Global Precipitation Measurement (GPM) Project

Inertial Reference Unit Performance Specification

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

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CHANGE RECORD PAGE

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List of TBXS

Item No.	Location	TBX Summary	TBX Assignee	TBX Due Date
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	3.7.2.0-5			
	4.6.0-2.0-1			

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1 SCOPE

This specification describes the electrical, mechanical, operating environment, and verification testing requirements for space-qualified, 3-axis, single-string Inertial Reference Units/ Systems for a Goddard Space Flight Center (GSFC) payload, the Global Precipitation Measurement Satellite (GPM).

2 DOCUMENTATION AND DEFINITIONS

2.1 APPLICABLE DOCUMENTS

The following documents and drawings shall apply to the fabrication and to the electrical, mechanical, and environmental requirements of the Inertial Reference Unit (IRU) 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 (SOW), GPM-GN&C-SOW-0008, in which case the SOW takes precedence.

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

DOCUMENT NUMBER	TITLE	Revision/Date
GPM-GN&C-SOW-0008	Inertial Reference Unit Statement of Work	Revision -
MIL-STD-462	Measurement of Electromagnetic Interference Characteristics	Revision D
NASA-HDBK-4002	Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging	2/17/99
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
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and De-rating	

3 REQUIREMENTS

All of the written requirements in this document must apply at the end of spacecraft (SC) life (EOL), as defined in Section 3.8.

3.1 DESCRIPTION

IRU-47 The IRU systems shall provide three axis, single string, rate information based on the use of flight qualified, high-grade inertial sensors. The IRU's are intended for use as high accuracy, fine resolution attitude references.

3.2 IRU-SPECIFIC FUNCTIONAL/PERFORMANCE REQUIREMENTS

IRU-49 The specifications given herein shall apply when the IRU's are operated in accordance with the mechanical, electrical, thermal, and environmental requirements of this specification.

3.2.1 Input Rates

IRU-51 The IRU's shall perform as specified herein when powered and subjected to the following angular input rates:

IRU-52 a. Survival Rates: The IRU shall survive, and meet all of this specification's requirements, after exposure to angular rates up to, and including, 70 rpm. (420 deg/sec).

IRU-53 b. Performance Rates: After the removal of the input rates specified in a., above, and within rates of 18 deg/sec, the IRU shall meet all the requirements of this specification within 5 minutes.

IRU-54 c. Polarity: The IRU shall output the proper polarity for rates to at least 60 rpm.

Dual rate range solutions are acceptable.

3.2.2 Cross-Axis Coupling

IRU-57 The cross-axis coupling for input rates (3.2.1.b) shall be less than 0.03% including gyro intra-axis misalignment. The bandwidth for this requirement may be limited to 1 Hz. Over the total bandwidth, specified in paragraph 3.2.3.2, Bandwidth, of this specification, the cross-axis coupling shall not exceed 0.06%. The cross axis coupling shall be stable within 0.005% of the input rate during continuous operation up to 30 days.

3.2.3 IRU Performance

The following requirements apply to the outputs over the performance range specified in 3.2.1, Input Rates.

3.2.3.1 Scale Factor

IRU-61 a. Resolution: The IRU data shall have a resolution no larger then than 1.0 arc-sec/pulse, maximum. The actual scale factor shall be within 1% of the nominal scale factor. The scale factor shall be measured prior to delivery to an accuracy of 0.1%.

IRU-62 b. Linearity: The scale factor linearity shall be within 300 ppm. Linearity shall be defined as the worst-case deviation from the positive rate or negative rate averages.

IRU-63 c. Asymmetry: The scale factor asymmetry shall be within 150 ppm. Asymmetry shall be defined as the difference between the positive rate and negative rate averages determined from the Scale Factor Linearity measurements.

IRU-64 d. Stability: The scale factors of the outputs shall be stable within 1.0% per month of the nominal scale factor specified in 3.2.3.1, Scale Factor. These stability requirements are based on continuous operation, and shall apply over the total ranges specified in 3.2.1, Input Rates.

3.2.3.2 Bandwidth

IRU-66 Signal bandwidth in all modes shall be greater than or equal to 7.0 Hz to the -3 dB point. Response shall approximate a second order system with a damping ratio of between 0.5 and 1.0.

3.2.3.3 Acceleration Insensitive Drift Rate (AIDR)

IRU-68 The incremental AIDR shall meet the following requirements:

IRU-69 a. Absolute Value: The absolute value of the AIDR shall not exceed 5.0 arc-sec/sec using a 10 minute sampling period.

IRU-70 b. Stability: The AIDR shall be stable within 1.27 arc-sec/sec for 6 hours of continuous operation.

IRU-71 c. Environment: The AIDR shall be stable within 2.0 arc-sec/sec through each environment. This change shall be determined from a comparison of the pre and post environmental test data including data taken at hot, cold, and nominal temperatures.

3.2.3.4 Noise Equivalent Angle

IRU-73 The noise equivalent angle of the incremental angle outputs shall not exceed 92.2 arc-sec.

The noise equivalent angle is defined as the peak-to-peak difference between the following two functions over a 1 hour interval, for input rates of both 0 and 200 arc-sec/sec:

a. Function 1: The IRU angular measurement over a 1 hour duration with a sample interval of 250 msec: +/- 5%.

b. Function 2: The best linear fit (angle vs time) of Function 1, in a least squares manner.

3.3 PHYSICAL CHARACTERISTICS

3.3.1 Mass

IRU-83 Total as delivered IRU mass shall be less than or equal to 4.54 kg.

3.3.2 Center of Mass

IRU-85 The contractor shall define the center of mass. The center of mass shall be determined to within ±6.5 mm relative to an external reference.

3.3.3 Envelope

IRU-87 The IRU system shall occupy a space of less than:

height: 18 cm (7.09 in)

width: 25cm (9.84 in)

length: 25cm (9.84 in)

For the purposes of clarifying this requirement, the length and width dimensions define the mounting surface and the height and length dimensions define the connector face. See figure below:

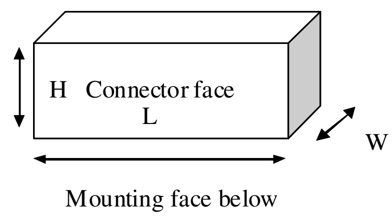


Figure 3-1 Envelope Dimension Definitions

3.3.4 Demise

IRU-95 In order to limit debris re-entry survival, the IRU 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

3.3.5.1 Stowed Frequency Requirements

IRU-98 The GPM IRUs in their stowed configuration shall have a frequency greater than 50 Hz when hard mounted at their spacecraft interface.

3.3.5.2 Deployed Frequency Requirements

IRU-100 The GPM IRUs shall have a deployed frequency greater than 3 Hz in their deployed configuration when hard mounted at their spacecraft interface.

3.3.6 Mounting and Flatness

The package will be hard-mounted on a mechanical surface of the spacecraft structure.

IRU-103 The IRU shall have an interface flatness of 0.05 mm per 100 (0.006 inch per 12 inches) or better.

IRU-104 Proper fit/alignment of the IRU 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 vendor shall provide a drill template with alignment cube, as required, to meet any alignment requirements as defined in Section 3.3.9. The mounting interface shall be defined in the Interface Control Document.

3.3.7 External Adjustment

IRU-106 The IRU shall be designed so that no external adjustments are required after start of acceptance or qualification testing.

3.3.8 Finish

IRU-108 All parts should be passivated and mounting surfaces on IRUs shall be conductive as defined in paragraph 3.4.6 (surface conductivity.) Aluminum parts shall be finished with iridite per MIL-C-5541, Class 3. Titanium surfaces shall be finished per AMS 2488. Non-mounting surfaces shall be coated with a high emissivity coating (>0.7) such as black anodize per MIL-A-8625F Type II, Class 2.

3.3.9 Identification and Marking

IRU-110 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

IRU-112 A permanent optical reference cube that permits alignment on the spacecraft to the mechanical coordinate frame shall be provided on the IRU. Knowledge of the sensor axes alignment to the optical or mechanical reference shall be to 10 arc seconds or better in each axis.

IRU-113 Throughout environments, the sensor axes shall not shift with respect to the optical or mechanical reference by more than 30 arcsec in each axis. Additionally, the IRU mounting system shall maintain the mechanical frame within 30 arc-seconds (in each axis) of its original placement with respect to the mounting surface, over environments.

IRU-114 Two adjacent surfaces of the optical reference shall be available for alignment measurements without affecting the basic integrity of the IRU. Optical reference surfaces shall be at least 0.5 x 0.5 inches and shall be capable of producing an autocollimation indication.

IRU-115 ABSOLUTE ALIGNMENT: The electrical axes shall be aligned to the mechanical axes within 10 arcminutes.

3.4 ELECTRICAL REQUIREMENTS

3.4.1 Power

3.4.1.1 IRU Power Input Voltage

IRU-119 Each IRU shall meet all performance requirements with prime power input between 21 and 35 VDC at its primary power input. The nominal power input is 28 VDC.

3.4.1.2 IRU Power Consumption

IRU-121 Each IRU power consumption shall not exceed 32 W.

3.4.1.3 Maximum Sustained Input Current

IRU-123 Each IRU's peak input current during operation shall not exceed 1.9 A. The peak current draw requirement can be met through the use of a phased power-up scheme.

3.4.1.4 Power System Electronics Output Switching Profile

IRU-125 Each IRU shall survive without degradation the following power switching profiles:

IRU-126 When a service is switched on, the voltage will rise from 0 to the steady-state voltage no faster than 50 microseconds (µs) to reduce the in-rush at the user circuitry.

IRU-127 When a service is switched on, the voltage will rise from 0 to the steady-state voltage no slower than 3 milliseconds (ms) to allow for proper operation of power-on reset circuitry.

IRU-128 When a service is switched off or trips off due to a fault condition, the voltage will fall to 0 V no faster than 20 µs, prohibiting a sharp turn-off from producing an induced EMI emission.

3.4.1.5 Turn-on Transients (In-Rush Current)

IRU-130 Turn on transient current drawn by the IRUs shall be within the following limits as listed and as shown in Figure 3.4.1.5:

The SC PSE utilizes SSPC devices to control the power. Unlike the electromechanical switches, the solid-state power switch devices control the turn-on time by limiting the input voltage rise time. The typical turn-on time of a solid-state power switch device is between 50 and 200 µs. The input voltage rises linearly with respect to the turn-on time. This delay may eliminate the need for the IRU to employ an active means for reducing in-rush current at its power input. The contractor should plan, analyze and test to verify that a current limiter is not required.

IRU-132 The GPM IRU transient in-rush current shall be within the following limits as listed below and as provided in the figure below for 2 Amp Services.

IRU-133 If the inrush current is measured with an electromechanical device as the input power switching device, the inrush current of the IRU not to exceed a rate of change of 1 amp per microsecond (A/µs) in the first 10 µs.

IRU-134 If the inrush current is measured with an electromechanical device as the input power switching device, the inrush current of the IRU shall not have a maximum rate of change of greater than or equal to 20 mA/µs after the initial 10 µs surge.

IRU-135 If the inrush current is measured with an electromechanical device as the input power switching device, the IRU transient current shall never exceed 300% of the maximum steady-state current in the first 10 ms.

IRU-136 If the inrush current is measured with an SSPC as the input power switching device, the inrush current of the IRU shall not exceed a rate of change of 200 milliamp per microsecond (mA/µs) until the voltage reaches the nominal level.

