CII Environmental Guidelines

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Interface Assumptions

- The Host Spacecraft will have a primary mission different than that of the Instrument. As a hosted payload, the Instrument's most important directive is to not interfere or cause damage to the Host Spacecraft or any of its payloads, sacrificing its own safety for that of the rest of the observatory/bus.
- [GEO] Nominal Orbit: The Host Spacecraft will operate in GEO with an altitude of approximately 35786 kilometers and eccentricity and inclination of approximately zero.
- [LEO] Nominal Orbit: The Host Spacecraft will operate in LEO with an altitude between 350 and 2000 kilometers with eccentricity less than 1 and inclination between zero and 180°, inclusive.
- Responsibility for Integration: The Host Spacecraft Manufacturer will integrate the Instrument onto the Host Spacecraft with support from the Instrument Developer.

Interface Assumptions

The CII environmental guidelines assume the following regarding the Host Spacecraft, launch vehicle, and/or integration and test facilities:

- During the matching process, the Host Spacecraft Manufacturer/ Systems Integrator and the Instrument Developer will negotiate detailed parameters of the environmental interface. The Environmental Interface Control Document (EICD) will record those parameters and decisions.

  Note: the design of the Instrument modes of operation are the responsibility of the Instrument Developer. For purposes of illustration, the operational modes in this section are equivalent to the Instrument modes and states as defined in Appendix G.

Interface Assumptions

- The Shipping/Storage Environment represents the time in the Instrument's lifecycle between when it departs the Instrument Developer's facility and arrives at the facility of the Spacecraft Manufacturer/Systems Integrator. The Instrument is dormant and is attached mechanically to its container (see Figure 8-1).

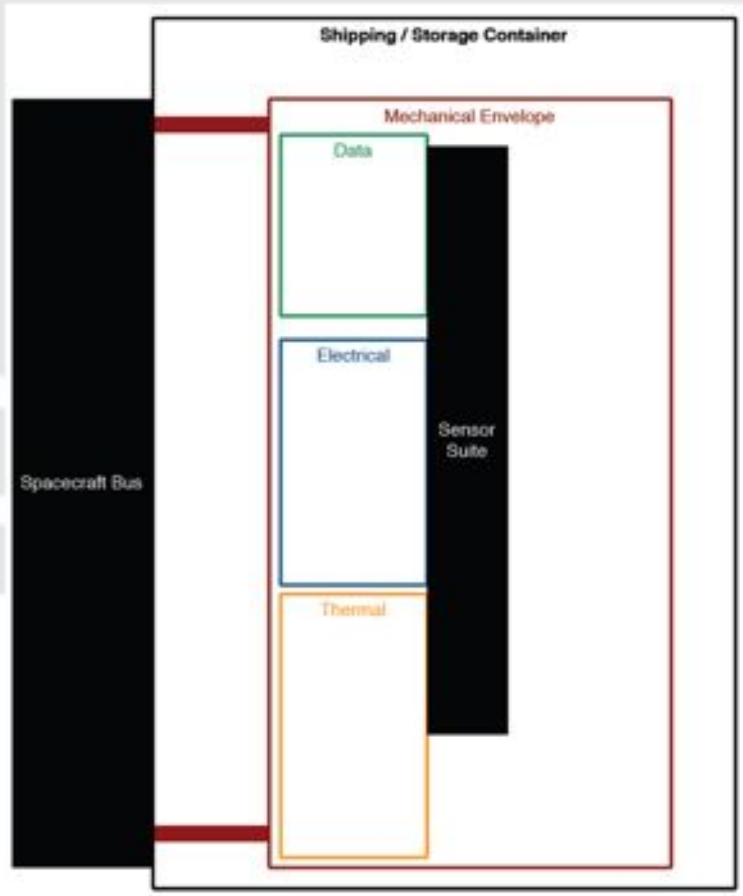


Figure 8-1: Shipping / Storage Environment

Interface Assumptions

- The Integration and Test Environment represents the time in the Instrument's lifecycle between when it arrives at the facility of the Spacecraft Manufacturer/Systems Integrator through payload encapsulation at the launch facility. During this phase, the Host Spacecraft Manufacturer/Systems Integration will attach the Instrument to the Host Spacecraft Bus and verify that system will perform as designed throughout various environmental and dynamics regimes. The Instrument may be attached to the Host Spacecraft Bus or to various ground support equipment that transmits power, thermal conditioning, and diagnostic data (see Figure 8-2).

