NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

Standard Bus
Reaction Wheel Component Specification

NCST-D-SB009 **11 May 2006**

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RECORD OF CHANGES

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1.0 General

This specification establishes the design and performance requirements for a reaction wheel. The reaction wheel will be referred to as the RW and/or component within this specification.

This document defines the environmental conditions that the reaction wheel RW will encounter during all phases of the mission storage, component and spacecraft testing, launch, and on-orbit operation. This specification gives the design and verification requirements levied on this component.

This component shall be designed to meet the performance specifications in paragraph 3.1 under the conditions of humidity, pressure, temperature, vibration, acoustic, shock, radiation and EMC as defined in paragraph 3.2. The performance specifications are to be met before, during (as appropriate) and after exposure to the specified environments. The component shall be tested at the component level as specified in this document. The adequacy of the component design to perform within specification in the defined environments shall be established through design, analysis, and test and documented in a component verification document.

2.0 Applicable Documents

MIL-STD-461C	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462 (Notice 2)	Measurement of Electromagnetic Interference Characteristics
NASA MSFC-SPEC-3029	Guidelines for Selection of Metallic Materials for Stress Corrosion Cracking Resistance
NASA Ref Publ 1124	Outgassing Data for Spacecraft Materials
EEE-INST-002 Level 2	EEE Parts Selection and Screening
NASA-STD-8739.7	Electrostatic Discharge Control
MIL-PRF-55110	Performance Specification, Printed Wiring Board, Rigid, General Specification for
IPC-6012A	Qualification and Performance Specification for Rigid Printed Boards
IPC-6011	Generic Performance Specification for Printed Boards
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
MIL-P-50884	Military Quality and Performance Specification Governing the Manufacture of Flexible and Rigid-Flex Printed Wiring Boards

IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards
ISO-14644	Cleanrooms and associated controlled environments
MIL-STD-1540D	Product Verification Requirements for, Launch, Upper Stage, and Space Vehicles
MIL-HDBK-1547A	Electronic Parts, Materials, and Processes for Space and Launch Vehicles
IPC-D-275	Standard for PCB Design and Assembly

3.0 Requirements

3.1 Performance & Configuration Requirements

3.1.1 Momentum Storage

Each RW shall be able to store at least 4 Nms of angular momentum.

3.1.2 Reaction Torque

Each RW shall be able to provide at least 10 mNm of net reaction torque near the required maximum momentum storage identified in paragraph 2.1 and accelerating.

3.1.3 Mass

Each RW shall be less than 5 kg including RW electronics, if electronics in separate box then RW should include RW drive electronics mass divided equally between flight set of wheels.

3.1.4 Size

Assumed to be roughly cylindrical with diameter less than 300 mm and height less than 150 mm.

3.1.5 Lifetime

Greater than 1 year mission life after two years of ground testing and storage.

3.1.6 Primary Power

The component shall be designed to accept unregulated input power from the Spacecraft's Electrical Power System (EPS) and provide preregulation for use within the subsystem. Switching of input power (i.e., power-on and power-off) shall be accomplished in the EPS. The equipment shall operate as specified herein when supplied with input power having the characteristics specified below, and shall not impose emissions on the power bus in excess of those specified herein.

3.1.6.1 Input Voltage

The steady state voltage at the input connector of the equipment will be 28 ±6 Vdc, excluding noise, ripple and transients.

3.1.6.2 Steady-State Power Draw
Steady-State power draw per wheel shall not exceed 12W while providing the required maximum momentum storage identified in paragraph 2.1

3.1.6.3 Peak Power Draw
Peak power draw per wheel shall not exceed 30 W while providing the required maximum momentum storage identified in paragraph 2.1 and while providing the peak reaction torque specified in paragraph 2.2.

3.1.6.4 Isolation
The equipment shall be compatible with a single-point ground for primary power with separate positive and return wires brought out to the power input connector. Primary input power and returns to the equipment shall be isolated from the case (chassis) and secondary power circuitry by a minimum dc resistance of 100 kohm. The case (chassis) or mounting structure shall not be used to conduct power currents.

3.1.6.5 Inrush Current
The inrush current to the equipment when switching from power-off to power-on in any mode shall not exceed 15 amps, and the input current shall settle to twice its nominal operating value within 20 milliseconds after the application of power.

3.1.7 Imbalance
Static imbalance shall be < 1 gm-cm. Dynamic imbalance shall be < 15 gm-cm^2. Torque ripple shall be less than 10% rms.

3.1.8 Electrical Interface
The electrical interface to the spacecraft command and data handling system shall be analog for commands to the component and telemetry from the component.

3.1.8.1 Torque Command Range
The specified torque command range shall be less than +/- 10V with minimum input impedance at the wheel of 10k Ohms.

3.1.8.2 Telemetry Range
The telemetry range is +/- 6.66V at 8 bit accuracy and will be sensed differentially. The driver in the reaction wheel must provide a linear and accurate signal to drive a minimum impedance of 100k Ohms in the interface electronics card.

3.1.8.3 Command and Telemetry Rates
Commanding and telemetry rates are limited to 10 Hz max.

3.1.8.4 Isolation
The reaction wheel must maintain a minimum isolation of 100 kohm between the primary power ground and the secondary ground.

3.1.8.5 Command and Telemetry Signals

The commanding and telemetry signals shall be referenced to the secondary (isolated) ground.

3.2 Environmental Test & Analysis Requirements

3.2.1 Thermal Design & Test Environment

The component thermal interface will be the component mounting plate or surface with heat exchange through conduction. The component shall be designed and tested to the following thermal vacuum requirements:

3.2.1.1 Operational Temperature Limits

The component will be tested from -25 ^{o}C to 55 ^{o}C at the mounting plate.

