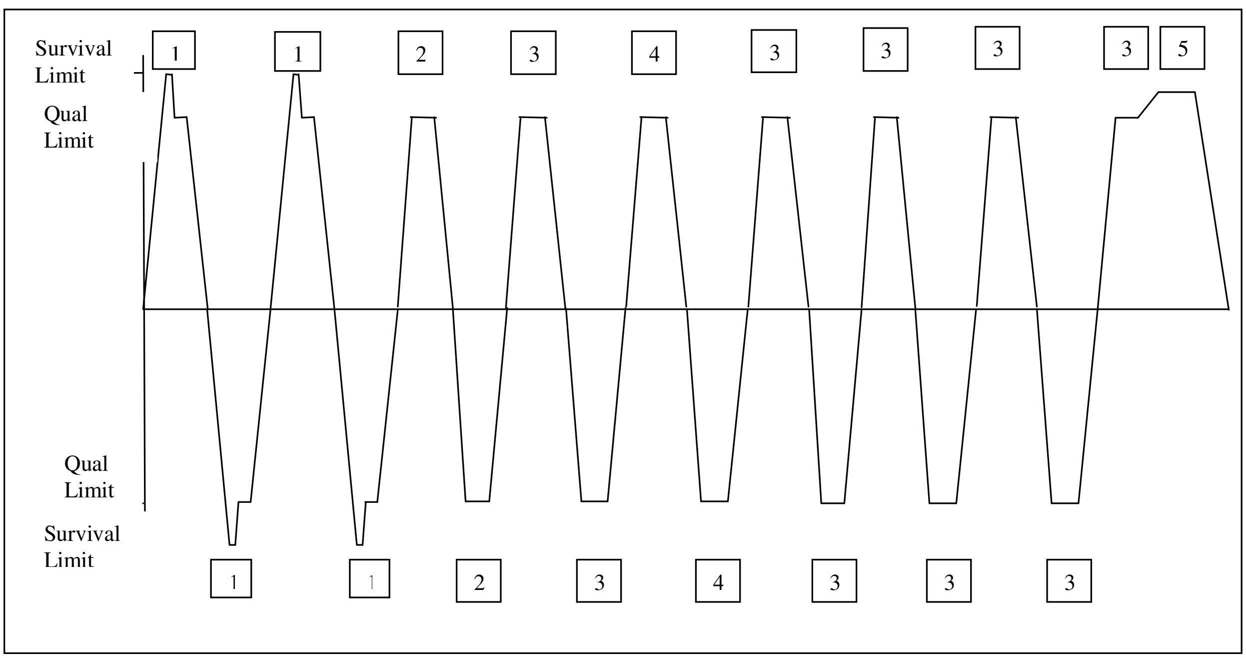
ST-632 The ST shall be subjected to swept sine vibration testing to the appropriate levels in Section 3.6.2. The sweep rate shall be 4 octaves/minute for Acceptance and Protoflight Tests and 2 octaves/minute for Prototype Tests.

The Signature Sine sweep will be conducted on each component before and after vibration testing in each axis. This test is a tool to verify no change in structural integrity from testing and to verify the primary resonant frequency meets requirements of section 3.3.4.

4.5.7 Thermal Vacuum Test

ST-635 The ST shall be cycled in vacuum at temperatures beyond those predicted on orbit. Each ST shall be cycled a total of eight (8) times (see figure below). During these tests, chamber pressure shall be less than 1.33 X 10-3 Pa. (1 X 10-5 torr).

ST-636 During thermal vacuum testing the ST shall be in flight configuration. Thermal blankets may be omitted to speed the transition times between temperature extremes.



1 = Achieve survival temp, stabilize 1 hour, return to QUAL temperature, turn on, soak at test temperature 4 hours, run performance test.