Interface Assumptions

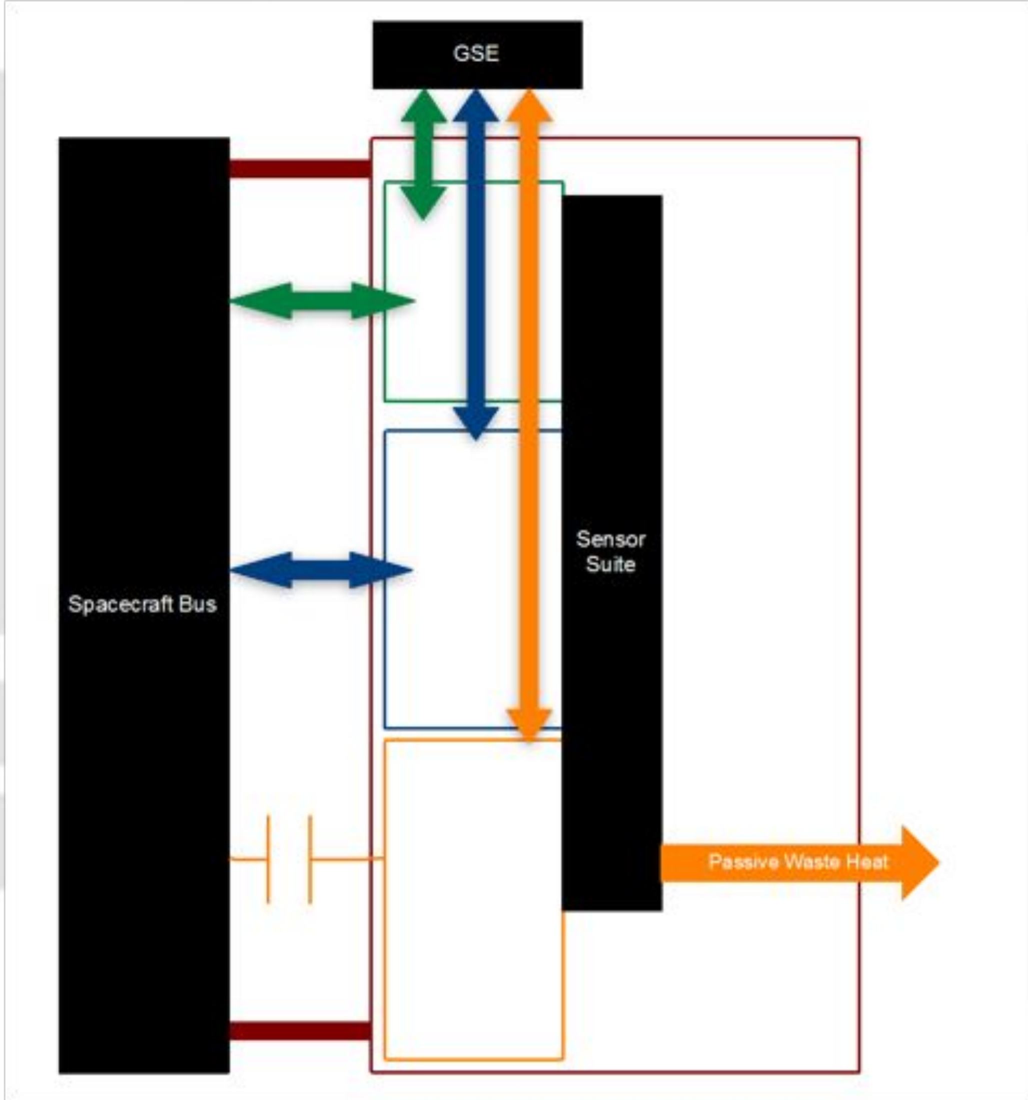


Figure 8-2: Integration and Test

Interface Assumptions

- The Launch Environment represents that time in the Instrument's lifecycle when it is attached to the launch vehicle via the Host Spacecraft, from payload encapsulation at the Launch facility through the completion of the launch vehicle's final injection burn (see Figure 8-3).