3.2.1.2 Survival Temperature Limits

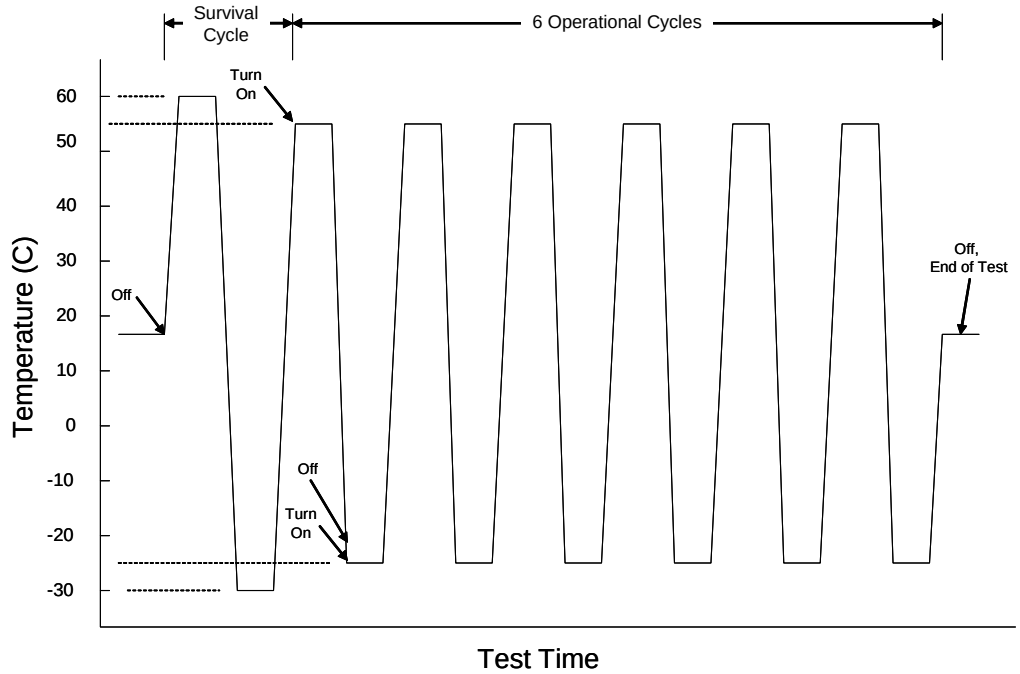
The component will be tested from -30°C to 60°C at the mounting plate.

3.2.1.3 Thermal Vacuum Cycling Test Requirements

A minimum of six operating cycles plus one survival cycle shall be performed as shown in Figure 1. Cold and hot turn on capability shall each be demonstrated. The pressure shall be less than 1 x 10^{-5} torr. The rate of change of the temperature shall be no faster than 5˚C per minute. Components shall be powered and critical parameters monitored for proper operation during the total test except for "turn-on" tests and temperature "Survivability." Performance tests shall be performed at all plateaus except for the Survival temperature plateaus. Temperature shall be measured at the component mounting feet on the baseplate. Tolerance on the temperature extremes shall be ±3°C. During pump down, it shall be demonstrated that components generate no corona, multipaction, or arcing while operating in the launch mode.

3.2.2 Pressure Decay Environment

The ambient pressure range shall be less than 1×10^{-5} torr (space vacuum) after launch and during launch it will follow the pressure decay rate of change of 0.7 psi/sec.



Plateau dwell time: Baseplate within 3 C of plateau, then 4 hour soak.

Figure 1: Spacecraft Component Thermal Vacuum Profile

3.2.3 Structural Design Requirements

3.2.3.1 Design Loads

The reaction wheel shall be designed to withstand the quasi-static limit loads given in Table 1, applied separately along 3 orthogonal axes. These levels are intended to be applied as net center-of-gravity loads for component structural design. They are not intended to envelope all possible component subassembly or piece part responses that may occur during a sine or random vibration test. Excessive internal responses due to vibration testing must be addressed by the supplier. The mass shown is assumed to be the mass of the item up to its interface with the spacecraft.

Table 1: Quasi-Static Load Limits

Component Mass	Limit Loads
< 5 kg	40 g's
5 kg to 25 kg	30 g's

3.2.3.2 Factors of Safety

The loads in Table 1 shall be multiplied by the applicable design factor-of-safety given in Table 2 to obtain the final design loads for analysis. Stress analysis results must indicate positive margins of safety (greater than zero) for all load conditions.

Margin of Safety = {Allowable Stress/ (Limit Stress * Factor of Safety)} -1

Allowable Stress may also be referred to as Allowable Load, and Limit Stress may also be referred to as Limit Load.

Table 2: Design Factors of Safety

Design	Factor of Safety
Material Yield	1.25 x limit loads
Material Ultimate	1.40 x limit loads
Composites	2.00 x limit loads
Bonded Joints	2.00 x limit loads
Buckling	2.00 x limit loads
Glass	3.00 x limit loads

3.2.3.3 Stiffness/Frequency Constraints

The component shall be designed to have its first mode structural frequency above 150 Hz in each of the (3) principal orthogonal axes.

3.2.4 Random Vibration Environment

The protoflight random vibration spectrum shall be as shown in Table 3. The component will be tested to this level individually in 3 orthogonal axes. Any request to modify the specified random vibration test through methods such as force limiting, input notching, response limiting, or use of qualification/acceptance levels and durations will be addressed on a case by case basis.

Table 3: Component Protoflight Random Vibration Test Levels, All Axes

Frequency (Hz)	PSD Level
20	0.0263 g^2/Hz
20-50	+6 dB/Oct
50-800	0.16 g^2/Hz
800-2000	-6.0 dB/Oct
2000	0.026 g^2/HZ
Overall Amplitude = 14.1 Grms Duration = 60 seconds	

3.2.5 Pyroshock Environment

The maximum shock spectrum shall be as shown in Table 4. Pyroshock testing will be performed during spacecraft system level testing so is not required at the component level. The design must be shown to be capable of withstanding this environment.