IRU-137 If the inrush current is measured with an SSPC as the input power switching device, the inrush current of the IRU shall not exceed a rate of change of 20 mA/µs after the voltage reaches the nominal level.

IRU-138 If the inrush current is measured with an SSPC as the input power switching device, the transient current shall never exceed 300% of the rated output current of the SSPC in the first 70 ms.

IRU-139 In-rush current shall be reduced to nominal load at 100 ms after turn-on.

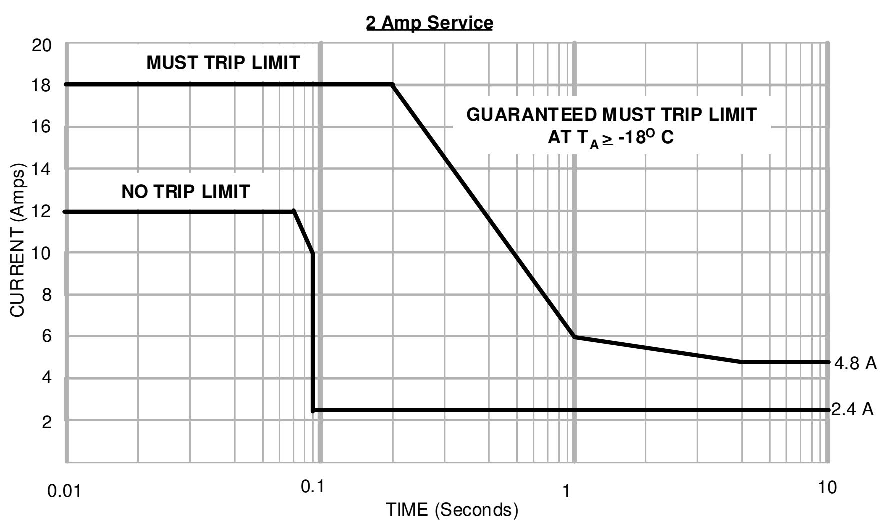


Figure 3-2 SSPC In-rush and Trip Current Limits Curve for 2 A service

3.4.1.6 Survival of Anomalous Voltage

IRU-143 The IRU 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.

No flight IRU will be subjected to these tests.

IRU-145 Verification shall be by analysis or test on an engineering test unit (ETU) or at a board level only.

IRU-146 If the IRU includes parts that are not guaranteed to perform down to 0 VDC, anomalous voltage analysis or test low limit shall be:

a. lowest voltage guaranteed by manufacturer of that IRU or

b. low voltage that corresponds to the maximum sustainable current for that subsystem's switched service, whichever is lower

IRU-149 The IRUs shall meet performance requirements during the single-event transient (SET) of +/- 3.0 V superimposed on the power bus described in 3.4.1.9 below.

3.4.1.7 Ripple

IRU-151 The IRUs shall meet operational performance requirements in the presence of ripple as described in Conducted Susceptibility (CS) 01/CS02 testing in Section 3.4.3.4.1.

3.4.1.8 Operational Bus Transients

IRU-153 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.

3.4.1.9 Single-Event Power Bus Transients

IRU-156 Single event transients superimposed on the power bus due to normal subsystem load switching shall be limited to +/- 5 V for a period up to 50 ms.

3.4.1.10 Turn-Off Transients

IRU-158 When the power service is switched off, the peak voltage transients induced on the power service shall not exceed +40V, nor fall below -2V.

3.4.1.11 Turn-Off Protection

IRU-160 The IRU shall not be damaged by the unannounced removal of power.

IRU-161 Any operations required on a routine basis prior to power turn off shall be listed in the IRU ICD.

IRU-162 Any minimum time following power turn-off that the IRU must remain off prior to power turn-on shall be listed in the ICD.

3.4.1.12 Polarity Reversal Protection

IRU-164 All Components shall prevent damage due to polarity reversal of input power prior to final component integration on the observatory. This requirement may be satisfied with diode-protected connector savers.

IRU-165 No flight component shall be subjected to this test.

3.4.1.13 Subsystem Over-Current Protection

IRU-167 The IRU shall not use non-resetting over-current protection (i.e., fuses) internal to the IRU.

3.4.1.14 IRU Power Redundancy

IRU-169 The IRU shall provide redundant prime power and prime power return lines. The spacecraft will provide power over both sets of lines simultaneously. Independent power sources shall be diode isolated.

3.4.1.15 Redundant Power Supplies

IRU-171 The IRU shall not be damaged by the simultaneous application of power to both power supply inputs.

3.4.1.16 IRU Brownout protection

IRU-173 The IRU design shall provide brownout protection for the secondary power in the IRU. This protection should disable the output of the 1553 bus when the voltage to the digital logic drops below recommended operational levels.

3.4.2 <u>Grounding</u>

3.4.2.1 Primary Input Isolation

IRU-176 At the IRU primary power interfaces, primary power (28 VDC) and primary power returns shall be isolated from the IRU chassis by greater than or equal to 1 Megohms (Mohms) direct current (DC).

3.4.2.2 Secondary Ground

IRU-178 The secondary return (power, signal, analog, or digital grounds) shall be locally connected to the IRU chassis with low impedance paths (<= 2.5 milliohms DC per joint) to minimize stray current.

IRU-179 Both secondary power (or signal) inputs and returns shall be isolated from primary power by equal to or greater than 1 Mohms DC.

3.4.2.3 Reserved

3.4.2.4 Bonding or Mating

IRU-182 The primary mating method for a IRU shall be the metal-to-metal contact between IRU mounting feet (or baseplate) and the GPM structure. Mating (electrically bonding) surfaces should be free from nonconductive finishes and should establish at least 80 square millimeters of contact area.

IRU-183 The electrical DC resistance of a mechanical joint between two conductive mating surfaces shall not exceed 2.5 milliohm.

3.4.2.5 Grounding of Conductors

IRU-185 All conductors shall be grounded to the SC structure, with no floating conductors.

3.4.2.6 Grounding of External Surfaces

IRU-187 All external surfaces shall be grounded. Where this is not possible, it will be identified in the individual IRU Electrical ICD.

3.4.2.7 Connector Grounding

IRU-189 IRU connectors and backshells shall be electrically mated to the chassis through an electrical resistance not exceeding 5 milliohms DC.

3.4.3 Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC)

3.4.3.1 Test Methods

IRU-192 The EMI/EMC test methods shall be per the requirements of MIL-STD-462 (Notice 1) unless noted in this document.

3.4.3.2 Conducted Emissions (CE01/CE03)

3.4.3.2.1 CE01/CE03

IRU-195 Conducted emissions (CE) from the IRU shall not exceed the values shown in the figure below when subjected to CE01 (30 Hz - 20 kHz) and CE03 (20 kHz - 50 MHz) narrowband testing.

IRU-196 All tests shall be performed in ambient with the IRU in its most sensitive mode for susceptibility testing and in its most noisy mode as appropriate for the EMI emission test.

IRU-197 CE01/CE03 shall be performed on all +28V primary power and return lines to each IRU.

IRU-198 CE01/CE03 shall be performed in differential and common mode.

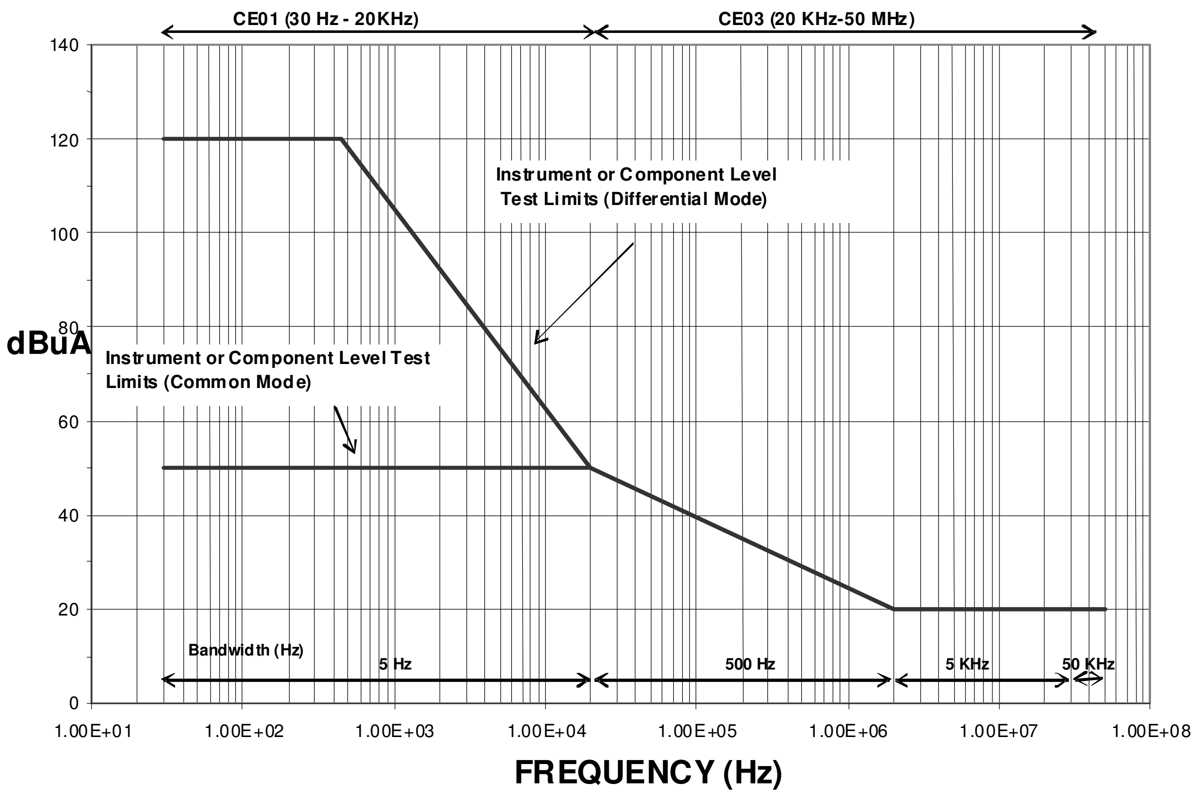


Figure 3-3 Narrowband Conducted Emissions CE01/CE03 Limits

3.4.3.3 Radiated Emissions (RE02)

IRU-204 Radiated emissions (RE) from the IRU shall not exceed the values shown in the figure below when subjected to RE02 narrowband testing.

Table 3-1 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

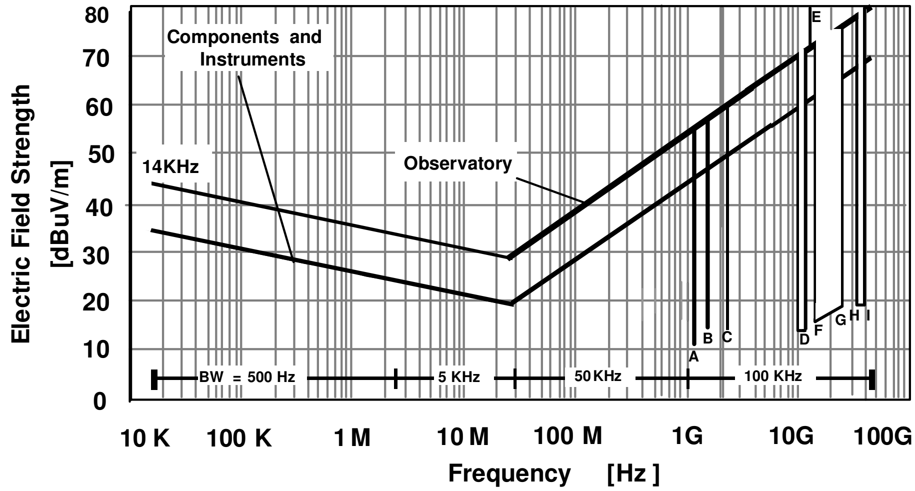


Figure 3-4 RE02 Radiated Narrowband Emissions Limits

RE02 Limits for the Spacecraftand IRUs that are ON from launch to vehicle separation

3.4.3.4 Conducted Susceptibility

IRU-270 Undesirable response, malfunction, or degradation of performance shall not be produced in the IRU during CS testing with the tests specified below.