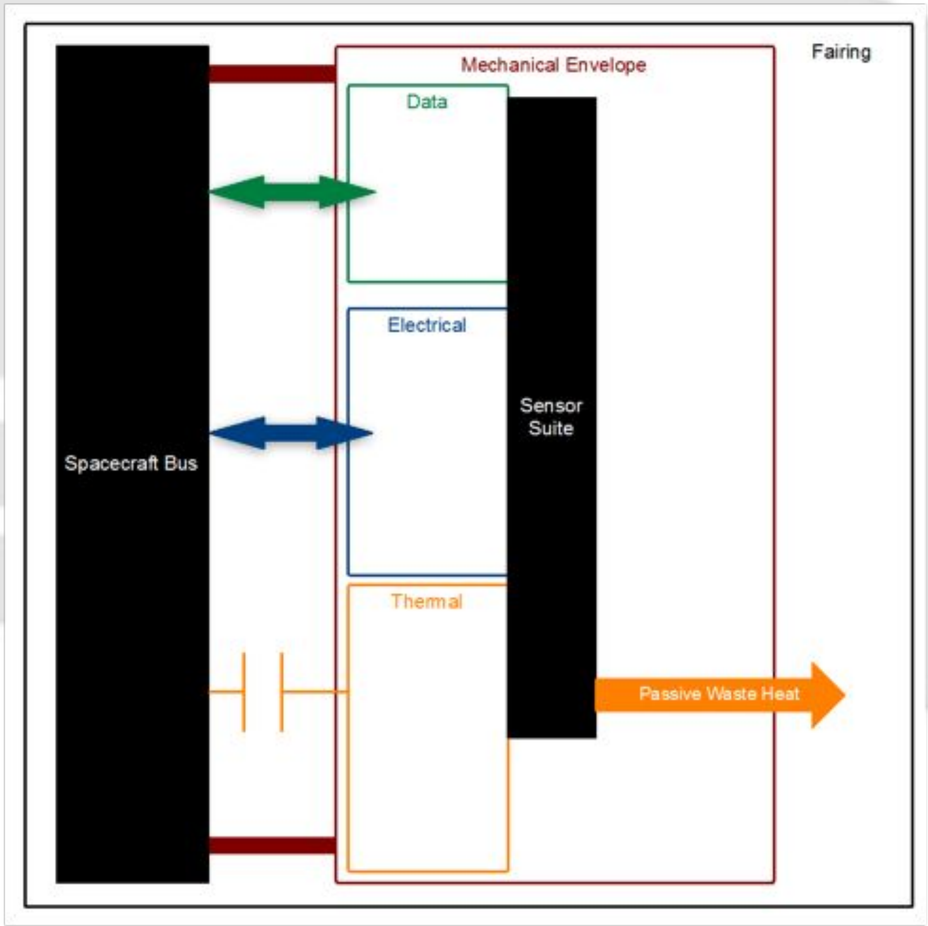


Figure 8-3: Launch Environment

Interface Assumptions

- The Operational Environment represents that time in the Instrument's lifecycle following the completion of the launch vehicle's final injection burn, when the Instrument is exposed to space and established in its operational orbit (Figure 8-6).

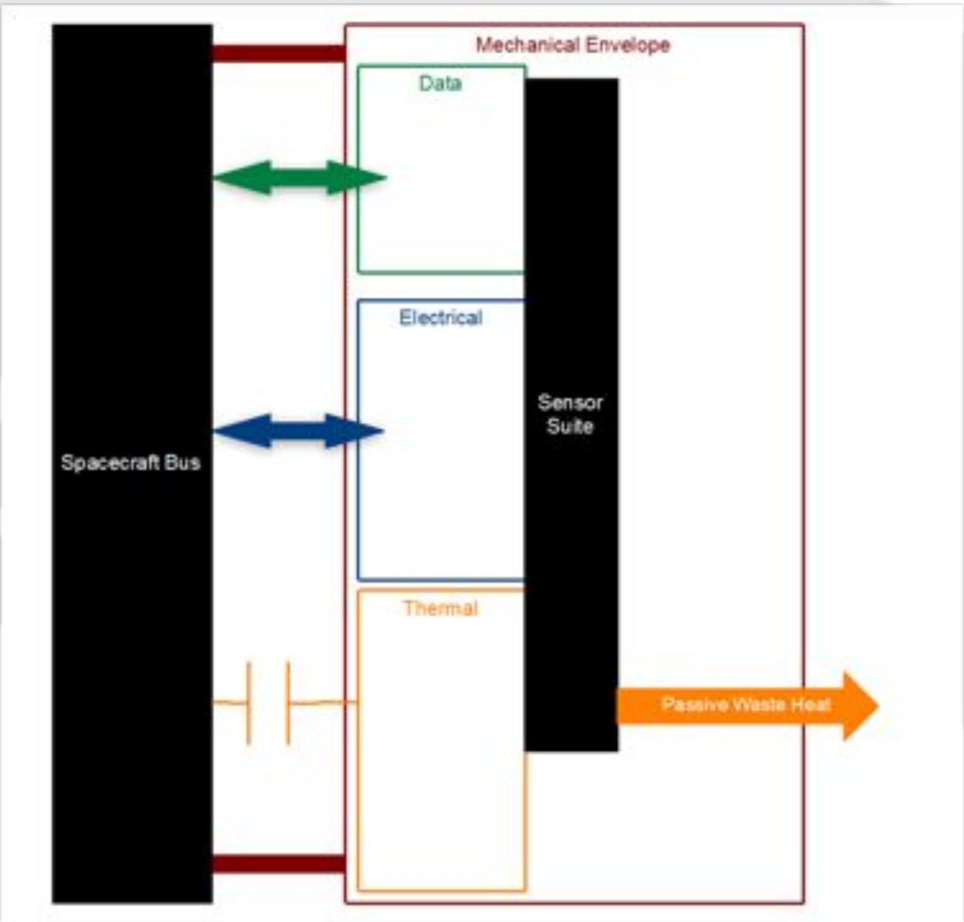


Figure 8-6: Operational Environment

Environmental L1 Guidelines

ID	Function	Guidelines	Rationale/Comment
2.2.1	Hosted Payload Worldview	The Instrument should prevent itself or any of its components from damaging or otherwise degrading the mission performance of the Host Spacecraft or any other payloads.	The most important constraint on a hosted payload is to “do no harm” to the Host Spacecraft or other payloads. The Satellite Operator will have the authority to remove power or otherwise terminate the Instrument should either the Host Spacecraft's available services degrade or the Instrument pose a threat to the rest of the Spacecraft. This guideline applies over the period beginning at the initiation of Instrument integration to the Host Spacecraft and ending at the completion of the disposal of the Host Spacecraft. It is important to note that most GEO communications satellites have a nominal mission lifetime in excess of 15 years or more while a hosted payload Instrument nominal lifetime is on the order of five years.