Table 4: Light Band Separation System SRS

Frequency (Hz)	SRS* Levels (g's)
100	6
10000	900

Based on Q=10

3.2.6 Sine Vibration Environment

The component shall be subjected to the sinusoidal vibration levels along each of three orthogonal axes shown in Table 5. A sine burst test may be used in place of the sine

vibration test provided the peak amplitudes listed in Table 1 are used. These levels are for the component mounting interface.

Table 5: Sine Vibration Test Levels

Frequency (HZ)	Acceleration Items <50 Kg
5-20	0.5 in. (double amplitude)
20-23	15.5 g
23-100	2.0 g

Rate = 4 octaves/min

3.2.7 EMC/EMI Environments

EMI testing is required in order to establish a reasonable level of confidence, with acceptable margin, that a component's subsequent operation after integration with other components and during operation in realistic environments, will 1) not experience degradation consequential to influences of EMI and 2) not cause interference to the operation of other components. These tests are specifically intended to determine, prior to integration with other components, the EMI characteristics of component parts of a larger system. Test data is used to 1) determine if corrective actions are required, 2) to demonstrate margins against anticipated environments, and 3) to make performance comparisons with other components. Components that have been previously qualified for EMC/EMI compliance may be granted a waiver from additional qualification testing at the approval of the contracting officer's representative (COR).

Test conditions and limits presented herein are, in part, derived from mission–specific anticipated environments as well as from performance requirements of associated components. This information has been used to supplement and to tailor the requirements of MIL-STD-461C/462, Part 3, for class A2a (spacecraft) equipment, to which the following emission and susceptibility requirements are applicable:

CE-01 Conducted Emissions; Power Leads, 30 Hz to 15 kHz
CE-03 Conducted Emissions; Power Leads, 15 kHz to 50 MHz
CE-07 Conducted Emissions; Power Leads, Spikes, Time Domain
CS-01 Conducted Susceptibility; Power Leads, 30 Hz to 50 kHz
CS-02 Conducted Susceptibility; Power Leads, 50 kHz to 400 MHz
CS-06 Conducted Susceptibility; Spikes, Power Leads
RE-01 Radiated Emissions, Magnetic Field
RE-02 Radiated Emissions; Electric Field, 14 kHz to 10 GHz
RS-03 Radiated Susceptibility; Electric Field; 14 kHz to 15 GHz

Note that 461E is the latest issue of this specification; however, it allows re-procurements of equipment previously qualified under an earlier issue to remain under that issue. Since radical changes in the content of MIL-STD-461 were implemented between the C and D versions, 461C/462 is deemed to be the most logical EMC/EMI standard for this program. EMC test data for off-the-shelf components from prior testing shall be reviewed and evaluated to determine their level of compliance.

All EMI testing shall be conducted at room ambient temperature and pressure with a primary power DC input of 28.0 volts, unless otherwise indicated. Primary power return shall be referenced through an appropriate connection (as defined in the test configuration diagrams) to the Subsystem's structure (chassis) ground (thereby simulating the Spacecraft's Primary Power Single Point Ground) which is also to be connected to test equipment safety ground.

3.2.7.1 Conducted Emission

The component shall meet the conducted emissions levels defined below:

A. CE01 & CEO3– As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored to Figure 2.
   a. Differential Mode Limits:
      Differential mode limits are 80 dBµA (10 mA rms) from 100 Hz to 24 kHz then decreasing to 20 dBµA (10 µA rms) at 2 MHz from which it continues at that level to 50 MHz.
   b. Common Mode Limits:
      Common mode limits are 60 dBµA (1.0 mA rms) from 100 Hz to 100 kHz then decreasing to 20 dBµA (10 µA rms) at 2 MHz from which it continues at that level to 50 MHz.
B. CE07 – As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored as follows:
   a. Voltage Limits:
      Time domain conducted voltage ripple shall not exceed 700 mV peak–to–peak for differential measurements. Common mode voltage shall not exceed 500 mV peak–to–peak.
   b. Current Limits:
      Time domain conducted current ripple and spikes shall not exceed 200 mA peak–to–peak for differential measurements and 50 mA peak–to–peak for common mode measurements.

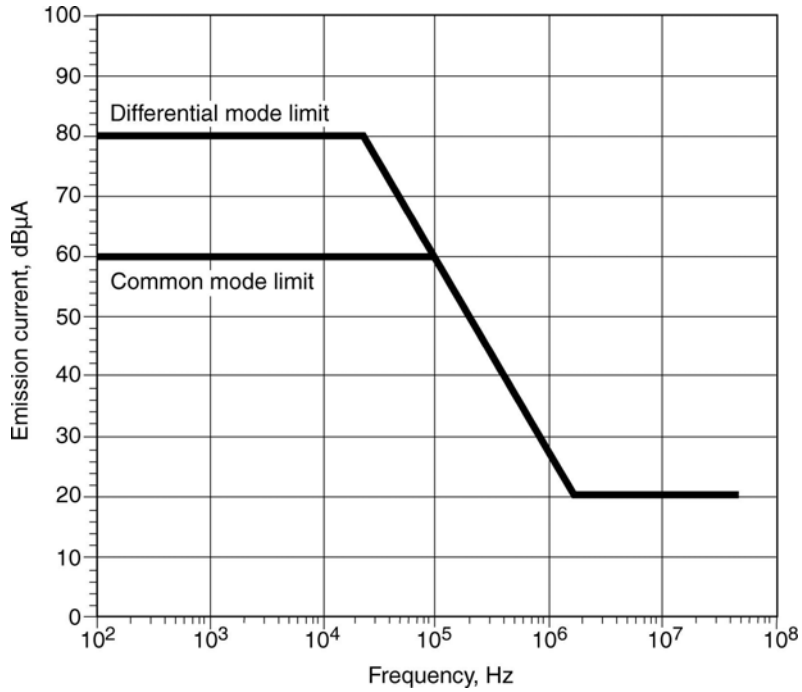


Figure 2: CE-01 & CE-03 Conducted Emissions Limits

3.2.7.2 Conducted Susceptibility

The component shall not exhibit malfunctions, degradation of performance, or deviation from specifications when subjected to the levels defined below.