3.4.3.4.1 CS01/CS02

IRU-272 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.

IRU-273 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.

IRU-274 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.

IRU-275 The CS01 and CS02 (injection of energy into power lines) performance shall be verified at the nominal +28V only.

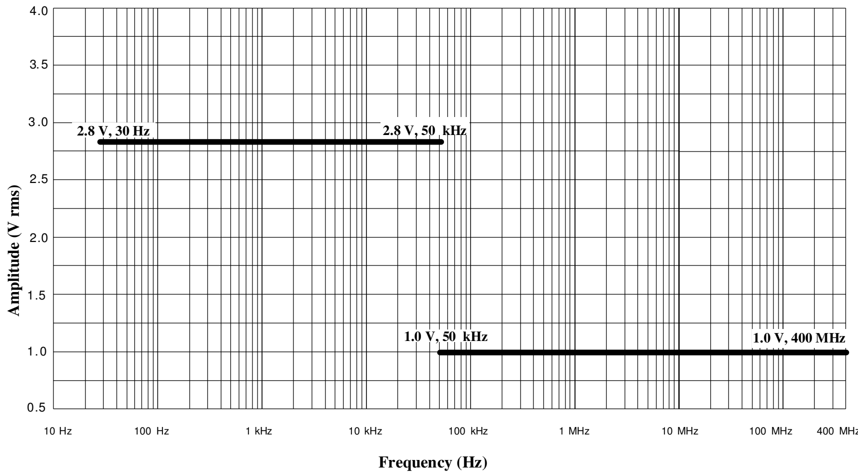
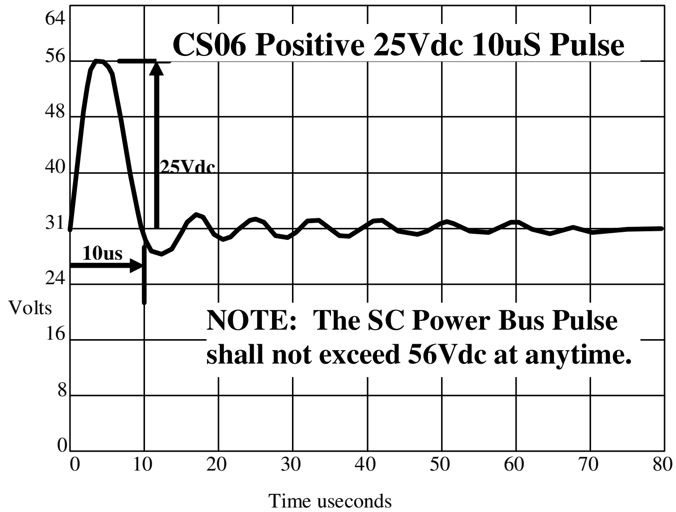


Figure 3-5 CS01/CS02 Limits

3.4.3.4.2 CS06

IRU-279 The CS06 (Powerline Transient) shall be performed on all electronics that contain DC/DC converters or power regulation devices.

The CS06 (Powerline Transient) test consists of both a positive transient test and a negative transient test, having amplitude of +25V, or -31V, superimposed on the +31V power bus as shown in the figure below.



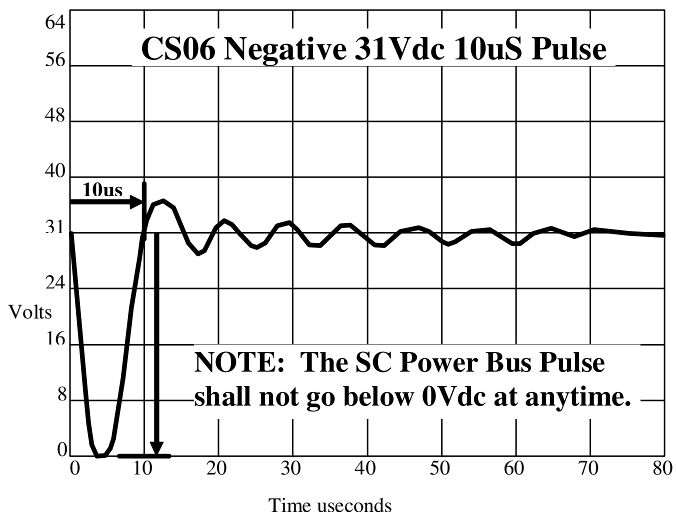


Figure 3-6 CS06 Conducted Susceptibility Test Pulse

3.4.3.5 Radiated Susceptibility (RS03)

IRU-284 Undesirable response, malfunction, or degradation of performance shall not be produced during IRU Radiated Susceptibility (RS) testing with the E-field levels shown in the table below.

Table 3-2 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

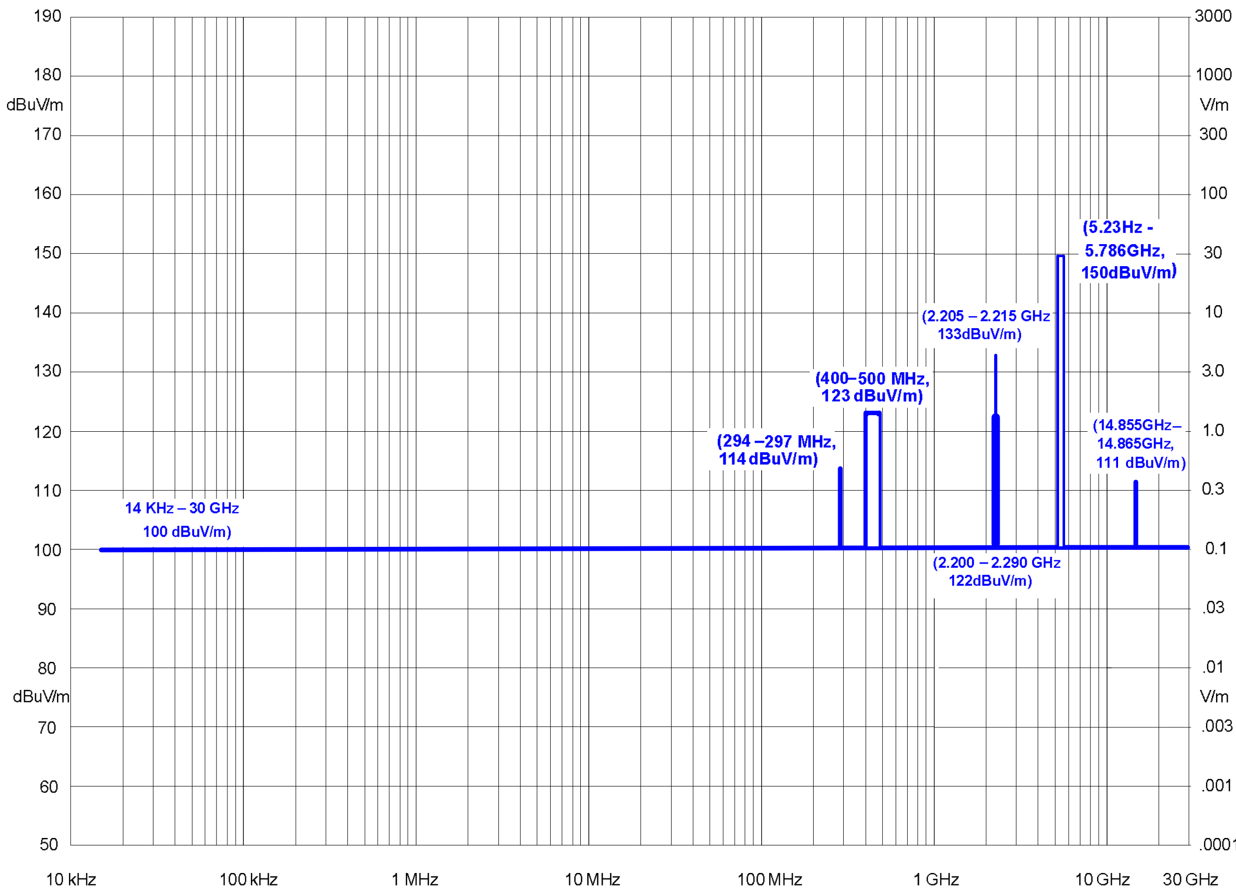
Table 3-3 Launch Site/Vehicle RS Test Levels

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

- IRU-339 RS03 shall be performed on all subsystems
- Subsystems that are OFF at launch may be powered OFF during Launch Site/Vehicle RS Tests.

Figure 3-7 Launch Vehicle Transmitter Emission Levels (GPM RS03)



3.4.4 Data and Signal Interfaces

IRU-344 The presence or absence of any combination of the input signals applied in any sequence shall not cause damage to the IRU, reduce its life expectancy, or cause any malfunction, whether the IRU is powered or not.

3.4.4.1 Data Bus

IRU-346 All 1553 coupling transformer devices shall comply with MIL-STD-1553B requirements.

3.4.4.2 GPM 1553 Data Bus Topology

IRU-348 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, as shown in the first figure below. The complete 1553 data bus will be assembled as shown in the second figure below. The GPM-unique 1553B bus implementation requirements and clarifications are described below.

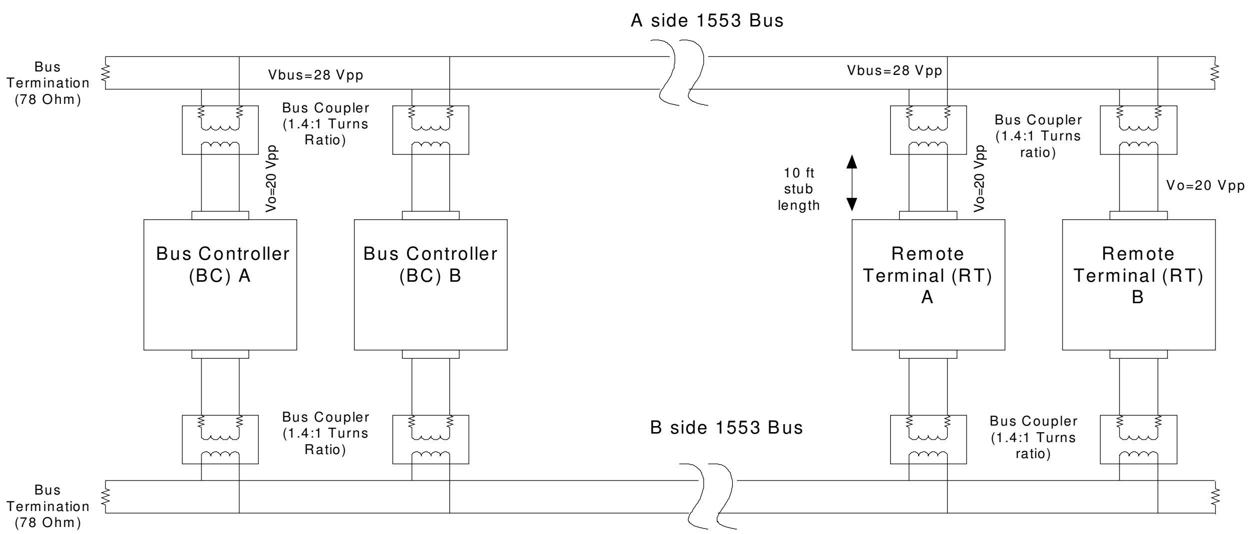


Figure 3-8 1553 Data Bus SubSystem Diagram

3.4.4.3 GPM 1553 Remote Terminal Address Assignments

IRU-352 The IRUs shall use Remote Terminal addresses TBD.