Environmental L1 Guidelines

ID	Function	Guidelines	Rationale/Comment
2.2.9	[GEO] Attitude Control System Pointing Accommodation	The Instrument 3σ pointing accuracy required should exceed 1440 seconds of arc (0.4 degrees) in each of the Host Spacecraft roll, pitch, and yaw axes.	The Host Spacecraft bus pointing accuracy varies significantly both by manufacturer and by spacecraft bus configuration. 1440 arc-seconds represents a pointing accuracy that all of the primary manufacturers' buses can achieve, and requiring a "looser" pointing accuracy significantly increases the likelihood of finding a suitable Host Spacecraft. If Instrument pointing requirements are more stringent than 1440 arc-seconds, then the Instrument Developer may consider the following courses of action: perform a more restrictive Instrument / Host Spacecraft pairing exercise; procure an upgraded (and likely more expensive) version of a Host Spacecraft that meets those requirements; or incorporate a pointing-control system into the Instrument.

Environmental L1 Guidelines

ID	Function	Guidelines	Rationale/Comment
2.2.10	[GEO] Attitude Determination System Pointing Knowledge Accommodation	The Instrument 3σ pointing knowledge required should exceed 450 seconds of arc (0.125 degrees) in the Host Spacecraft roll and pitch axes and 900 seconds of arc (0.25 degrees) in the yaw axis.	The Host Spacecraft bus pointing knowledge varies significantly both by manufacturer and by spacecraft bus configuration. 450 arc-seconds (roll/pitch) and 900 arc-seconds (yaw) represent a pointing knowledge that all 380 of the primary manufacturers' buses can achieve, and requiring a "looser" pointing knowledge significantly increases the likelihood of finding a suitable Host Spacecraft. If Instrument pointing knowledge requirements are more stringent than 450/900 arc-seconds, then the Instrument Developer may consider the following courses of action: perform a more restrictive Instrument / Host Spacecraft pairing exercise; procure an upgraded (and likely more expensive) version of a Host Spacecraft that meets those requirements; or incorporate an attitude determination system into the Instrument.

Environmental L1 Guidelines

ID	Function	Guidelines	Rationale/Comment
2.2.11	[GEO] Payload Pointing Stability Accommodation	The Instrument should require a short term (≥ 0.1 Hz) 3σ pointing stability that is greater than or equal to 110 seconds of arc/second (0.03 degrees/second) in each spacecraft axis and a long term (Diurnal) 3σ pointing stability that is greater than or equal to 440 seconds of arc (0.12 degrees/second) in each spacecraft axis.	Host Spacecraft pointing stability varies significantly both by manufacturer and by bus configuration. In order to maximize the probability of matching an available hosting opportunity, an instrument should be compatible with the maximum pointing knowledge accuracy defined for all responding Host Spacecraft Manufacturers' buses and configurations. According to information provided by industry, the level of short term (≥ 0.1 Hz) pointing stability available for secondary hosted payloads is ≤ 110 seconds of arc/second (0.03 degrees/second) in each of the spacecraft axes. The level of long term (Diurnal) pointing stability available for secondary hosted payloads is ≤ 440 seconds of arc/second (0.12 degrees/second) in each of the spacecraft axes. Therefore, an Instrument pointing stability requirement greater than these values will ensure that any prospective Host Spacecraft bus can accommodate the Instrument. If Instrument pointing stability requirements are more stringent than this guideline, then the Instrument Developer may consider the following courses of action: perform a more restrictive Instrument / Host Spacecraft pairing exercise; procure an upgraded (and likely more expensive) version of a Host Spacecraft that meets those requirements; or incorporate an attitude determination and control system into the Instrument.

Environmental L1 Guidelines

ID	Function	Guidelines	Rationale/Comment
2.2.12	Environmental Interface	The Instrument should be compatible with, and as appropriate, function according to its operational specifications in those environments encountered during Shipping/Storage, Integration and Test, Launch, and Operations as defined in Section 8.0.	From the time the Instrument departs the facility in which it was constructed through on-orbit operations and decommissioning, it will encounter disparate environments with which it needs to be compatible and, as appropriate, function reliably and predictably.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.2.1	Shipping / Storage Environment Documentation	The EICD will document the expected environment the Instrument will experience between the departure from the Instrument assembly facility and arrival at the Host Spacecraft integration facility.	The nature of the Shipping/ Storage Environment is dependent upon the point at which physical custody of the Instrument transfers from Instrument Developer to the Satellite Contractor/Systems Integrator as well as negotiated agreements on shipping/ storage procedures. The interfaces associated with the shipping/storage environment include the allowable temperatures and the characteristics of the associated atmosphere.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.2.2	Shipping / Storage Environment Instrument Configuration	The EICD will document the configuration and operational state of the Instrument during the Shipping/Storage phase.	Specifying the configuration of the Instrument during shipping/storage drives the volume requirements for the container as well as any associated support equipment and required services. The Instrument will likely be in the OFF/SURVIVAL mode while in this environment.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.3.1	Integration and Test Environment Documentation	The EICD will document the expected environments the Instrument will experience between arrival at the Host Spacecraft integration facility and Launch.	The nature of the Integration and Test Environment is dependent upon the choice of Host Spacecraft and Launch Vehicle as well as the negotiated workflows at the Systems Integration and Launch facilities. Example environmental properties include the thermal, dynamic, atmospheric, electromagnetic, radiation characteristics of each procedure in the Integration and Test process. The EICD may either record these data explicitly or refer to a negotiated Test and Evaluation Master Plan (TEMP).