A. CS01 - As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored as follows:

   AC sinusoidal ripple shall be applied to the 28 V primary power input lines to produce a differential input voltage of 1.0 V RMS. Ripple current injected into the component under test shall be limited to 5 Amps peak-to-peak.

B. CS02 - As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored as follows:

   AC sinusoidal ripple shall be applied to the 28 V primary power input lines to produce a differential input voltage of 1.0 V RMS. All test frequencies shall be pulse modulated at 1 kHz with 50% duty factor.

C. CS06 - As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored as follows:

   Peak transient voltage, relative to nominal line voltage, for MIL STD 461C spike #1(slow) and spike #2 (fast) shall be +/-20 volts differential, +/-10 volts return-to-chassis.

3.2.7.3 Radiated Emissions

The component shall not radiate emissions in excess of the levels defined below:

A. RE01 - As specified in MIL-STD-461C, Part 3, Class A2a equipment and tailored to Figure 3.

Emission limits are 120 dBpT (1000 gamma) starting at 100 Hz then decreasing to 20 dBpT (10 milligamma) at 32 kHz from which it continues at the same level to 49 kHz.

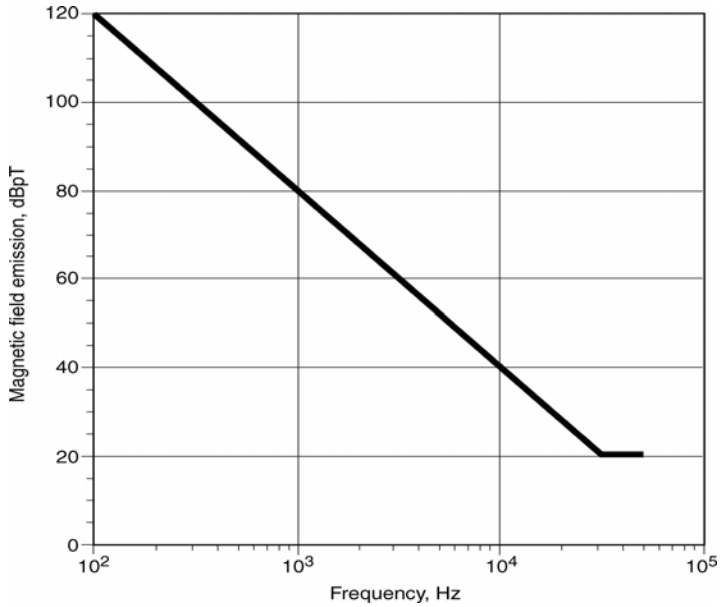


Figure 3: RE-01 Magnetic Field Emissions Limits

B. RE02 - As specified in MIL-STD-461C, Part 3, Class A2a equipment as tailored in Figure 4.
   a. General Emission Limits
      Narrowband emission limits are 45 dBµV/m from 14 kHz decreasing to 30 dBµV/m at 25 MHz then increasing to 70 dBµV/m at 10 GHz.
   b. Spacecraft Transponder Receive Band
      In the band 1800 +/-60 MHz, the limit is 25 dBµV/m (10 kHz resolution bandwidth and 5 dB noise figure).
   c. Spacecraft GPS Receive Bands
      In the bands 1227 +/-15 MHz and 1575 +/-15 MHz, the limit is 30 dBµV/m (10 kHz resolution bandwidth and 5 dB noise figure).
   d. RF Payload Receiver Bands
      In the UHF band 280 – 420 MHz, the limit is -4.8 dBµV/m. In the X band 7900 – 8400 MHz, the limit is 17.2 dBµV/m.