3.4.4.4 Redundancy

IRU-354 A dual, standby-redundant bus as defined in MIL-STD-1553B shall be used.

3.4.4.5 Data Bus Connectors

IRU-356 The IRUs shall utilize a connectors compatible with the GPM 1553 harness which uses a Trompeter PL3155AC connector.

3.4.4.6 GPM 1553 Stub Coupling

IRU-358 The 1553 bus shall use transformer coupling as defined in Section 4.5.1.5.1 of MIL-STD-1553B.

IRU-359 The 1553 bus coupling transformer shall have a turn ratio of 1:1.41+/-3% (stub to bus).

IRU-360 The 1553 bus coupling transformer shall include fault isolation resistors in accordance with Section 4.5.1.5.1.2 of MIL-STD-1553B with Zo = 70 ohms +/- 10%

IRU-361 All RT isolation transformers shall be designed to provide an output signal level of 18 to 27V p-p at the IRU output interface.

3.4.4.6.1 Pulse per Second (1 pps)

IRU-363 The GPM SC shall provide a 1 Pulse per Second (pps) to subsystems that require SC timekeeping information.

IRU-364 The 1 pps shall be transmitted using RS-422 differential signals and shall adhere to the electrical terminations as given in Discrete Command Interface Section above.

IRU-365 Users of the 1 pps shall use receivers and termination compatible with the C&DH which is using an Intersil HS-26CLV31RH differential driver.

IRU-366 The 1 pps shall have timing characteristics as shown in the figure and table below. The fiducial occurs on the rising edge of 1pps_int.

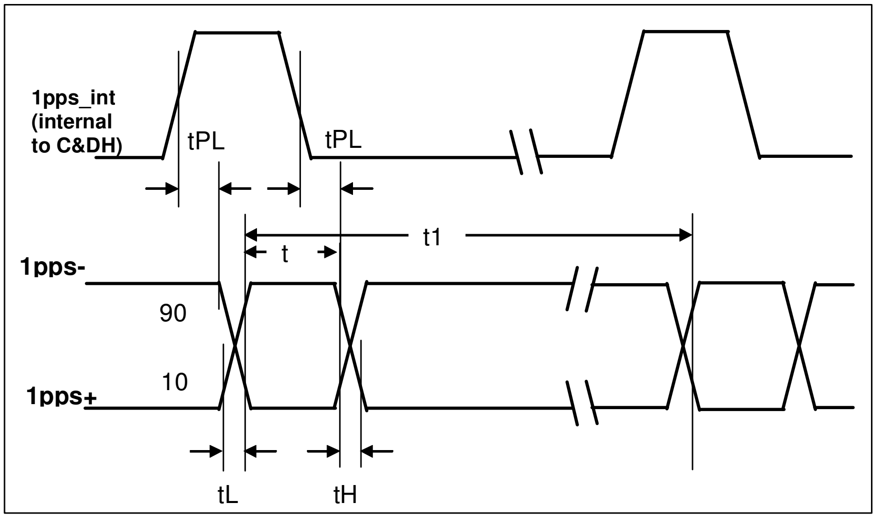


Figure 3-9 1 pps Timing Characteristics

Table 3-4 1pps Timing Characteristics

Parameter	Value	Description
tPLH, tPHL	2-30 nanoseconds	Delay through driver
tTLH, tTHL	<1 microsecont	Rise & Fall times
tH	250 milliseconds	Pulse width
t1S	1s +/- 1 millisecond	Pulse-to-pulse accuracy

3.4.4.6.2 Other Inter-IRU Communications

IRU-392 Other IRU interfaces not specified in this section shall be identified in the specific applicable IRU Electrical ICD.

3.4.4.7 IRU Test Interfaces

IRU-394 All test points shall be protected or isolated from the facility-induced noise, ESD, and GSE malfunction.

IRU-395 GSE cable connectors that mate with flight test connectors shall be flight-approved connectors.

IRU-396 Test connectors shall be capped with flight-approved RF and static control covers when not in use, including in orbit.

IRU-397 Wherever possible, IRU power shall not be applied or accessed at or through a test connector.

Test signals and flight signals should not be located together in the same connector.

3.4.5 Multipaction and Corona

IRU-400 IRUs with high-voltage circuits shall be immune to corona and arcing while in a nominal orbital vacuum environment.

3.4.6 Charging Mitigation

IRU-402 External surfaces >6 cm^2 shall be conductive with a resistivity of less than 10^9 ohms per square (ohms/sq.) and grounded to the IRU chassis.

IRU-403 Insulating films such as Kapton and other dielectric materials on the external surface shall be less than 5 mil thick and assembled to minimize surface charge build-up and grounded to bleed surface charge.

IRU-404 System impacts of the discharges from any unavoidable non-conductive surfaces shall be assessed and approved. If necessary, a waiver request will be submitted for each specific non-compliant application.

IRU-405 The contractor shall supply a comprehensive list of non-conductive surfaces on the outside of the IRU.

IRU-406 Ungrounded (floating) conductors shall not be allowed in the spacecraft. This includes unused wires in harnesses; ground test sensors; ground use signals in cables; unused or unpopulated circuit board traces; ungrounded integrated circuit (IC), relay, transistor, or capacitor cases; spare pins in connectors; thermal blankets; 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. Exceptions are allowed by waiver if analysis shows that no direct or radiated path to victim circuitry exists or that the victim can survive discharge.

IRU-407 Leakage impedance of conductive internal parts shall be less than 10,000 ohms. This requirement applies to conductive fittings on dielectric structural parts.

3.4.7 Harness Requirements

IRU-409 Qualified wire, cable, and connectors specified in the Instructions for EEE Parts Selection, Screening, Qualification, and De-rating (EEE-INST-002) shall be used for any of the IRU harnesses.

IRU-410 Wires, connectors, connector contacts, and other harness piece parts shall be de-rated per the Instructions for EEE Parts Selection, Screening, Qualification, and De-rating (EEE-INST-002).

3.4.7.1 Connectors

3.4.7.1.1 Accessibility

IRU-413 The IRU connectors, on each box, shall be spaced far enough apart to access the harness connector with EMI backshells by a hand or with an extraction tool. Any harness cable or connector should not touch any other adjacent connectors or harnesses.

3.4.7.1.2 Sizing

IRU-415 All connectors on an IRU, with the exception of the 1553 data connectors, shall be different sizes, pin counts and/or genders to prevent any miss-mating of harness to IRU connectors.

3.4.7.1.3 Keying

IRU-417 Wherever possible, with exception of the 1553 data connectors, keying shall be used.

3.4.7.1.4 Connector Savers

IRU-419 Connector savers shall be used during integration and test to minimize wear on connector contacts.

3.4.7.1.5 Mate/Demate Logs

IRU-421 Connector mate/demate logs shall be used to record mates and demates.

3.4.7.1.6 Connector List

IRU-423 The IRU contractor shall provide a list of connectors.

3.4.7.1.7 EMI Backshell

IRU-425 All IRU input/output (I/O) connector interfaces shall be designed to accommodate an EMI backshell.

3.4.7.1.8 Separation of Signals

If possible, the power and signal should not share the same connectors.

3.4.7.1.9 Connector Gender

IRU-429 The connector half that sources power to another IRU shall be female (socketed) to protect against inadvertent grounding prior to mating.

3.5 RADIATION REQUIREMENTS

3.5.1 Introduction

This section gives the Total Ionizing Dose (TID), non-ionizing Displacement Damage Dose (DDD), and Single Event Effects (SEE) requirements for the Global Precipitation Measurement (GPM). We have assumed in this section a top-level shielding requirement of at least 100 mils equivalent aluminum shielding between all parts and free space. That is, there must be 100 mils equivalent aluminum shielding in all solid angles projected from the part out towards free-space. The requirements below assume that shielding for each part meets this minimum shielding requirement.

3.5.1.1 Definitions

Single Event Upset (SEU) - a change of state or transient induced by an energetic particle such as a cosmic ray or proton in a device. This may occur in digital, analog, and optical IRUs or may have effects in surrounding interface circuitry (a subset known as Single Event Transients (SETs)). These are "soft" errors in that a reset or rewriting of the device causes normal device behavior thereafter.

Single Hard Error (SHE) - a SEU that causes a permanent change to the operation of a device. An example is a stuck bit in a memory device.

Single Event Latchup (SEL) - a condition that causes loss of device functionality due to a single event induced high current state. A SEL may or may not cause permanent device damage, but requires power cycling of the device to resume normal device operations.

Single Event Functional Interrupt (SEFI) - a condition that causes loss of device functionality due to a single event in a device control register. It generally requires a device reset to resume normal device operations, but, for some devices, a power cycle is necessary to resume normal device operations.

Single Event Burnout (SEB) - a condition that can cause device destruction due to a high current state in a power transistor.

Single Event Gate Rupture (SEGR) - a single ion induced condition in power MOSFETs that may result in the formation of a conducting path in the gate oxide.

Single Event Effect (SEE) - any measurable effect to a circuit due to an ion strike. This include (but is not limited to) SEUs, SETs, SHEs, SELs, SEFIs, SEBs, SEGRs, and Single Event Dielectric Rupture (SEDR).

Multiple Bit Upset (MBU) - an event induced by a single energetic particle such as a cosmic ray or proton that causes multiple upsets or transients during its path through a device or system.

Linear Energy Transfer (LET) - a measure of the energy deposited per unit length as an energetic particle travels through a material. The common LET unit is MeV*cm^2/milligram (mg) of material (International System of Units [Si] for Metal Oxide Semiconductor [MOS] devices, etc.).

Threshold LET (LET_{th}) - the minimum LET to cause an effect at a particle fluence of 1E7 ions/cm^2. Typically, a particle fluence of 1E5 ions/cm^2 is used for SEB and SEGR testing.

3.5.2 Total Ionizing Dose

IRU-445 No effect due to TID shall cause permanent damage to, or degradation of the IRU.

IRU-446 All parts shall be assessed for sensitivity to TID effects.

IRU-447 If part test data do not exist, ground testing shall be required.

IRU-448 For commercial parts, testing shall be required on the flight procurement lot.

IRU-449 All testing shall be Cobalt-60 (Co-60) testing as per Test Method Standard, Microcircuits (MIL-STD-883 Method 1019.6).

IRU-450 For any part that is estimated to have on-orbit performance degradation due to TID, an analysis shall be performed to show that this degradation does not cause damage to or induce degradation of the IRU performance.