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.3.2	Integration and Test Environment Instrument Configuration	The EICD will document the configuration and operational mode of the Instrument during the Integration and Test phase.	Proper configuration of the Instrument during the various Integration and Test procedures ensures the validity of the process.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.1	Launch Environment Documentation	The EICD will document the expected environments the Instrument will experience between Launch and Host Spacecraft / Launch Vehicle separation.	The nature of the Launch Environment is dependent upon the choice of Host Spacecraft and Launch Vehicle. Significant parameters related to the launch environment include temperature, pressure, and acceleration profiles.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.2	Launch Environment Instrument Configuration	The EICD will document the configuration and operational state of the Instrument during the Launch phase.	The Launch phase is the most dynamic portion of the mission, and the Instrument configuration and operational mode are chosen to minimize damage to either the Instrument or Host Spacecraft. The Instrument will likely be in the OFF/SURVIVAL mode while in this environment.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.3	Launch Environment Atmospheric Pressure Range	The instrument should function according to its operational specifications after being subjected to a range of atmospheric pressures from 101 kPa (~760 Torr) at sea level to 1.3×10-15 kPa (10-14 Torr) in space.	The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the pressure range that will be experienced during ground processing, launch ascent and on orbit. For verification testing, the vacuum test level should be ≤ 1×10-5 Torr.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.4	Launch Environment Launch Pressure Profile	The Instrument should function according to its operational specifications after being subjected to an atmospheric pressure decay rate of 7 kPa/s (53 Torr/s).	The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environments without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the maximum expected pressure decay rate during launch ascent and applies to LEO and GEO launch vehicles. The following sources provide information: Commercial Launch Vehicle User's Guides, NASA RFI responses, NASA GEVS and the GEOS R GIRD.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.5	Launch Environment Explosive Atmosphere	The instrument should operate in the presence of flammable vapors without initiating an explosion or fire.	The Instrument must able to withstand conditions typical of the AI&T, launch and on orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with conditions in and around the spacecraft bus and launch vehicle fairing during spacecraft integration, launch vehicle integration and processing, and launch ascent.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.6	Launch Environment Quasi-Static Acceleration	[LEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced quasi-static acceleration environment represented by the Mass Acceleration Curve (MAC) defined in Figure 8-4.	The Instrument must able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the quasi-static loads that will be experienced during launch ascent. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities* responses, *General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects and the Geostationary Operational Environmental Satellite (GOES) R (General Interface Requirement Document) GIRD.*