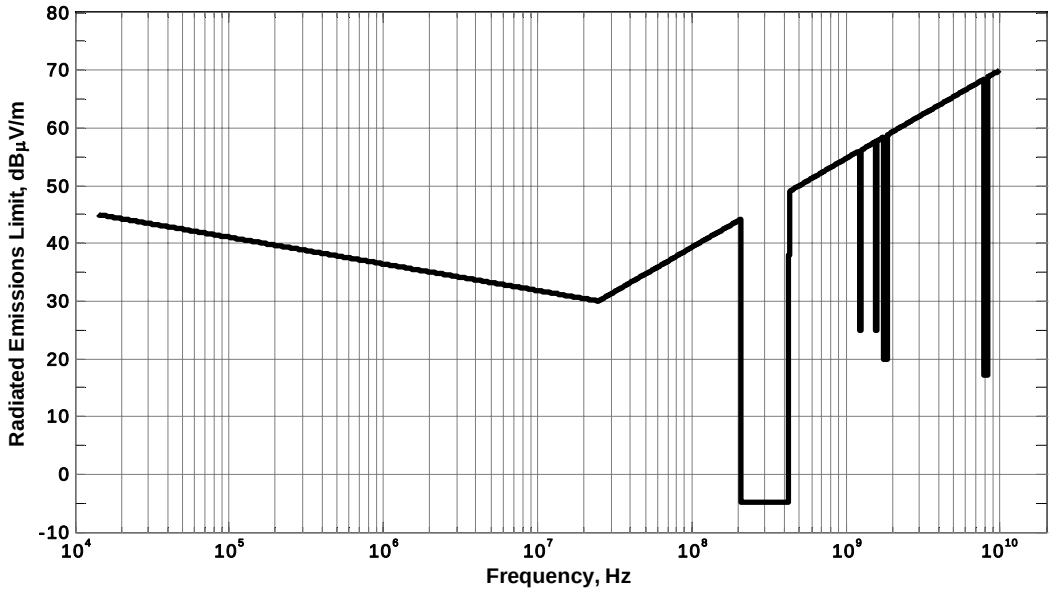


Figure 4: RE-02 Electric Field Emissions Limits

3.2.7.4 Radiated Susceptibility

The component shall not exhibit malfunctions, degradation of performance, or deviation from specifications when subjected to the levels defined below and in Figure 5:

a.) RS03 – As specified in MIL-STD-461C, Part 3, Class A2a equipment with the following limits:

Frequency Range	E-Field (Volts/Meter)
14 KHz to 1.0 GHz	20
1.0 GHz to 15 GHz	20
2.0 to 3.10 GHz, 5.50 to 5.90 GHz, & 9.1 to 9.4 GHz	40

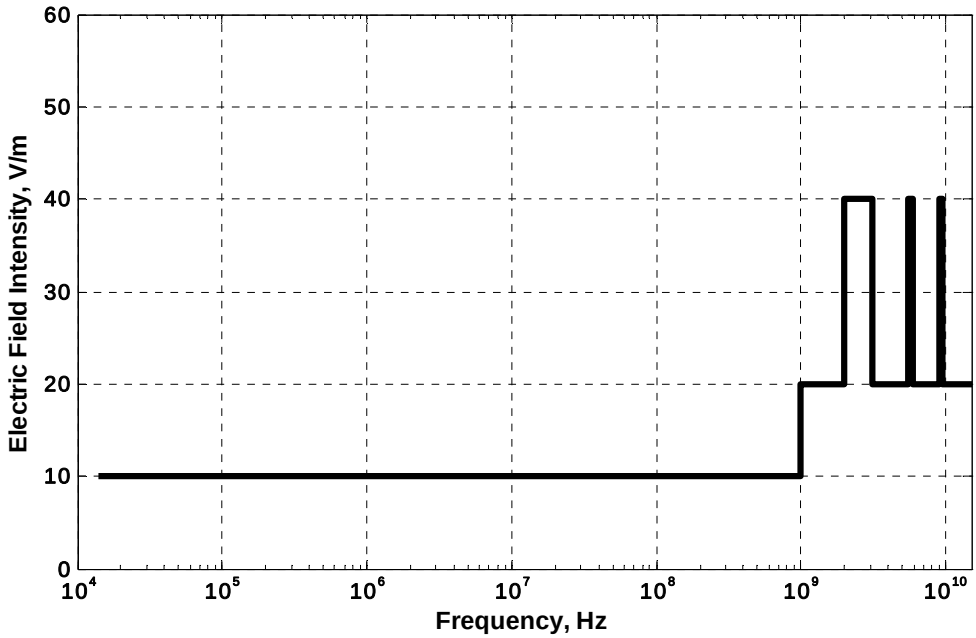


Figure 5: RS-03 Radiated Susceptibility Levels

3.2.8 Radiation Environments

The radiation environment is indicative of the environment experienced by the spacecraft over the entire orbit.

3.2.8.1 Total Dose

All parts in the component shall be selected to survive a total accumulated does for the mission of 30 krads (Si) at the part level assuming 200 mils of aluminum shielding exists in the design. It can be assumed that 50 mils of this shielding is provided by the average spacecraft structure. Figure 6 provides the total ionizing dose as a function of aluminum shielding for other shielding thicknesses. Parts that fall between 20 and 30 krads (Si) may be considered for waiver. Parts that require additional component spot shielding to meet the total ionizing dose in Figure 6 shall be identified along with requirement for additional shielding.

3.2.8.2 Single Event Effects

No destructive single event effects will be tolerated at the part level for LET thresholds = 60 MeV/(mg/cm^2). Figure 7 provides the cosmic ray environment for the worst case 5 minute period. Parts that display a threshold for destructive single event effects between LET values of 30 and 60 MeV/(mg/cm^2) may be considered for waiver provided it can be shown that such parts do not degrade the overall system reliability. Parts that are potential susceptible to non-destructive single event effects shall be identified and their upset rates evaluated for suitability based on whether they will degrade the overall system operations.