2 = Soak at test temperature 4 hours, run performance test voltage = 21V

3 = Soak at test temperature 4 hours, run performance test voltage = 28V

4 = Soak at test temperature 4 hours, run performance test voltage = 35V

5 = Bakeout phase

Figure 4-1 Thermal Vacuum Profile 8 Hot/Cold Cycles with Bakeout

4.5.7.1 Chamber Pump-Down

During the pump-down, power and RF line voltages will be monitored to demonstrate the absence of corona discharge and multipaction (per paragraph 3.4.10). Only those items powered during launch will be powered for this test.

4.5.7.2 Temperature Transitions

ST-643 Transitions from cold to hot conditions increase contamination hazards because material that has accreted on the chamber walls may evaporate and deposit on the relatively cool test item. Transitions shall be conducted at rates of 5 deg/min or less to prevent that from occurring. Testing shall start with a hot soak and end with a hot soak to minimize this risk.

4.5.7.3 Hot/Cold Turn-On Demonstration

ST-645 Components or subsystems shall be turned on twice after exposure to hot and cold survival temperatures. (see the profile of Figure 4-1).

4.5.7.4 Electrical System Performance

The electrical system and performance will also be verified for minimum, maximum, and nominal voltages at minimum and maximum temperatures. The electrical system and functionality will also be verified for minimum, maximum, and nominal voltages during temperature transitions.

Maximum Bus Voltage: 35V

Nominal Bus Voltage:28V

Minimum Bus Voltage: 21V

Functional tests or performance tests will be conducted during the hot and cold soaks. Immediately following the component thermal vacuum cycling will be the bakeout phase to eliminate volatiles. See Figure 4-1.

First 2 cycles (all units) During the transition from cold to warm, switch component OFF, increase temperature to survival temperature for 1 hour, then return to qualification temperature, verify that component turns ON, and verify nominal performance once the component has reached the qualification temperature. Begin hot soak.

During the transition from warm to cold, switch component OFF, decrease temperature to survival temp for 1 hour, then return to qualification temperature, verify that component turns ON, and verify nominal performance once the component has warmed to the qualification temperature. Begin cold soak.

Soak time at each temperature: 4 hours, run Performance Test during soak.

Number of complete cycles:

Prototype Unit: 8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Qualification temperatures per Table 3-7 as the "test temperature."

Protoflight Unit: 8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Qualification temperatures per Table 3-7 as the "test temperature."

Flight / Copy / Spare Unit: 8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Acceptance temperatures per Table 3-7 as the "test temperature."

Maximum Bus Voltage: 35V

Nominal Bus Voltage: 28V

Minimum Bus Voltage: 21V

4.5.7.5 Bake-out / Outgassing Certification Requirements

ST-663 The Star tracker shall be baked-out prior to delivery to GSFC. The bake-out performance shall be measured using a temperature-controlled Quartz Crystal Microbalance (TQCM) at chamber pressures below 10-5 torr. The bake-out / outgassing certification shall be performed at the star tracker maximum on-orbit temperature and the TQCM shall be controlled at -40 °C or lower throughout the test to measure total outgassing of Volatile Outgassed Condensables (VOC's), without influence of water vapor condensation. The bake-out / outgassing certification test shall be deemed successful when the outgassing rates are 2.5 x 10-8g/s or below per hour for 5 consecutive hours. The following test data shall be collected and delivered to GSFC: chamber configuration, TQCM reading (taken as a minimum every 0.5 hours), hardware temperature, chamber/ shroud temperature, TQCM temperature, and pressure.

Additional Clarification:

If the vendor's vacuum chamber uses a shroud to elevate and sustain an item's temperature for bake-out, background TQCM measurements must be conducted before the bake-out with chamber in bake-out configuration in order to determine flight hardware contribution. Provision must be made to measure effectiveness of pump system. The value of a chamber's exit conductance is generally much lower than the rating of its pump alone. This is necessary to relate TQCM deposition rates to source outgassing rates.