Environmental L2 Guidelines

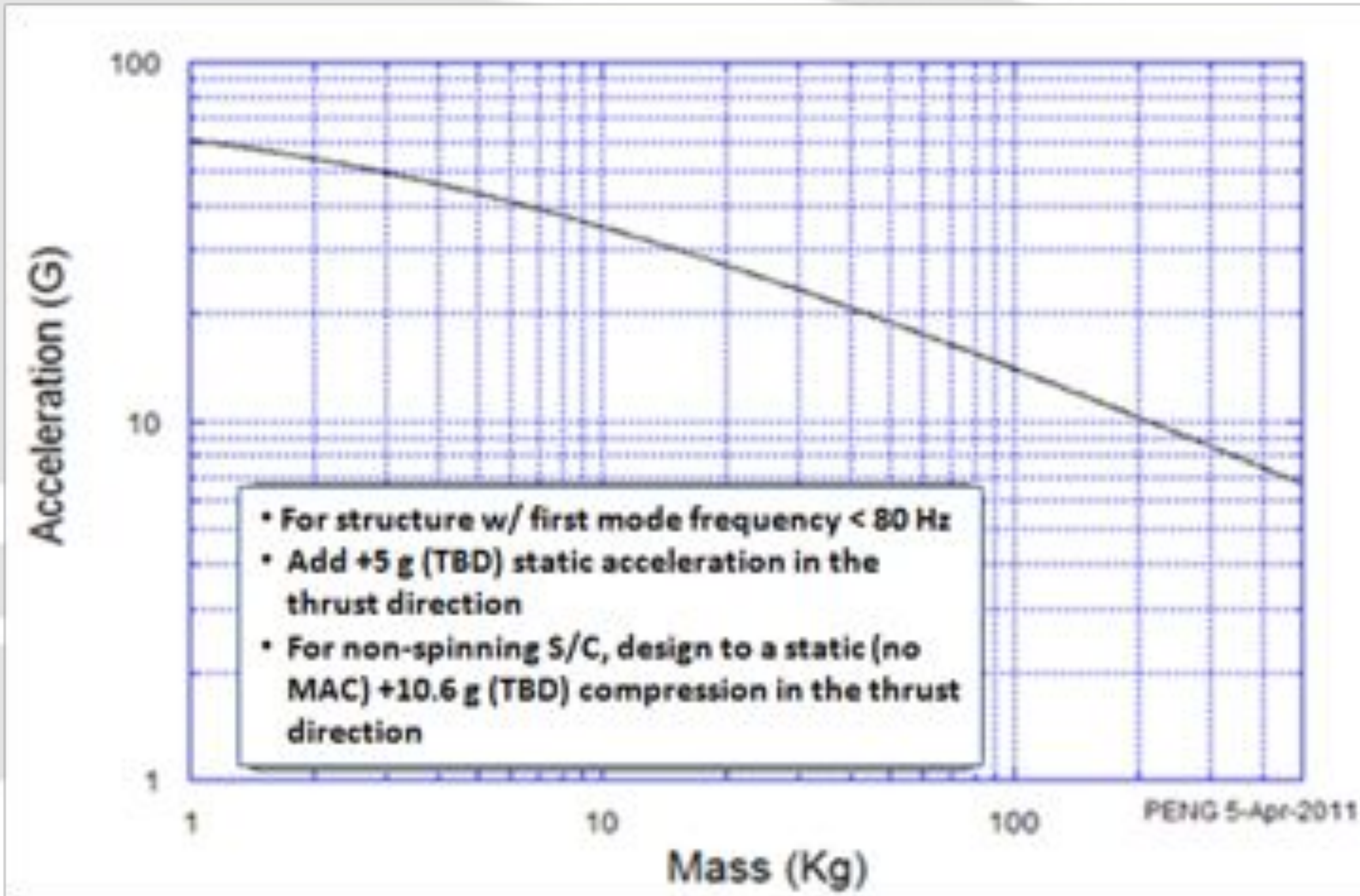


Figure 8-4: [LEO] Mass Acceleration Curve

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.6	Launch Environment Quasi-Static Acceleration	[GEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced quasi-static acceleration environment represented by the MAC defined in Table 8-1.	As previously specified

Table 8-1: [GEO] Mass Acceleration Curve

Mass (Kg)	Acceleration (g)
0 to 2.5	±55
2.5 to 30	$= \pm(-1.273\ Mass + 58.182)$
> 30	±20

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.7	Launch Environment Sinusoidal Vibration	The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the sinusoidal vibration environment defined in Table 8-2.	The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the coupled dynamics loads that will be experienced during ground processing and launch ascent. Data source is the composite of all publically available Launch Vehicle Payload Planner's Guidebooks.

Table 8-2: Sinusoidal Vibration Environment

Frequency (Hz)	Acceleration Amplitudes	
	Acceptance	Qualification
2 – 5	1.0 g peak	1.4 g peak
5 – 18	1.4 g peak	2.0 g peak
18 – 30	1.5 g peak	2.1 g peak
30 – 40	1.0 g peak	1.4 g peak
40 – 55	3.0 g peak	4.2 g peak
55 – 100	1.0 g peak	1.4 g peak
Acceptance Sweep Rate: From 5 to 100 Hz at 1.0 octaves/minute except from 40 to 55 Hz at 12 Hz/min		
Qualification Sweep Rate: From 5 to 100 Hz at 0.5 octaves/minute except from 40 to 55 Hz at 6 Hz/min		

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.8	Launch Environment Random Vibration	[LEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the random vibration environment defined in Table 8-3. All flight article test durations are to be 1 minute per axis. Non-flight article qualification test durations are to be 2 minutes per axis.	The random vibration design guidelines are derived from: (a) launch vehicle-induced acoustic excitations during liftoff, transonic and max-q events; and (b) mechanically transmitted vibration from the engines during upper stage burns. The Instrument must able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the random vibration that will be experienced during launch ascent. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities responses, NASA GEVS and the GOES R GIRD.*

Environmental L2 Guidelines

Table 8-3: [LEO] Random Vibration Environment

Zone/Assembly	Frequency (Hz)	Protoflight / Qualification	Acceptance
Instrument	20	0.026 g^2/Hz	0.013 g^2/Hz
	20 – 50	+6 dB/octave	+6 dB/octave
	50 - 800	0.16 g^2/Hz	0.08 g^2/Hz
	800 - 2000	-6 dB/octave	-6 dB/octave
	2000	0.026 g^2/Hz	0.013 g^2/Hz
	Overall	14.1 g_{rms}	10.0 g_{rms}

Table 8-3 represents the random vibration environment for instruments with mass less than or equal to 25 kg. Instruments with mass greater than 25 kg may apply the following random vibration environment reductions:

1)The acceleration spectral density (ASD) level may be reduced for components weighing more than 25 kg according to:

$$ASD_{new} = ASD_{original}*(25/M)$$

Where *M = instrument mass in kg*

2) The slope is to be maintained at ±6 dB/octave for instruments 887 with mass less than or equal to 65 kg. For instruments greater than 65 kg, the slope should be adjusted to maintain an ASD of 0.01 g2/Hz at 20 Hz and at 2000 Hz for qualification testing and an ASD of 0.005 g2/Hz at 20 Hz and at 2000 Hz for acceptance testing.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.8	Launch Environment Random Vibration	[GEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the random vibration environment defined in Table 8-4. All flight article test durations are to be 1 minute per axis. Protoflight and non-flight article qualification test durations are to be 3 minutes per axis.	As previously specified