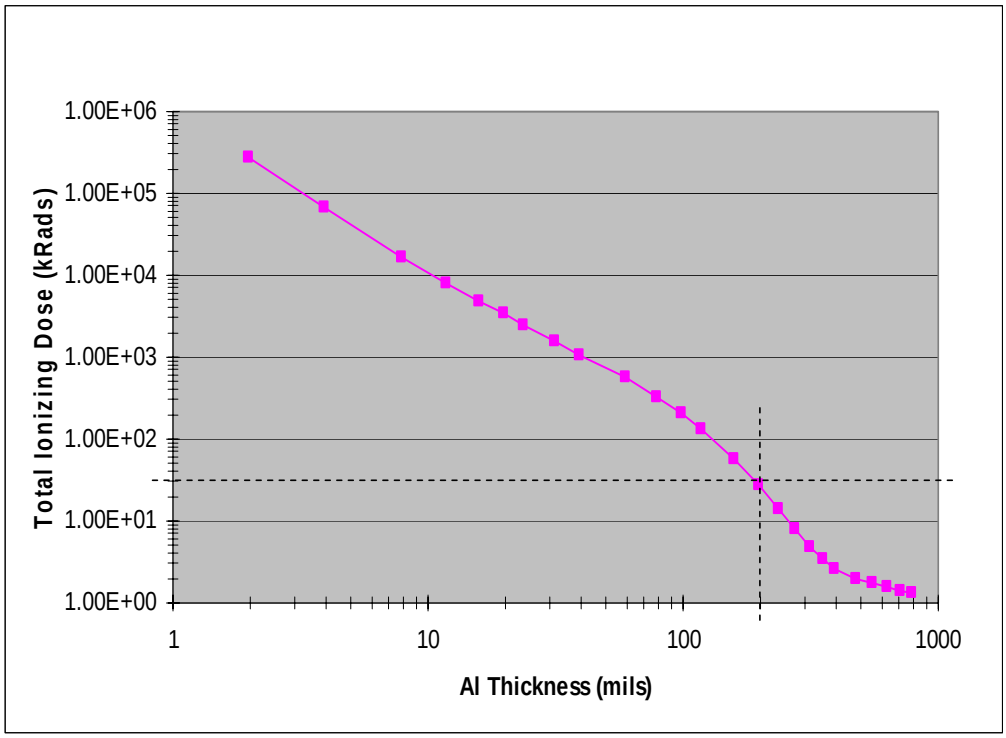


Figure 6: Total Ionizing Dose

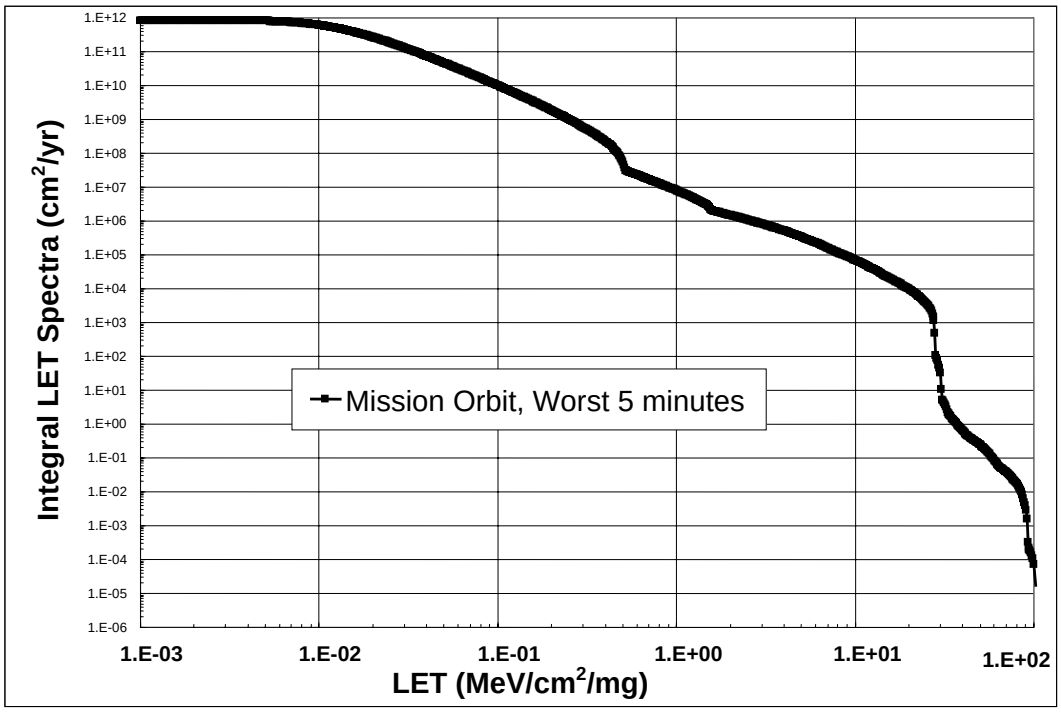


Figure 7: Cosmic Ray Environment

4.0 Quality Assurance (QA) Provisions

4.1 General

This section describes the analyses, tests, and inspections required for the reaction wheel verification process. Verification of the reaction wheel's design, construction, and performance shall ensure that the hardware and software conform to the requirements stated herein. The preferred method shall be test, where practical, to obtain empirical data to support verification. The supplier shall implement a Quality Assurance program to verify compliance with specified requirements. The analyses, tests, and inspections specified in this specification shall be conducted to verify that all requirements specified in this specification have been achieved. Test requirements shall be as stated herein and defined by MIL-STD-1540D or its equivalent.

4.2 Parts and Materials

Parts, Materials, and Processes implemented in this procurement shall meet the general guidelines specified within MIL-HDBK-1547A (or equivalent). All PMP shall be approved by the COR.

4.2.1 Parts List

The Supplier shall provide a parts and materials list for the item. This list shall identify all magnetic materials, nonconforming materials, outgassing materials, and limited life materials/components.

4.2.2 Control and Use of Nonconforming Material

Nonconforming material shall not be used without approval from the COR.

4.2.3 Magnetic Materials

Magnetic materials shall be used only if necessary for equipment operation. The materials used should minimize permanently induced and transient magnetic fields. Magnetic materials shall be identified to the COR. Major magnetic components shall be evaluated for stray fields and need for shielding.

4.2.4 Metallic Materials

Metallic materials shall be corrosion resistant by nature or shall be corrosion inhibited by means of protective coatings. Base metals intended for intermetallic contact that form galvanic couples shall be plated with those metals that reduce the potential difference or shall be suitably insulated by a nonconducting finish. Electrical bonding methods shall include provisions for corrosion protection of mating surfaces. Use of dissimilar metals shall be avoided. Metallic materials shall be used in accordance with MSFC-SPEC-3029, Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance.