If the vendor uses a bake-out box, the chamber should feature a shroud held at temperatures below the TQCM reading so as not to interfere with it, otherwise the bake-out box should feature a coldplate near the bake-out box vent to collect contaminants that would otherwise interfere with the TQCM readings. In such cases, knowledge of the chamber pump effectiveness is not necessary.

Alternate methods of bakeout may be considered for discussion at any Kick-off Meetings or Design Conformance Reviews."

4.5.8 Magnetic Dipole Verification

ST-669 The magnetic requirement of section 3.6.12 may be satisfied by analysis, but any component or subsystem that exceeds the requirements found in 3.6.12 shall be subjected to a magnetic test. The magnetic test shall be performed on every serial number for components designated for testing.

ST-670 If performed, the test shall occur after vibration testing. This is because magnetic fields induced by the vibration lab may reside in the component following the vibration test sequence.

4.6 MOUNTING INTERFACE AND ALIGNMENT HARDWARE

ST-672 The mounting interface and alignment hardware (1 drill template with specific boresight reference knowledge to each star tracker, jigs, optical reference surface, etc.) shall support the following ST requirements:

- Knowledge of the ST mechanical reference frame to 20 arcsecs (3 sigma) or better in each axis
- Stability through environment testing of 30 arcsecs (3 sigma) or better in each axis
- Optical Reference *(See Section 3.3.10)*

APPENDIX A - ABBREVIATIONS AND ACRONYMS

Al	Aluminum
CE	Conducted Emissions
CS	Conducted Susceptibility
DA	Double Amplitude
EEE	Electrical, Electronic, and Electromechanical
EMI	Electro Magnetic Interference
EOL	End of Life
GEO	Geosychronous Orbit
I&T	Integration and Test
LET	Linear Energy Transfer
LISN	Line Impedance Simulation Network
M ohms	Mega ohms
RE	Radiated Emissions
RS	Radiated Susceptibility
SC	Spacecraft
SDO	Solar Dynamics Observatory
SEB	Single Event Burnout
SEGR	Single Event Gate Rupture
SEE	Single Event Effects
SEU	Single Event Upset
SEM	Scanning Electron Microscope
SOW	Statement of Work
SPL	Sound Pressure Level
ST	Star Tracker
TID	Total Ionizing Dose
UUT	Unit Under Test

APPENDIX B - VERIFICATION

Requirement Number		Object Heading	I	A	D	T	Responsible Org
ST-60	3.1.0-1	Description					
ST-61	3.1.0-2	Description					
ST-64	3.2.1.0-1	Lifetime					
ST-66	3.2.2.0-1	Rates					
ST-68	3.2.3.0-1	Exclusion and Interference Angles					
ST-73	3.2.4.0-1	Acquisition Time					
ST-75	3.2.5.0-1	Update Rate					
ST-78	3.2.6.1.0-1	Boresight Error (Bias + Systematic)					
ST-80	3.2.6.2.0-1	Random Boresight Error (NEA)					
ST-82	3.2.6.3.0-1	Transverse Error (Bias + Systematic)					
ST-84	3.2.6.4.0-1	Random Transverse Error (NEA)					
ST-86	3.2.7.0-1	Warm-Up Time					
ST-88	3.2.8.0-1	Sky Coverage					
ST-90	3.2.9.0-1	Bright Source Protection					
ST-92	3.2.10.0-1	Maintainability					
ST-98	3.3.1.0-1	Mass					
ST-100	3.3.2.0-1	Center of Mass					
ST-102	3.3.3.0-1	Envelope					
ST-104	3.3.4.0-1	Demise					
ST-106	3.3.5.0-1	Minimum Resonant Frequency					
ST-108	3.3.6.0-1	Mounting and Flatness					
ST-110	3.3.7.0-1	External Adjustment					
ST-112	3.3.8.0-1	Finish					
ST-114	3.3.9.0-1	Identification and Marking					
ST-116	3.3.10.0-1	Optical Reference					
ST-117	3.3.10.0-2	Optical Reference					
ST-118	3.3.10.0-3	Optical Reference					
ST-120	3.3.10.0-5	Optical Reference					
ST-122	3.4.0-1	Electrical Characteristics					
ST-124	3.4.1.0-1	Inputs					
ST-126	3.4.1.1.0-1	Reset					
ST-128	3.4.1.2.0-1	Upload					
ST-132	3.4.1.4.0-1	Power Input Configuration					
ST-134	3.4.1.5.0-1	Power Consumption					
ST-138	3.4.1.7.0-1	Input Noise and Ripple					
ST-140	3.4.1.8.0-1	Source Impedance					
ST-143	3.4.1.9.0-1	Input Power Transients					
ST-144	3.4.1.9.0-2	Input Power Transients					