Table 8-4: [GEO] Random Vibration Environment

Zone/Assembly	Frequency (Hz)	Protoflight / Qualification	Acceptance
Instrument	20	0.2 g^2/Hz	0.14 g^2/Hz
	20 - 45	+6 dB/octave	+6 dB/octave
	45 - 500	1.0 g^2/Hz	0.71 g^2/Hz
	500 - 2000	-6 dB/octave	-6 dB/octave
	2000	0.06 g^2/Hz	0.04 g^2/Hz
	Overall	28.9 g_{rms}	24.2 g_{rms}

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.9	Launch Environment Acoustic Noise	[LEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the acoustic noise spectra defined in Table 8-5. [GEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the acoustic noise spectra defined in Table 8-6.	Acoustic design guidelines are based on maximum internal payload fairing sound pressure level spectra. The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the acoustic noise that will be experienced during launch ascent. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities* responses, NASA GEVS and the GOES R GIRD. The acoustic noise design requirement for both the instrument and its assemblies is a reverberant random-incidence acoustic field specified in 1/3 octave bands. The design / qualification / protoflight exposure time is 2 minutes; acceptance exposure time is one minute.

Environmental L2 Guidelines

Table 8-5: [LEO] Acoustic Noise Environment

1/3 Octave Band Center Frequency (Hz)	Design/Qual/PF Sound Pressure Levels (dB re 20 µPa)	Flight Acceptance Sound Pressure Levels (dB re 20 µPa)
31.5	122.5	119.5
40	125.5	122.5
50	129.5	126.5
63	131.0	128.0
80	131.5	128.5
100	132.5	129.5
125	133.0	130.0
160	133.0	130.0
200	133.5	130.5
250	134.5	131.5
315	135.5	132.5
400	134.5	131.5
500	131.0	128.0
630	128.0	125.0
800	125.0	122.0
1000	123.0	120.0
1250	121.0	118.0
1600	120.0	117.0
2000	119.5	116.5
2500	119.0	116.0
3150	118.0	115.0
4000	116.5	113.5
5000	114.0	111.0
6300	110.0	107.0
8000	106.0	103.0
10000	103.0	100.0
Overall	**143.8**	**140.8**

Environmental L2 Guidelines

Table 8-6: [GEO] Acoustic Noise Environment

1/3 Octave Band Center Frequency (Hz)"	Design/Qual/Protoflight (dB w/ 20 μPa reference)"	Acceptance (dB w/ 20 μPa reference)"
25	128.23	125.23
31.5	132	129
40	133.5	130.5
50	134	131
63	135	132
80	136.6	133.6
100	137.4	134.4
125	136.3	133.3
160	137.1	134.1
200	137.23	134.23
250	138.2	135.2
315	139	136
400	137.5	134.5
500	134.23	131.23
630	134.23	131.23
800	131.5	128.5
1000	129.23	126.23
1250	129.23	126.23
1600	124.8	121.8
2000	125	122
2500	124.23	121.23
3150	121.5	118.5
4000	120	117
5000	120	117
6300	118	115
8000	118	115
10000	119	116

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.10	Launch Environment Mechanical Shock	[LEO] The Instrument should function according to its operational specifications after being subjected to a spacecraft to launch vehicle separation or other shock transient accelerations represented by Figure 8-5.	The Instrument must able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the mechanical shock that will be experienced during ground processing, launch ascent and on orbit. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities responses, NASA GEVS and the GOES R GIRD.*