4.2.5 Positive Locking Devices

Screw-type hardware on the space segment shall employ positive locking fasteners. Staking is allowable. As a goal, lockwashers will not be used.

4.2.6 Finishes

Protective methods and materials for cleaning, surface treatment, and applications of finishes and protective coatings shall be implemented. Neither cadmium nor zinc coatings shall be used. Unfused electroplated tin shall not be used. No unprotected silver plating shall be used. No unprotected copper shall be used. The exterior of the module except for thermal interface shall be painted with Aero Glaze Z306 black paint using the appropriate primer.

4.2.7 Outgassing

Materials shall meet the outgassing criteria of 1.0% total mass loss (TML) and 0.1% condensable volatiles (CVCM) (refer to NASA Reference Publication 1124) after being subjected to 125°C for 24 hours at 10-5 torr or less. For hermetically sealed components, materials installed inside, used to clean inside or service the inside of the component do not need to meet the outgassing requirements. These materials shall be identified in the parts and materials list.

4.2.8 EEE Parts

All EEE parts to be used on flight components shall be selected, screened, and controlled per EEE-INST-002 Level 2. Provide a record of additional parts screening beyond original procurement.

4.2.9 Non EEE Parts

Non EEE parts shall be approved for use by the COR.

4.2.10 Part Stress Derating

The application of all EEE parts in the design shall be derated such that the applied stresses do not exceed the derating criteria established for this program.

4.2.11 GIDEP Alerts

The Supplier will review all published Government-Industry Data Exchange Program (GIDEP) alerts to assess their applicability and impact on their hardware. Should a GIDEP alert involve a part used in this procurement, the COR shall be notified.

4.2.12 Electrostatic Discharge Sensitive Parts

All electrical components utilizing electrostatic discharge sensitive parts shall provide adequate protection to preclude part failure resulting from handling, shipment, or storage situation, according to latest version of NASA-STD-8739.7 (or equivalent).

4.3 Processes and Controls

The manufacturing processes and controls shall provide a supplier-controlled baseline that ensures subsequent production items can be manufactured that are identical to, or better in performance, quality, and reliability than, initial production items used for qualification or flight demonstrations. For space equipment, these process controls shall be documented to give visibility to the procedures and specifications by which all processes, operations, inspections, and tests are to be accomplished by the supplier. This internal supplier documentation shall include the name of each component or part, each material required, the point it enters the manufacturing flow, and the controlling specification or drawing. The

documentation shall indicate required tooling, facilities and test equipment, the manufacturing check points, the quality assurance verification points, and the verification procedures corresponding to each applicable process or material listed. The specifications, procedures, drawings, and supporting documentation shall reflect the specific revisions in effect at the time the item(s) used for qualification were produced. When approved by the COR, these flowcharts and referenced specifications, procedures, drawings, and supporting documentation shall become the manufacturing process control baseline and shall be retained by the supplier for reference. Any changes to the baseline processes used, or the baseline documents used, when approved by the COR, shall be recorded by the supplier following the production of the first item. The supplier shall provide calibration control with traceability to NIST standards for all measuring and test equipment used during manufacturing and testing of the component.

4.3.1 Soldering and Other Processes

Soldering and other processes shall be specified in Supplier-approved process specifications. Other special processes (e.g., adhesive bonding, plating, etc.) shall be according to the Supplier's approved process specifications. Printed Circuit Boards (PCBs) used in the fabrication of the equipment shall conform to the applicable requirements (or equivalent requirements)

- Rigid Printed Wiring Boards (PWBs) shall meet the requirements of MIL-PRF-55110.
- Design requirements governing printed wiring boards and printed wiring board assemblies shall be in accordance with IPC-D-275.
- In cases where IPC-6012A is used in place of the MIL STDs, PWB design shall meet Class 3 requirements per IPC-6011.
- PWB design requirements shall be in accordance with IPC-2221 and IPC-2222.
- Flex and rigid flex PWBs shall meet the requirements of MIL-P-50884.
- In cases where IPC-6013 is used in place of the MIL STDs, PWB design shall meet Class 3 requirements per IPC-6011.
- In both cases, design requirements governing printed wiring boards and printed wiring board assemblies shall be in accordance with IPC-2221 and IPC-2223.
- All rigid, flex and rigid flex PWB design, PWB test coupon design as well as PWB coupon analysis results are subject to audit by the customer.
- A spare PWB coupon that represents the flight PWB lot shall be supplied to the customer. In cases where the coupon is not available, a spare board that comes from the same lot as flight boards shall be furnished in lieu of the coupon.

4.4 Cleanliness

Fabrication and assembly of electrical, electromechanical and precision mechanical flight hardware shall be conducted in an environment appropriate to space hardware per ISO-14644 Clean rooms and Associated Controlled Environments Class-8 (Class 100,000 Clean Room Environment).

4.5 Configuration Management

4.5.1 Configuration Control

The vendor shall maintain configuration control covering all phases of procurement, specification, design, change, fabrication, test and delivery of contract hardware. A

configured article list giving asbuilt configuration and design configuration of deliverable component to major module level shall be provided for the Delivery Readiness Review.

4.5.2 Serialization of Assemblies and Subassemblies
Each contract item shall be assigned a serial number prior to start of fabrication. The serial numbers shall be permanently and legibly affixed on the external housing of the item and shall appear on all documentation relating to that particular component including travel tags, MRB's, test data, change notices, effectivity, etc.

4.5.3 Marking and Identification
Marking and identification by part number and serial number where appropriate, shall be accomplished by the vendor to identify fabricated parts, components, assemblies and deliverable components.