3.5.2.1 Total Ionizing Dose Environment Specifications

IRU-452 The TID requirement shall be 10.8 krad-Si.

If high dose rate archival data are used for considering TID sensitivity of any particular linear bipolar or Bipolar Complementary Metal Oxide Semi-Conductor (BiCMOS) part, the TID requirement is 37.8 krad-Si.

IRU-454 If a part's performance degradation due to TID is not acceptable using the top-level requirements, then the space radiation environments shall be estimated using a 3 dimensional Monte Carlo analysis or a ray trace analysis. The table below shows the mission dose level requirement as a function of aluminum shielding thickness.

Table 3-5 Mission Dose Requirement Versus Al Shield Thickness

Al shield Thickness (mils)	Mission dose (krad-Si)
100	10.8
150	6.4
200	4.6
300	2.6

3.5.3 Part Displacement Damage Dose Specification

IRU-473 No effect due to Displacement Damage Dose (DDD) shall cause permanent damage to or degradation of the IRU.

IRU-474 Each part shall be assessed for potential sensitivity to DDD effects.

IRU-475 For those parts deemed sensitive to DDD, if part test data do not exist, ground testing shall be required.

IRU-476 For commercial parts, testing shall be required on the flight procurement lot.

IRU-477 All testing shall be performed using protons to a mission equivalent fluence.

IRU-478 For any part that is estimated to have on-orbit performance degradation due to DDD, an analysis shall be performed to show that this degradation does not cause damage to or induce degradation of the IRU performance.

3.5.3.1 Displacement Damage Dose Environment Specifications

IRU-480 The top level DDD requirement for parts shall be 2.7E10 protons/cm2 of 10 MeV protons.

IRU-481 Alternative proton energies can be used for test and analysis. The requirement shall be scaled according to the Non Ionizing Energy Loss (NIEL).

3.5.4 Single Event Effects Specification

3.5.4.1 Part Single Event Effects Specification

IRU-484 No SEE shall cause damage to an IRU or induce performance anomalies or outages that require ground intervention to correct.

IRU-485 If part test data do not exist, ground testing shall be required.

IRU-486 For commercial parts, testing shall be required on the flight procurement lot.

IRU-487 Immunity shall be defined as a LETth > 75 MeVcm2/mg.

IRU-488 For any part that is not immune to SEL, an analysis shall demonstrate that the SEL probability of occurrence is negligible in the GPM mission environment.

IRU-489 All N channel power Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) may be susceptible to SEB in the off mode. N channel MOSFET shall be evaluated at the worst-case application.

IRU-490 The survival V Drain-Source (VDS) voltage shall be established from exposure to minimum fluence of 1E6 ions/cm2 with a minimum LET of 26 MeVcm2/mg and a range that is sufficient to penetrate the depletion depth of the device at its maximum voltage. The minimum ion range as a function of rated VDS is given in the table below.

Table 3-6 Minimum Ion Range as a Function of Rated VDS

Max rated V_{DS} (V)	Minimum ion range (µm)
Up to 100	30
100 to 250	40
250 to 400	80
400 to 1000	200

IRU-509 The application shall be de-rated to 75% of the established survival voltage.

IRU-510 In the event that the application cannot be de-rated to 75% of the established survival voltage, a de-rating factor of 40% (of VDS rated) shall be applied for up to 200V devices from International Rectifier and Intersil when no data are available.

IRU-511 For any other device type and/or vender, a de-rating factor of 25% shall be applied when no data is available.

IRU-512 All power MOSFET may be susceptible to SEGR in the off mode, sensitivity shall be evaluated at the worst-case application.

IRU-513 The survival VDS voltage shall be established from exposure to minimum fluence of 1E6 ions/cm2 with a minimum LET of 26 LET MeVcm2/mg and a range that is sufficient to penetrate the depletion depth of the device at its maximum voltage. The minimum ion range as a function of rated VDS is given in the table above.

IRU-514 The application shall be de-rated to 75% of the established survival voltage.

IRU-515 In the event that the application cannot be de-rated to 75% of the established survival voltage, a de-rating factor of 40% (of VDS rated) shall be applied for up to 200V devices from International Rectifier and Intersil when no data are available.

IRU-516 For any other device type and or vendor, a de-rating factor of 25% shall be applied when no data is available.

IRU-517 For single particle events like SEU, SET, and MBU, the criticality of a part in its specific application shall be defined. Please refer to the Single Event Effect Criticality Analysis (SEECA) document (431-REF-000273) for details. A SEECA analysis or a Failure Modes Effects Analysis (FMEA) should be performed at the system level.

IRU-518 IRU heavy-ion and proton testing (and from these a rate calculation) shall be performed on each application of each part.

IRU-519 SEE testing and analysis shall take place based on LETth of the candidate parts as described in the table below.

Table 3-7 Environment to be Assessed Based on SEE part LET Threshold

Part Threshold	Environment to be Assessed
LET_{th} < 12 $MeVcm^2/mg$	Galactic Cosmic Rays, Solar Events Heavy ions and protons
LET_{th} = 12-75 $MeVcm^2/mg$ (destructive events) LETth = 12-37 $MeVcm^2/mg$ (non destructive events)	Galactic Cosmic Ray Heavy Ions, Solar Events Heavy Ions
LET_{th} > 75 $MeVcm^2/mg$ (destructive events) LETth > 37 $MeVcm^2/mg$ (non destructive events)	No analysis required

SEE environment specification (recall top level shielding is 100 mils equivalent Al):

IRU-535 For non-destructive events, a radiation design margin of 2 shall be used on all environment estimates when considering their effects on IRU performance.

IRU-536 The cosmic ray integral-flux LET spectrum to be used for analysis shall be per Figure 3-10 and Table A8 of the GPM Radiation Environment Specification (431-SPEC-000020).

IRU-537 The solar particle event integral-flux LET spectrum to be used for analysis shall be per Figure 3-11 and Table A9 of the GPM Radiation Environment Specification (431-SPEC-000020).

IRU-538 The worst-case solar proton energy spectra to be used for analysis shall be per Figure 3-12 and Table A10 of the GPM Radiation Environment Specification (431-SPEC-000020).

IRU-539 The improper operation caused by single particle events like SEU, SET and MBU shall be reduced to acceptable levels.

IRU-540 Systems engineering analysis of circuit design, operating modes, duty cycle, device criticality, etc. shall be performed to determine acceptable levels for that device. Means of gaining acceptable levels include part selection, error detection and correction schemes, redundancy and voting methods, error tolerant coding, or acceptance of errors in non-critical areas.r

3.6 MECHANICAL REQUIREMENTS

This section defines the limit loads, mechanical environments, and mechanical verification requirements of the GPM spacecraft IRUs. All loads and environments in this document are preliminary and will be updated as the GPM spacecraft is defined.

3.6.1 Definitions

Qualification Test: A test performed on non-flight hardware. The purpose of the test is to prove that a new design meets one or more of its design requirements. Qualification testing is performed at maximum expected flight levels plus a margin. Test durations are typically longer than for acceptance tests.

Protoflight Test: A test performed on flight hardware. The purpose of the test is to prove that a new design meets one or more of its design requirements. Protoflight testing is performed at maximum expected flight levels plus a margin. Test durations are typically the same as for acceptance tests.

Acceptance Test: A test performed on flight hardware. The purpose of this test is to prove that a particular flight unit has been manufactured properly. The design has already been proven during a qualification or protoflight test program. Acceptance testing is performed at maximum expected flight levels.

3.6.2 Environments

3.6.2.1 Launch Limit Loads

IRU-549 The IRUS shall demonstrate their ability to meet its performance requirements after being subjected to the net CG limit loads shown in the table below. If the mass is either higher or lower than that specified in the table, the GPM project will supply an appropriate limit load for the actual mass.

Table 3-8 IRU Limit Loads

IRU Mass (kg)	Limit Load (applied to each axis independently)
4.0 to 5.0 kg	32.0 g

IRU-558 Limit loads shall be updated upon completion of GPM Core spacecraft coupled loads analysis.

3.6.2.2 On-Orbit Limit Loads

IRU-560 The IRU shall meet its performance requirements while being subjected to 0.1 g loads during on-orbit operations.

3.6.2.3 Sinusoidal Vibration

IRU-562 The IRU shall demonstrate its ability to meet its performance requirements after being subjected to the following sine vibration environment. These levels are to be applied at the GPM/IRU interface.

Table 3-9 Instrument Sine Vibration Environment

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

IRU-578 Levels may be notched to not exceed 1.25 times the design limit load. These levels will be updated as coupled-loads analysis (CLA) data becomes available. IRUs shall test for this environment up to 50 Hz and be analyzed from 50 to 100 Hz.

3.6.2.4 Acoustics

IRU-580 The IRU shall be designed to meet its performance requirements after being subjected to the acoustic environment listed in the table below. The sound pressure level is based on the H-IIA launch vehicle. If the IRU is not considered susceptible to the acoustic environment, acoustic testing can be deferred to the spacecraft level of assembly.

Table 3-10 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.

3.6.2.5 Random Vibration

IRU-629 The IRU shall demonstrate its ability to meet its performance requirements after being subjected to the following random vibration environment. These levels are to be applied at the GPM/IRU interface. The duration for the test shall be 1 minute per axis for Acceptance and Protoflight Test and 2 minutes per axis for Prototype Tests.

Table 3-11 IRU Random Vibration Environment

Frequency (Hz)	Protoflight/Qual Level	Acceptance Level
20	0.026 g^2/Hz	0.013 g^2/Hz
20 - 50	+6 dB/Octave	+6 dB/Octave
50 - 800	0.160 g^2/Hz	0.080 g^2/Hz
800 - 2000	-6 dB/Octave	-6 dB/Octave
2000	0.026 g^2/Hz	0.013 g^2/Hz
Over All	14.1 grms	10.0 grms

IRU-662 The above random environment is appropriate for IRUs weighing 22.7 kg (50 lbs) or less. This environment may be updated with random vibration analysis. Note for lightweight IRUs, the highest design loads may be from this random vibration environment. The contractor shall perform random vibration analysis along with static loads analysis. Please see NASA-HDBK-7005 and NASA-STD-7001 for more information.

3.6.2.6 Shock

The maximum expected shock environment at the IRU interface is shown in the table below. This shock environment may be updated.

IRU-665 The IRUs shall be assessed for damage due to shock based on shock sensitivity or proximity to shock sources. If the IRU is not considered susceptible to the shock environment, shock testing can be deferred to the level of assembly that allows for actuation of the actual shock-producing device.

If the IRUs are considered to be susceptible to the shock environment, the contractor may need to perform a shock test to demonstrate that the item can survive the predicted shock environment. The GPM project will assess shock environment based on the specific IRU location.

Table 3-12 Limit Level Shock Response Spectrum

Frequency (Hz)	Level (Q=10)
100 100 to 800 800 to 20000	77 g +7.97 dB/Octave 635 g

3.6.2.7 Venting

IRU-676 The IRUs shall be vented to prevent pressure buildup during the ascent phase of launch. The IRUs shall survive external depressurization from one atmosphere (atm) to 10^{-5} Torr in 60 seconds.

IRU-677 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.

3.6.3 Frequency Requirement

IRU-679 The IRU shall have a fundamental frequency greater than 100 Hz when hard mounted at its SC interface.