Requirement Number		Object Heading	I	A	D	T	Responsible Org
ST-146	3.4.1.10.0-1	Induced Transients					
ST-147	3.4.1.10.0-2	Induced Transients					
ST-148	3.4.1.10.0-3	Induced Transients					
ST-149	3.4.1.10.0-4	Induced Transients					
ST-150	3.4.1.10.0-5	Induced Transients					
ST-151	3.4.1.10.0-6	Induced Transients					
ST-152	3.4.1.10.0-7	Induced Transients					
ST-153	3.4.1.10.0-8	Induced Transients					
ST-155	3.4.1.11.0-1	Internal Fusing/Over-Current Protection					
ST-157	3.4.1.12.0-1	External Commands					
ST-159	3.4.1.13.0-1	Test Inputs					
ST-161	3.4.1.13.0-3	Test Inputs					
ST-162	3.4.1.13.0-4	Test Inputs					
ST-163	3.4.1.13.0-5	Test Inputs					
ST-164	3.4.1.13.0-6	Test Inputs					
ST-167	3.4.2.1.0-1	Telemetry					
ST-169	3.4.2.2.0-1	Data Bus Topology					
ST-173	3.4.3.0-1	Connectors					
ST-175	3.4.4.0-1	Wiring					
ST-179	3.4.4.0-5	Wiring					
ST-181	3.4.4.1.0-1	Wire Sizing and Number					
ST-183	3.4.4.2.0-1	Cable and Signal Shielding					
ST-185	3.4.5.0-1	Grounding					
ST-186	3.4.5.0-2	Grounding					
ST-188	3.4.6.0-1	Surface/Dielectric Charging Protection					
ST-190	3.4.6.1.0-1	Surface Conductivity/External Discharge Protection					
ST-191	3.4.6.1.0-2	Surface Conductivity/External Discharge Protection					
ST-192	3.4.6.1.0-3	Surface Conductivity/External Discharge Protection					
ST-194	3.4.6.2.0-1	Internal Charging					
ST-195	3.4.6.2.0-2	Internal Charging					
ST-200	3.4.6.2.0-7	Internal Charging					
ST-201	3.4.6.2.0-8	Internal Charging					
ST-202	3.4.6.2.0-9	Internal Charging					
ST-204	3.4.7.0-1	Dielectric Strength					
ST-206	3.4.8.0-1	Insulation Resistance					
ST-208	3.4.9.0-1	EMI/EMC					