4.5.4 Traceability and Inspections
A system for categorizing electronic parts into sets of homogeneous groups and tracing those parts through the fabrication, assembly, test, and delivery cycles shall be maintained.

a. The item's parts and materials shall be traceable from the initial source of material through the completed hardware.
b. Parts shall be traced by part number, serial number (when available), and lot number (when available).

Fabrication records (i.e., travelers), capable of providing two-way traceability from the first stages of assembly through final acceptance testing, shall be maintained. Specific entries shall be made, recording this information as parts are installed.

The Supplier shall provide traceability records as shown in Table 6: Traceability and Lot ControlTable 6. All electronics piece parts installed shall be identified and documented in order to be traceable to a specific manufacturer, lot number, and/or date code. A record shall be prepared for each flight component that provides the following information for each EEE part that is installed:

a. Part Number and Location;
b. Manufacturer;
c. Lot Number and/or Date Code; and
d. Serial Number (when necessary).

The records shall include the traceability of critical materials (including sampling test records), processes, pre-acceptance testing records, and sources of supply to the greatest extent practical. The records shall be identifiable to the item's serial number. All discrepancies, material reviews, malfunction reports, and incorporation of engineering changes shall be included with inspection information.

Table 6: Traceability and Lot Control

Part	Relevant Information
Electronic Piece Parts	Manufacturer/Date/Lot Code
Printed Circuit Boards	Serial Number
Potting/Adhesives/Coatings	Batch Number
Plating of Electronic Housings	Production/Manufacturer Lot Number
Modules and Assemblies	Serial Number
Connectors	Manufacturer Lot Number and Date Code
Chassis Case/Structures	Lot/Heat Treat Number

4.6 Failure Reporting and Corrective Action System

A closed loop failure reporting and corrective action system (FRACAS) for reporting, analysis, and corrective action shall be in effect for failures occurring during the acceptance testing phases. The FRACAS shall determine whether failures are caused by design deficiencies, human error, defective parts, infant mortality, test equipment, environmental exposure, or software.

4.7 Surveys, Audits and Inspections

The COR reserves the right to perform QA surveys, audits and/or workmanship inspections to verify conformance to requirements, failure resolution, and corrective actions.
A set of high resolution digital pictures of each of the sub-assembly/boards and the end item hardware shall be included in the deliverable end item package.

4.8 Software Quality Assurance

For deliverable software, the supplier shall have in place a system of software assurance controls and reviews with written procedures and guidelines.

4.9 End Item Documentation Records

Records that provide evidence of inspections, performance tests, configuration and material review actions during the fabrication and assembly process shall be maintained; these records shall be become a part of the Acceptance Data Package. The documentation listed below shall be used to provide a complete record of the component including traceability, configuration control and component history:

- Digital photos showing all visible sides and associated identification and serial numbers for all boards, sub-assemblies and components shall be reviewed prior to acceptance test and delivered at buy-off.
- Inspection records shall be available for review prior to acceptance test and at buy-off.
- Acceptance Test Report shall be delivered at buy-off.
- Operation Manual shall be delivered at buy-off (if applicable).
- Component Drawing Tree Listing shall be delivered at buy-off (if applicable).
- Component Test Log shall be available for review at buy-off (if applicable)
- Final Parts and Materials lists shall be delivered prior to acceptance test.
- Final EEE parts screening and qualification data shall be available for review prior to

acceptance test.

- Reliability prediction and failure mode(s) identification shall be delivered prior to acceptance test (if applicable).
- PWB Test Reports shall be available for review prior to fabrication (if applicable).
- Safety Analysis shall be delivered prior to acceptance test (if applicable).
- Final Limited-Life Item List shall be delivered prior to acceptance test.
- Waiver, Deviation and Problem Failure Report shall be delivered at buy-off.
- Design Review Action Items Closure shall be available for review prior to acceptance test and at buy-off (if applicable).

4.10 Packaging and Shipping

Packaging procedures shall provide for protection from damage or deterioration of the articles being shipped. These procedures shall take into consideration any problems unique to the purchased equipment. Shock-watches and/or temperature monitors may be required depending on the sensitivity of the hardware being delivered. This will be determined before Pre-Delivery Inspection by the supplier lead engineer and the COR.

5.0 Deliverables

5.1 Monthly Status Reports

The supplier shall provide monthly email status reports indicating status of design, analysis, parts procurement, test, and delivery (A001 DD Form 1423). The status report should include any management or technical issues and an updated schedule of activities.

5.2 Interface Control Document

The supplier shall provide an interface control document (ICD) within one month after receipt of order (A002 DD Form 1423). Update the ICD as required if changes are made to any mechanical and electrical interface. The ICD shall identify all mechanical, electrical, and software interfaces as well has provide mass, mass properties, component center of gravity, thermal properties, performance, and power consumption.

5.3 Qualification Technical Report

The supplier shall provide within twelve months after receipt of order (with goal of nine months) a Qualification Technical Report showing qualification of design via analysis, similarity, test, or combination of methods for the environments identified in the requirements paragraphs in 3.2. If testing is required then a fourth component shall be added & used as a qualification component (A003 DD Form 1423).

5.4 Acceptance Test Plan

The supplier shall provide an Acceptance Test Plan one month prior to testing (A004 DD Form 1423). The plan can follow vendor standard format.

5.5 Acceptance Data Package

The supplier shall provide an acceptance data package including test reports within twelve months after receipt of order (with goal of nine months) (A005 DD Form 1423). Test reports shall show functional and performance verification of the performance (paragraph 3.1) and environmental (paragraph 3.2) requirements identified in this specification.

5.6 Component Buy-Off

The supplier shall hold a buy-off review at vendor facility prior to shipment of hardware. The acceptance data package will be available for review and should include test reports, build paperwork, configuration control, component traceability, parts list, and material list. In addition a compliance/verification matrix to the reaction wheel specification should be available for review.