3.6.4 Verification Requirements

3.6.4.1 Factors of Safety

IRU-682 The IRU as well as MGSE shall demonstrate positive Margins of Safety for all yield and ultimate failures using the Factors of Safety (FS) defined in the table below (see NASA-STD-5001 for more information on other materials [e.g. glass]).

Table 3-13 Factors of Safety

Type of Hardware	Design Factor of Safety	
	Yield	Ultimate
Tested Flight Structure - metallic	1.25	1.4
Tested Flight Structure - beryllium	1.4	1.6
Tested Flight Structure - composite*	N/A	1.5
Pressure Loaded Structure	1.25	1.5
Pressure Lines and Fittings	1.25	4.0
Untested Flight Structure - metallic only	2.0	2.6
Ground Support Equipment	3.0	5.0
Transportation Dolly/Shipping Container	2.0	3.0

*All composite structures must be tested to 1.25 x limit loads

Margin of Safety (MS) is defined as follows:

MS = (Allowable Stress(or Load)/(Applied Limit Stress(or Load) x FS)) -1

3.6.4.2 Test Factors

IRU-728 The following test factors and durations, shown in the following table, shall be used for prototype, protoflight, and flight hardware. The hardware definitions are included in GEVS (GSFC-STD-7000).

Table 3-14 Test Factors and Durations

Test	Qualification	Protoflight	Acceptance
Structural Loads Level Duration Centrifuge Sine Burst(1)	1.25 X Limit Load 1 Minute 5 Cycles Full Level	1.25 X Limit Load 30 Seconds 5 Cycles Full Level	Limit Load(2) 30 Seconds 5 Cycles Full Level
Acoustic Level Duration	Limit Level +3dB 2 Minutes	Limit Level +3dB 1 Minute	Limit Level 1 Minute
Random Vibration Level Duration	Limit Level +3dB 2 Minutes/Axis	Limit Level +3dB 1 Minute/Axis	Limit Level 1 Minute/Axis
Sine Vibration Level Sweep Rate(3)	1.25 X Limit Level 2 Octaves/Minute/Axis	1.25 X Limit Level 4 Octaves/Minute/Axis	Limit Level 4 Octaves/Minute/Axis
Shock Actual Device Simulated	2 Actuations 1.4 X Limit Level 2 Actuations/Axis	2 Actuations 1.4 X Limit Level 1 Actuations/Axis	1 Actuation Limit Level 1 Actuation/Axis

IRU-761 (1) Sine burst testing shall be done a frequency sufficiently below primary resonance as to ensure rigid body motion.

IRU-762 (2) All composite structures must be tested to 1.25 x limit loads. All beryllium structures must be tested to 1.4 x limit loads.

IRU-763 (3) Unless otherwise specified these sine sweep rates shall apply.

3.6.4.3 Frequency Verification Requirements

IRU-765 The contractor shall perform a frequency verification test, such as a low-level sine sweep.

IRU-766 Frequencies shall be verified and reported up to 200 Hz.

3.6.5 Finite Element Model Requirements

IRU-768 If the IRU 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

IRU-770 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

IRU-780 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. (Visit <http://femci.gsfc.nasa.gov/ValidityChecks/> for details.)
- Finite element models used for thermal analysis pass a unit increased temperature check. (Visit <http://femci.gsfc.nasa.gov/ValidityChecks/> for details.)

3.7 THERMAL REQUIREMENTS

3.7.1 Definitions

Operational Temperature Limits (or Flight Allowable Limit, FAL):

(Nominal expected orbital range)

Acceptance Temperature Limits (AL):
(test temperatures for flight units) conducted only on flight hardware for which the design has already undergone a Qualification Program.
Qualification Temperature Limits (QL):
(maximum performance limits; test temps for first of multiple flight units if design not previously qualified)
Survival Temperature Limits (SL):
(each unit must continue to function after exposure to these temperatures)

the SL.

3.7.2 Flight Interface Design Temperature Limits

Table 3-15 Temperature Levels at Mounting Interface

Condition	Cold Limit (ºC)	Hot Limit (ºC)
Operational Temp (FAL)	-10	+50
Acceptance Temp (AL)	-15	+55
Qualification Temp (QL)	-20	+60
Survival Temp (*) (SL)	-TBD	+TBD

(*)Survival Limit (SL): is a not-to-exceed limit, sufficiently different from QL, at a minimum, to allow qual testing to proceed with real world imprecision (QL ± XX °C) without risking hardware damage.

All temperatures refer to the temperature of the IRU's mounting surface.

IRU-828 When powered "OFF", the IRU shall be capable of surviving indefinitely when its temperatures are within the survival limits without damage or permanent performance degradation. The IRU shall also survive indefinitely, without damage or permanent performance degradation, if powered "ON" anywhere within the specified survival limits. However, the IRU need not operate within spec over the full survival limit range, but must operate within spec over the full QL range.

IRU-829 The IRU shall demonstrate turn on at the cold survival limit of TBD ºC.

3.7.3 Vacuum

IRU-831 The IRU shall be capable of meeting all performance requirements of Section 3.2.3 (IRU Performance) at ambient as well as when exposed to a vacuum environment of 1 x 10-5 Torr, or less.

3.7.4 Thermal Cycling Testing

IRU-833 The IRU must be thermally cycled in a thermal vacuum chamber rather than in an air filled chamber. The IRU shall be flight like blanketed and cycled 8 times with the thermal interface held at the qualification temperatures listed in Table above (Temperature Levels at Mounting Interface) at the thermal interface and the TV chamber shroud at the hot or cold bias indicated by orbital analysis for the hot and/or cold plateaus as appropriate. The durations of temperature hold shall be 4 hours. If the IRU is sensitive to orbit transience, the IRU performance shall be monitored during hot to cold and cold to hot transitions at a rate equal to or greater than that which would be experienced during a flight like orbit transient worst case as shown by analysis results approved by the GPM Thermal Subsystem Lead. The IRU performance must by within spec during these transient test periods, as well as during the plateaus. Thermal Vacuum testing requirements can only be waived through approval of the GPM Thermal Subsystem Lead.

3.7.5 Ground Test Environment

IRU-835 The IRU shall be able to operate in a lab environment with air temperature between 15 and 25 degrees C and relative humidity between 35 and 70%.

IRU-836 The IRU shall be capable of meeting the requirements herein during and after exposure to 0% to 70% relative humidity for 2 years.

IRU-837 The component shall survive without degradation transportation temperatures of 15 to 30 degrees C and relative humidity of 0 to 70%.

3.7.6 Allocation of Spacecraft Monitored Temperature Sensors

IRU-839 The IRU shall provide one temperature sensor per gyro sensor (per axis) and another sensor internal to the IRU.

3.7.7 Model Documentation

IRU-841 The Thermal Math Models (TMMs) delivered to GSFC shall be accompanied by appropriate model documentation as specified in the Statement of Work GPM-GN&C-SOW-0008.

3.7.8 IRU Thermal Test Documentation

IRU-843 The final thermal qualification test plan shall be approved by the GPM Thermal Systems Lead.

IRU-844 Target temperatures and overall test setup shall be discussed with the GPM Thermal Systems Lead.

3.7.9 IRU Thermal Modeling

IRU-846 The IRU shall be modeled using Thermal Desktop (TD) thermal analysis software in accordance with the Detailed Drawings as stated in 3.7.6. The Thermal Math Model (TMM) provided to GPM shall consist of a 20 to 100 nodes, including MLI nodes If the original TMM exceeds this node size limit (this would be a Detailed TMM), then a Reduced TMM (RTMM) of the specified size range shall be provided instead. The size limit can only be waived through approval of the GPM Thermal Subsystem Lead on a case by case basis.

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3.8 LIFE REQUIREMENTS

3.8.1 Mission Life

IRU-850 The IRU shall meet all performance specifications throughout 2 years of ground testing and 38 months of operation in space.

3.8.2 Shelf Life

IRU-852 The IRU shall not suffer any degradation in performance when stored for five years when packaged using agreed-to procedures.

4 VERIFICATION REQUIREMENTS

IRU-854 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 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

IRU-862 Verification of requirements based on similarity shall include supporting rationale and documentation and shall be approved by the GSFC COTR

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

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.

IRU-867 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

IRU-870 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, provided that after such replacement, the equipment is tested as 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

IRU-872 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 IRU 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. Exceptions may be allowed on a case-by-case basis with approval of the COTR.

4.5 REQUIRED VERIFICATION METHODS

The following measurements, tests, environments, and inspections are required for each IRU to provide assurance that the IRU 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
d. Shock Test (if necessary)
e. Loads Test (Prototype/Protoflight only)
f. Sine Vibration
g. Random Vibration
h. Thermal Vacuum
i. Final Alignment (if necessary), Performance and Functional Tests

4.5.1 Weight and Envelope Measurement

IRU-887 Measurement of the weight and envelope of the IRU shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program.

4.5.2 Performance Tests

IRU-889 The IRU shall be tested to demonstrate compliance with performance requirements, including alignment if necessary. A Performance Test shall be conducted at the beginning and end of each acceptance test and again after completion of environmental testing. Functional Tests are abbreviated Performance Tests done periodically during or following the IRU environmental testing in order to show that changes or degradation to the IRU have not resulted from environmental exposure, handling, transporting, or faulty installation.

4.5.3 EMI/EMC

IRU-891 The tests described in the EMI/EMC requirements section shall be performed on each flight unit.

IRU-892 It is encouraged to perform these EMI tests as early as possible in the development. All tests shall be performed with the IRU 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 Verification

IRU-894 Structural design loads 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, a series of static loads pull tests, or, if approved, analysis.

No permanent deformation may occur as a result of the loads test, and all applicable alignment requirements must be met following the test. Units 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.

IRU-897 The IRU shall 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 IRU 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

4.5.4.3 Analysis

IRU-905 If appropriate development tests are performed to verify accuracy of the stress model, stringent quality control procedures are invoked to ensure conformance of the structure (materials, fasteners, welds, processes, etc.) to the design, and the structure has well-defined load paths, then strength qualification may be accomplished by a stress analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the limit load, and positive margins on ultimate at loads equal to 2.6 times the limit load. Such alternative approaches shall be reviewed and approved on a case-by-case basis. Please contact the GPM project to seek approval.

4.5.5 Random Vibration

IRU-907 The IRU shall be subjected to a random vibration test along each axis to the appropriate levels and durations shown in the mechanical requirements section. 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.

IRU-909 The IRU shall be powered during test.

4.5.6 Sine Vibration

IRU-911 The IRU shall be subjected to swept sine vibration testing to the appropriate levels and durations shown in the mechanical requirements section.

IRU-912 IRUs which are powered on at launch shall meet this requirement when powered.

4.5.7 Sine Sweep

The Signature Sine sweep between axes is not required but is useful as a pre- and post-test method of ensuring a structure has not significantly changed during vibration testing.

4.5.8 Thermal Vacuum Test

IRU-916 The IRU shall be cycled a total of eight (8) times at the IRU level.

IRU-917 During these tests, chamber pressure shall be less than 1.33 X 10-3 Pa. (1 X 10-5 torr).

IRU-918 IRUs shall be in flight configuration.

4.5.8.1 Chamber Pump-Down

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

4.5.8.2 Temperature Transitions

IRU-922 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 will be conducted at rates sufficiently slow to prevent that from occurring. Testing shall start with a hot soak and end with a hot soak to minimize this risk.

IRU-923 If the IRU is sensitive to orbit transience, its performance shall be monitored during hot to cold transitions at a rate that a flight like orbit average case might experience. (See Section 3.7 for more details.)