Requirement Number		Object Heading	I	A	D	T	Responsible Org
ST-211	3.4.9.1.0-1	Conducted Susceptibility (CS)					
ST-212	3.4.9.1.0-2	Conducted Susceptibility (CS)					
ST-213	3.4.9.1.0-3	Conducted Susceptibility (CS)					
ST-214	3.4.9.1.0-4	Conducted Susceptibility (CS)					
ST-215	3.4.9.1.0-5	Conducted Susceptibility (CS)					
ST-218	3.4.9.1.0-8	Conducted Susceptibility (CS)					
ST-222	3.4.9.2.0-1	Conducted Emissions (CE)					
ST-231	3.4.9.2.0-10	Conducted Emissions (CE)					
ST-235	3.4.9.3.0-1	Radiated Susceptibility (RS03)					
ST-289	3.4.9.3.0-2.0-3.0-2						
ST-292	3.4.9.4.0-1	Radiated Emissions (RE02)					
ST-360	3.4.10.0-1	Corona					
ST-363	3.5.1.0-1	Mission Life					
ST-365	3.5.2.0-1	Shelf Life					
ST-367	3.6.0-1	Environmental Requirements					
ST-369	3.6.1.0-1	Static Loads					
ST-379	3.6.2.0-1	Vibroacoustic Loads					
ST-427	3.6.3.0-1	Acoustic					
ST-476	3.6.4.0-1	Shock					
ST-480	3.6.5.0-1	Finite Element Model Requirements					
ST-482	3.6.5.1.0-1	Finite Element Model Documentation					
ST-492	3.6.5.2.0-1	Finite Element Model Submittal					
ST-503	3.6.6.0-1	Thermal					
ST-527	3.6.7.0-1	Vacuum					
ST-529	3.6.8.0-1	Atomic Oxygen					
ST-530	3.6.8.0-2	Atomic Oxygen					
ST-534	3.6.9.0-1	Radiation - Total Dose					
ST-535	3.6.9.0-2	Radiation - Total Dose					
ST-537	3.6.9.0-3	Radiation - Total Dose					
ST-538	3.6.9.0-4	Radiation - Total Dose					
ST-542	3.6.9.1.0-1	Non-Destructive Single Events Effects					
ST-544	3.6.9.1.0-3	Non-Destructive Single Events Effects					
ST-545	3.6.9.1.0-4	Non-Destructive Single Events Effects					
ST-547	3.6.9.2.0-1	Destructive Single Events Effects					
ST-552	3.6.9.3.0-1	Long-Term Displacement Damage					
ST-558	3.6.9.4.0-1	Transient Proton Radiation Flux					

Requirement Number		Object Heading	I	A	D	T	Responsible Org
ST-560	3.6.9.5.0-1	Transient Electron Radiation Flux					
ST-566	3.6.10.0-1	Humidity					
ST-568	3.6.11.0-1	Venting					
ST-569	3.6.11.0-2	Venting					
ST-570	3.6.11.0-3	Venting					
ST-572	3.6.12.0-1	Magnetic Dipole					
ST-574	4.0-1	Verification Requirements					
ST-582	4.1.3.0-1	Documentation Search					
ST-584	4.1.4.0-1	Exterior Cleanliness Requirements					
ST-589	4.3.0-2	Test					
ST-592	4.4.1.0-1	Failure During Tests					
ST-594	4.4.2.0-1	Modification of Hardware					
ST-608	4.5.1.0-1	Weight and Envelope Measurement					
ST-610	4.5.2.0-1	Performance Tests					
ST-612	4.5.3.0-1	EMI/EMC					
ST-615	4.5.3.0-4	EMI/EMC					
ST-617	4.5.4.0-1	Loads Tests					
ST-628	4.5.5.0-1	Random Vibration					
ST-630	4.5.5.0-3	Random Vibration					
ST-632	4.5.6.0-1	Sine Vibration					
ST-635	4.5.7.0-1	Thermal Vacuum Test					
ST-636	4.5.7.0-2	Thermal Vacuum Test					
ST-643	4.5.7.2.0-1	Temperature Transitions					
ST-645	4.5.7.3.0-1	Hot/Cold Turn-On Demonstration					
ST-663	4.5.7.5.0-1	Bake-out / Outgassing Certification Requirements					
ST-669	4.5.8.0-1	Magnetic Dipole Verification					
ST-670	4.5.8.0-2	Magnetic Dipole Verification					
ST-672	4.6.0-1	Mounting Interface and Alignment Hardware					