4.5.8.3 Hot/Cold Turn-On Demonstration

IRU-925 IRUs or subsystems shall be turned on twice after exposure to hot and cold survival temperatures (see figure below).

4.5.8.4 Electrical System Performance

The electrical system and performance will also be verified for minimum, maximum, and nominal voltages at minimum and maximum temperatures and 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 IRU thermal vacuum cycling will be the bakeout phase to eliminate volatiles. See the figure below.

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

During the transition from warm to cold, switch IRU OFF, decrease temperature to lower survival temp for 1 hour, then return to lower qualification temperature, verify that IRU turns ON, and verify nominal performance once the IRU 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:

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

Maximum Bus Voltage: 35V

Nominal Bus Voltage: 28V

Minimum Bus Voltage: 21V

4.5.8.5 Bakeout

IRU-941 The IRUs shall be baked-out prior to delivery to GSFC. The bake-out shall be at pressures below 10E-5 torr. The bake-out shall be performed at the hardware's maximum hardware survival temperature, unpowered, for 48 hours followed by a 12 hour period, powered, at the maximum operational temperature as defined in the Temperature Levels at Mounting Interface Table.

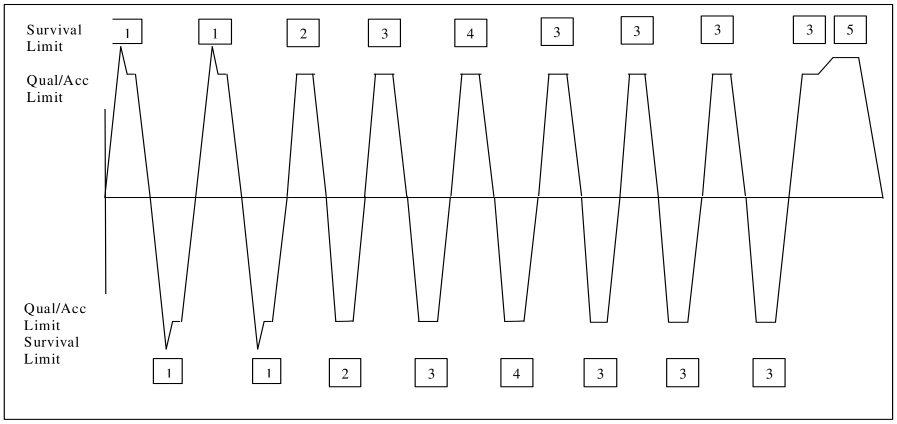

Figure 4-1 Thermal Vacuum Profile

1= Achieve survival temp, stabilize 1 hour, return to acceptance 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 = 31V

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

5 = Bakeout phase

4.5.9 Life Test

The IRU has been determined to require a life test or proof of existing life test data. Units that operate in a high number of cycles and are mission critical to GPM will require life test data be provided to the project. These units must perform life tests or vendors must present life test data to the project for exact designs similar to those purchased by GPM. Any deviations between the life test unit and the flight unit must be reviewed and approved by the project.

The minimum requirement for demonstrated life test operation without failure is 2.0 times the GPM mission life, as defined in section 3.8. Pre- and post-life test baseline performance tests will be conducted with clear requirements established for determining minimum acceptable performance at end-of-life. The GPM Project will accept existing life test data after screening for similarity with the current flight hardware.

IRU-952 The life test mechanism / unit shall be a prototype unit and shall undergo a prototype test program prior to the life test.

4.5.9.1 Considerations Prior to the Life Test

IRU-954 Prior to the start of life testing, mechanisms shall be subjected to the same ground testing sequence that is anticipated for the flight units. These tests will be performed at prototype qualification levels.

4.5.9.2 Considerations During the Life Test

IRU-956 During the life test, the thermal environment of the mechanism shall be representative of the on-orbit environment cycles with 10 degree C margin, and the tests shall be conducted in vacuum.

IRU-957 Life test IRUs shall be operating and monitored during the tests. Physical parameters that are an indication of the health of the mechanism should be closely monitored and trended during the life test. These parameters may include in-rush and steady-state currents, electrical opens or shorts, threshold voltages, temperatures (both steady-state and rate of change), torques, angular or linear positions, vibration, and times of actuation.

4.5.9.3 Considerations After the Life Test

IRU-959 Following the life test, the test units shall be meticulously disassembled and inspected for any anomalous conditions such as abnormal wear, significant lubrication breakdown, or excessive debris generation. A thorough investigation of all moving IRUs and wear surfaces will be conducted. This may include physical dimensional inspection of IRUs, high magnification photography, lubricant analysis, Scanning Electron Microscope (SEM) analysis, etc.

Life test units have satisfied their intent once the life test has been successfully completed. The life test units will not be used as flight spares without project approved reconditioning followed by an acceptance level test program.

APPENDIX A. ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	DEFINITION
A	Approval
CCB	Configuration Control Board
CCR	Configuration Change Request
CDR	Critical Design Review
CM	Configuration Management
CMO	Configuration Management Office
CO	Contracting Officer
COTR	Contracting Officer's Technical Representative
DCR	Design Conformance Review
DILS	Deliverable Items List and Schedule
GNC	Guidance Navigation and Control
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
I	Information
ICD	Interface Control Document
IRU	Inertial Reference Unit
MIP	Mandatory Inspection Point
MSR	Monthly Status Review
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit

PER	Pre-Environmental Review
PSR	Pre-Ship Review
PWB	Printed Wiring Board
R	Review
SOW	Statement of Work

NOTE: Each Requirement must have its own Object Heading.

APPENDIX B:VERIFICATION MATRIX

The following matrix table defines the method of verification for all requirements contained in this document:

Verification Matrix Table

Verification Method:		Level:
Inspection	(I)	1 Program
Analysis	(A)	2 Mission
Demonstration	(D)	3 Core Observatory
Test	(T)	4 Subsystem
		5 Component
		6 Assembly

Object Identifier			I	A	D	T	Responsible Organization
IRU-47	3.1.0-1	Description					
IRU-49	3.2.0-1	IRU-Specific Functional/Performance Requirements					
IRU-51	3.2.1.0-1	Input Rates					
IRU-52	3.2.1.0-2	Input Rates					
IRU-53	3.2.1.0-3	Input Rates					
IRU-54	3.2.1.0-4	Input Rates					
IRU-57	3.2.2.0-1	Cross-Axis Coupling					
IRU-61	3.2.3.1.0-1	Scale Factor					
IRU-62	3.2.3.1.0-2	Scale Factor					
IRU-63	3.2.3.1.0-3	Scale Factor					
IRU-64	3.2.3.1.0-4	Scale Factor					
IRU-66	3.2.3.2.0-1	Bandwidth					
IRU-68	3.2.3.3.0-1	Acceleration Insensitive Drift Rate (AIDR)					
IRU-69	3.2.3.3.0-2	Acceleration Insensitive Drift Rate (AIDR)					
IRU-70	3.2.3.3.0-3	Acceleration Insensitive Drift Rate (AIDR)					
IRU-71	3.2.3.3.0-4	Acceleration Insensitive Drift Rate (AIDR)					
IRU-73	3.2.3.4.0-1	Noise Equivalent Angle					
IRU-83	3.3.1.0-1	Mass					
IRU-85	3.3.2.0-1	Center of Mass					
IRU-87	3.3.3.0-1	Envelope					
IRU-95	3.3.4.0-1	Demise					
IRU-98	3.3.5.1.0-1	Stowed Frequency Requirements					

Object Identifier			**I**	**A**	**D**	**T**	**Responsible Organization**
IRU-100	3.3.5.2.0-1	Deployed Frequency Requirements					
IRU-103	3.3.6.0-2	Mounting and Flatness					
IRU-104	3.3.6.0-3	Mounting and Flatness					
IRU-106	3.3.7.0-1	External Adjustment					
IRU-108	3.3.8.0-1	Finish					
IRU-110	3.3.9.0-1	Identification and Marking					
IRU-112	3.3.10.0-1	Optical Reference					
IRU-113	3.3.10.0-2	Optical Reference					
IRU-114	3.3.10.0-3	Optical Reference					
IRU-115	3.3.10.0-4	Optical Reference					
IRU-119	3.4.1.1.0-1	IRU Power Input Voltage					
IRU-121	3.4.1.2.0-1	IRU Power Consumption					
IRU-123	3.4.1.3.0-1	Maximum Sustained Input Current					
IRU-125	3.4.1.4.0-1	Power System Electronics Output Switching Profile					
IRU-126	3.4.1.4.0-2	Power System Electronics Output Switching Profile					
IRU-127	3.4.1.4.0-3	Power System Electronics Output Switching Profile					
IRU-128	3.4.1.4.0-4	Power System Electronics Output Switching Profile					
IRU-130	3.4.1.5.0-1	Turn-on Transients (In-Rush Current)					
IRU-132	3.4.1.5.0-3	Turn-on Transients (In-Rush Current)					
IRU-133	3.4.1.5.0-4	Turn-on Transients (In-Rush Current)					
IRU-134	3.4.1.5.0-5	Turn-on Transients (In-Rush Current)					
IRU-135	3.4.1.5.0-6	Turn-on Transients (In-Rush Current)					
IRU-136	3.4.1.5.0-7	Turn-on Transients (In-Rush Current)					
IRU-137	3.4.1.5.0-8	Turn-on Transients (In-Rush Current)					
IRU-138	3.4.1.5.0-9	Turn-on Transients (In-Rush Current)					
IRU-139	3.4.1.5.0-10	Turn-on Transients (In-Rush Current)					
IRU-143	3.4.1.6.0-1	Survival of Anomalous Voltage					
IRU-145	3.4.1.6.0-3	Survival of Anomalous Voltage					
IRU-146	3.4.1.6.0-4	Survival of Anomalous Voltage					
IRU-149	3.4.1.6.0-7	Survival of Anomalous Voltage					
IRU-151	3.4.1.7.0-1	Ripple					
IRU-153	3.4.1.8.0-1	Operational Bus Transients					
IRU-156	3.4.1.9.0-1	Single-Event Power Bus Transients					
IRU-158	3.4.1.10.0-1	Turn-Off Transients					
IRU-160	3.4.1.11.0-1	Turn-Off Protection					
IRU-161	3.4.1.11.0-2	Turn-Off Protection					
IRU-162	3.4.1.11.0-3	Turn-Off Protection					
IRU-164	3.4.1.12.0-1	Polarity Reversal Protection					

Object Identifier			**I**	**A**	**D**	**T**	**Responsible Organization**
IRU-165	3.4.1.12.0-2	Polarity Reversal Protection					
IRU-167	3.4.1.13.0-1	Subsystem Over-Current Protection					
IRU-169	3.4.1.14.0-1	IRU Power Redundancy					
IRU-171	3.4.1.15.0-1	Redundant Power Supplies					
IRU-173	3.4.1.16.0-1	IRU Brownout protection					
IRU-176	3.4.2.1.0-1	Primary Input Isolation					
IRU-178	3.4.2.2.0-1	Secondary Ground					
IRU-179	3.4.2.2.0-2	Secondary Ground					
IRU-182	3.4.2.4.0-1	Bonding or Mating					
IRU-183	3.4.2.4.0-2	Bonding or Mating					
IRU-185	3.4.2.5.0-1	Grounding of Conductors					
IRU-187	3.4.2.6.0-1	Grounding of External Surfaces					
IRU-189	3.4.2.7.0-1	Connector Grounding					
IRU-192	3.4.3.1.0-1	Test Methods					
IRU-195	3.4.3.2.1.0-1	CE01/CE03					
IRU-196	3.4.3.2.1.0-2	CE01/CE03					
IRU-197	3.4.3.2.1.0-3	CE01/CE03					
IRU-198	3.4.3.2.1.0-4	CE01/CE03					
IRU-204	3.4.3.3.0-1	Radiated Emissions (RE02)					
IRU-270	3.4.3.4.0-1	Conducted Susceptibility					
IRU-272	3.4.3.4.1.0-1	CS01/CS02					
IRU-273	3.4.3.4.1.0-2	CS01/CS02					
IRU-274	3.4.3.4.1.0-3	CS01/CS02					
IRU-275	3.4.3.4.1.0-4	CS01/CS02					
IRU-279	3.4.3.4.2.0-1	CS06					
IRU-284	3.4.3.5.0-1	Radiated Susceptibility (RS03)					
IRU-339	3.4.3.5.0-2.0-2.0-1.0-2						
IRU-344	3.4.4.0-1	Data and Signal Interfaces					
IRU-346	3.4.4.1.0-1	Data Bus					
IRU-348	3.4.4.2.0-1	GPM 1553 Data Bus Topology					
IRU-352	3.4.4.3.0-1	GPM 1553 Remote Terminal Address Assignments					
IRU-354	3.4.4.4.0-1	Redundancy					
IRU-356	3.4.4.5.0-1	Data Bus Connectors					
IRU-358	3.4.4.6.0-1	GPM 1553 Stub Coupling					
IRU-359	3.4.4.6.0-2	GPM 1553 Stub Coupling					
IRU-360	3.4.4.6.0-3	GPM 1553 Stub Coupling					
IRU-361	3.4.4.6.0-4	GPM 1553 Stub Coupling					
IRU-363	3.4.4.6.1.0-1	Pulse per Second (1 pps)					
IRU-364	3.4.4.6.1.0-2	Pulse per Second (1 pps)					
IRU-365	3.4.4.6.1.0-3	Pulse per Second (1 pps)					

Object Identifier			I	A	D	T	Responsible Organization
IRU-366	3.4.4.6.1.0-4	Pulse per Second (1 pps)					
IRU-392	3.4.4.6.2.0-1	Other Inter-IRU Communications					
IRU-394	3.4.4.7.0-1	IRU Test Interfaces					
IRU-395	3.4.4.7.0-2	IRU Test Interfaces					
IRU-396	3.4.4.7.0-3	IRU Test Interfaces					
IRU-397	3.4.4.7.0-4	IRU Test Interfaces					
IRU-400	3.4.5.0-1	Multipaction and Corona					
IRU-402	3.4.6.0-1	Charging Mitigation					
IRU-403	3.4.6.0-2	Charging Mitigation					
IRU-404	3.4.6.0-3	Charging Mitigation					
IRU-405	3.4.6.0-4	Charging Mitigation					
IRU-406	3.4.6.0-5	Charging Mitigation					
IRU-407	3.4.6.0-6	Charging Mitigation					
IRU-409	3.4.7.0-1	Harness Requirements					
IRU-410	3.4.7.0-2	Harness Requirements					
IRU-413	3.4.7.1.1.0-1	Accessibility					
IRU-415	3.4.7.1.2.0-1	Sizing					
IRU-417	3.4.7.1.3.0-1	Keying					
IRU-419	3.4.7.1.4.0-1	Connector Savers					
IRU-421	3.4.7.1.5.0-1	Mate/Demate Logs					
IRU-423	3.4.7.1.6.0-1	Connector List					
IRU-425	3.4.7.1.7.0-1	EMI Backshell					
IRU-429	3.4.7.1.9.0-1	Connector Gender					
IRU-445	3.5.2.0-1	Total Ionizing Dose					
IRU-446	3.5.2.0-2	Total Ionizing Dose					
IRU-447	3.5.2.0-3	Total Ionizing Dose					
IRU-448	3.5.2.0-4	Total Ionizing Dose					
IRU-449	3.5.2.0-5	Total Ionizing Dose					
IRU-450	3.5.2.0-6	Total Ionizing Dose					
IRU-452	3.5.2.1.0-1	Total Ionizing Dose Environment Specifications					
IRU-454	3.5.2.1.0-3	Total Ionizing Dose Environment Specifications					
IRU-473	3.5.3.0-1	Part Displacement Damage Dose Specification					
IRU-474	3.5.3.0-2	Part Displacement Damage Dose Specification					
IRU-475	3.5.3.0-3	Part Displacement Damage Dose Specification					
IRU-476	3.5.3.0-4	Part Displacement Damage Dose Specification					
IRU-477	3.5.3.0-5	Part Displacement Damage Dose					

Object Identifier			I	A	D	T	Responsible Organization
		Specification					
IRU-478	3.5.3.0-6	Part Displacement Damage Dose Specification					
IRU-480	3.5.3.1.0-1	Displacement Damage Dose Environment Specifications					
IRU-481	3.5.3.1.0-2	Displacement Damage Dose Environment Specifications					
IRU-484	3.5.4.1.0-1	Part Single Event Effects Specification					
IRU-485	3.5.4.1.0-2	Part Single Event Effects Specification					
IRU-486	3.5.4.1.0-3	Part Single Event Effects Specification					
IRU-487	3.5.4.1.0-4	Part Single Event Effects Specification					
IRU-488	3.5.4.1.0-5	Part Single Event Effects Specification					
IRU-489	3.5.4.1.0-6	Part Single Event Effects Specification					
IRU-490	3.5.4.1.0-7	Part Single Event Effects Specification					
IRU-509	3.5.4.1.0-10	Part Single Event Effects Specification					
IRU-510	3.5.4.1.0-11	Part Single Event Effects Specification					
IRU-511	3.5.4.1.0-12	Part Single Event Effects Specification					
IRU-512	3.5.4.1.0-13	Part Single Event Effects Specification					
IRU-513	3.5.4.1.0-14	Part Single Event Effects Specification					
IRU-514	3.5.4.1.0-15	Part Single Event Effects Specification					
IRU-515	3.5.4.1.0-16	Part Single Event Effects Specification					
IRU-516	3.5.4.1.0-17	Part Single Event Effects Specification					
IRU-517	3.5.4.1.0-18	Part Single Event Effects Specification					
IRU-518	3.5.4.1.0-19	Part Single Event Effects Specification					
IRU-519	3.5.4.1.0-20	Part Single Event Effects Specification					
IRU-535	3.5.4.1.0-23	Part Single Event Effects Specification					
IRU-536	3.5.4.1.0-24	Part Single Event Effects Specification					
IRU-537	3.5.4.1.0-25	Part Single Event Effects Specification					
IRU-538	3.5.4.1.0-26	Part Single Event Effects Specification					
IRU-539	3.5.4.1.0-27	Part Single Event Effects Specification					
IRU-540	3.5.4.1.0-28	Part Single Event Effects Specification					
IRU-549	3.6.2.1.0-1	Launch Limit Loads					
IRU-558	3.6.2.1.0-3	Launch Limit Loads					
IRU-560	3.6.2.2.0-1	On-Orbit Limit Loads					
IRU-562	3.6.2.3.0-1	Sinusoidal Vibration					
IRU-578	3.6.2.3.0-3	Sinusoidal Vibration					
IRU-580	3.6.2.4.0-1	Acoustics					
IRU-629	3.6.2.5.0-1	Random Vibration					
IRU-662	3.6.2.5.0-4	Random Vibration					
IRU-665	3.6.2.6.0-2	Shock					
IRU-676	3.6.2.7.0-1	Venting					
IRU-677	3.6.2.7.0-2	Venting					

Object Identifier			I	A	D	T	Responsible Organization
IRU-679	3.6.3.0-1	Frequency Requirement					
IRU-682	3.6.4.1.0-1	Factors of Safety					
IRU-728	3.6.4.2.0-1	Test Factors					
IRU-761	3.6.4.2.0-3	Test Factors					
IRU-763	3.6.4.2.0-5	Test Factors					
IRU-765	3.6.4.3.0-1	Frequency Verification Requirements					
IRU-766	3.6.4.3.0-2	Frequency Verification Requirements					
IRU-768	3.6.5.0-1	Finite Element Model Requirements					
IRU-770	3.6.5.1.0-1	Finite Element Model Documentation					
IRU-780	3.6.5.2.0-1	Finite Element Model Submittal					
IRU-828	3.7.2.0-4	Flight Interface Design Temperature Limits					
IRU-829	3.7.2.0-5	Flight Interface Design Temperature Limits					
IRU-831	3.7.3.0-1	Vacuum					
IRU-833	3.7.4.0-1	Thermal Cycling Testing					
IRU-835	3.7.5.0-1	Ground Test Environment					
IRU-836	3.7.5.0-2	Ground Test Environment					
IRU-837	3.7.5.0-3	Ground Test Environment					
IRU-839	3.7.6.0-1	Allocation of Spacecraft Monitored Temperature Sensors					
IRU-841	3.7.7.0-1	Model Documentation					
IRU-843	3.7.8.0-1	IRU Thermal Test Documentation					
IRU-844	3.7.8.0-2	IRU Thermal Test Documentation					
IRU-846	3.7.9.0-1	IRU Thermal Modeling					
IRU-850	3.8.1.0-1	Mission Life					
IRU-852	3.8.2.0-1	Shelf Life					
IRU-854	4.0-1	Verification Requirements					
IRU-862	4.1.3.0-1	Documentation Search					
IRU-867	4.3.0-2	Test					
IRU-870	4.4.1.0-1	Failure During Tests					
IRU-872	4.4.2.0-1	Modification of Hardware					
IRU-887	4.5.1.0-1	Weight and Envelope Measurement					
IRU-889	4.5.2.0-1	Performance Tests					
IRU-891	4.5.3.0-1	EMI/EMC					
IRU-892	4.5.3.0-2	EMI/EMC					
IRU-894	4.5.4.0-1	Loads Verification					
IRU-897	4.5.4.0-4	Loads Verification					
IRU-905	4.5.4.3.0-1	Analysis					
IRU-907	4.5.5.0-1	Random Vibration					
IRU-909	4.5.5.0-3	Random Vibration					
IRU-911	4.5.6.0-1	Sine Vibration					

Object Identifier			**I**	**A**	**D**	**T**	**Responsible Organization**
IRU-912	4.5.6.0-2	Sine Vibration					
IRU-916	4.5.8.0-1	Thermal Vacuum Test					
IRU-917	4.5.8.0-2	Thermal Vacuum Test					
IRU-918	4.5.8.0-3	Thermal Vacuum Test					
IRU-922	4.5.8.2.0-1	Temperature Transitions					
IRU-923	4.5.8.2.0-2	Temperature Transitions					
IRU-925	4.5.8.3.0-1	Hot/Cold Turn-On Demonstration					
IRU-941	4.5.8.5.0-1	Bakeout					
IRU-952	4.5.9.0-3	Life Test					
IRU-954	4.5.9.1.0-1	Considerations Prior to the Life Test					
IRU-956	4.5.9.2.0-1	Considerations During the Life Test					
IRU-957	4.5.9.2.0-2	Considerations During the Life Test					
IRU-959	4.5.9.3.0-1	Considerations After the Life Test					