Environmental L2 Guidelines

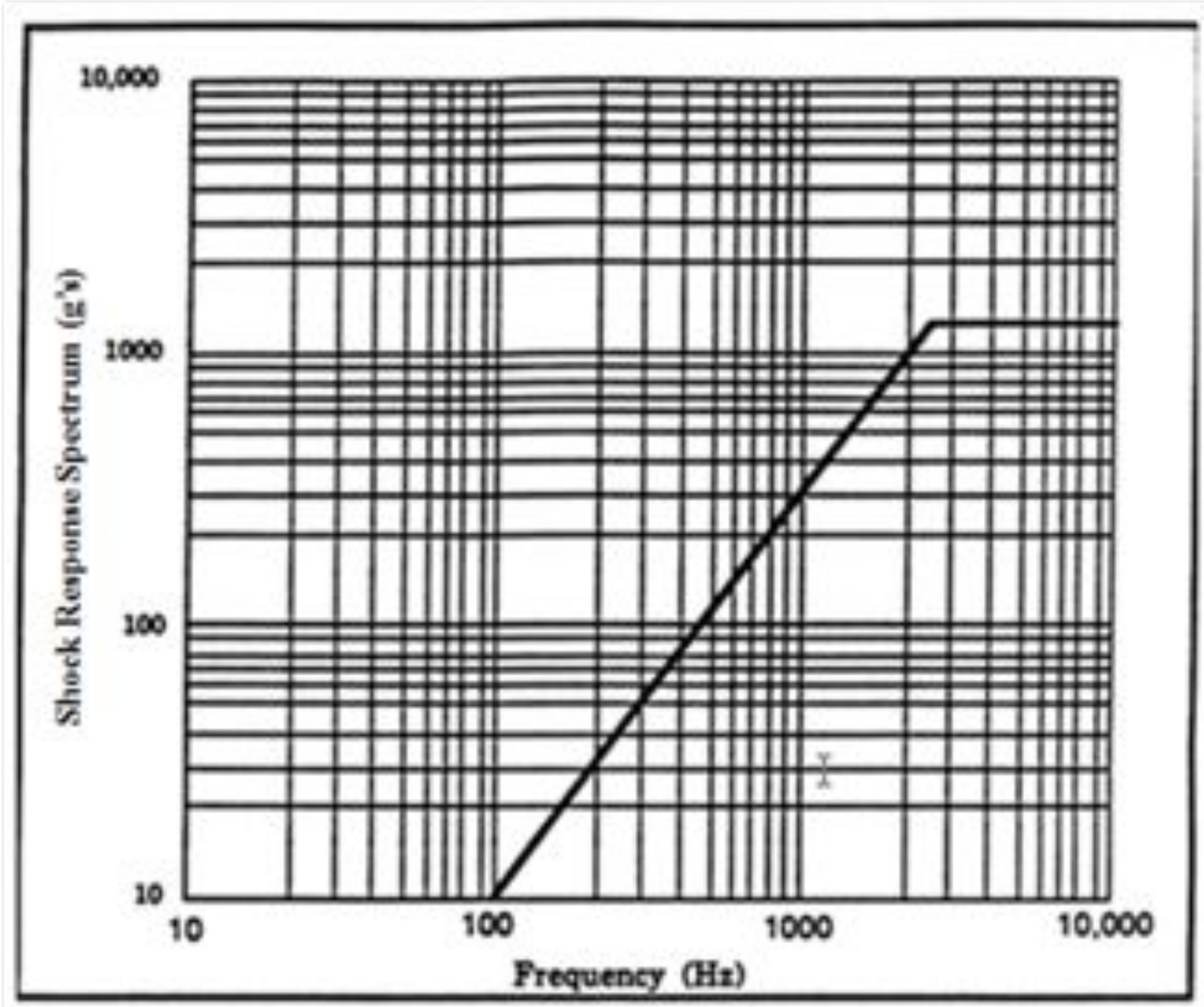


Figure 8-5: [LEO] Mechanical Shock Environment

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.10	Launch Environment Mechanical Shock	[GEO] The Instrument should function according to its operational specifications after being subjected to a spacecraft to launch vehicle separation or other shock transient accelerations represented by Table 8-7.	As previously specified

Table 8-7: [GEO] Mechanical Shock Environment

Frequency (Hz)	Acceleration (g)
100	115.1
600	2000
2000	5000
10000	5000

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.4.11	Launch Environment Mechanical Shock	The time-history of the Shock Response Spectrum (SRS) should be oscillatory and decay to within 10% of the peak value within 20 ms. Spacecraft to launch vehicle separation or other shock transients are defined at the instrument/spacecraft interface and the instrument should be designed and qualified to survive two shocks per axis. The guideline assumes that shock transients are generated externally to the instrument and attenuated to the level defined at the notated interface.	This guideline establishes the source and quantity of mechanical shock events that the Instrument must be able to withstand. The decay rate and amplitude specified are typical values for a pyrotechnic separation system shock event. Pyroshock design guidelines are intended to represent the structurally transmitted transients from explosive devices used to achieve various separations, including spacecraft separation from the upper stage motor. These values may be tailored based upon the shock environments anticipated/defined following the pairing of the Instrument and Host Spacecraft. This guidance represents the need to be compatible with the mechanical shock environment that an instrument will experience during launch ascent and during spacecraft and spacecraft payload deployments. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities responses, NASA GEVS and the GOES R GIRD.*

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.1	Operational Environment Orbital Acceleration	[LEO] The Instrument should function according to its operational specifications after being subjected to a maximum spacecraft-induced acceleration of 0.015g. [GEO] The Instrument should function according to its operational specifications after being subjected to a maximum spacecraft-induced acceleration of 0.04g.	The Instrument in its operational configuration must able to withstand conditions typical of the on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the Host Spacecraft or other payloads. This guidance represents the need to be compatible with the accelerations that will be experienced on-orbit. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities responses,* NASA GEVS and the GOES R GIRD.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.2	Operational Environment Corona	The Instrument should exhibit no effect of corona or other forms of electrical breakdown after being subjected to a range of ambient pressures from 101 kPa (~760 Torr) at sea level to 1.3×10-15 kPa (10-14 Torr) in space.	The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the environment that will be experienced during ground processing, launch ascent and on orbit as defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities responses, NASA GEVS and the GOES R* GIRD.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.3	Operational Environment Thermal Environment	The Instrument should function according to its operational specifications after being subjected to a thermal environment characterized by Table 8-8.	The Instrument must be able to withstand conditions typical of the on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. While the Earth albedo and long wave infrared radiation are non-zero values at GEO, their contribution to the overall thermal environment is less than 0.05% of that from solar flux.

Table 8-8: Thermal Radiation Environment

Domain	Solar Flux	Earth Albedo	Earth IR (Long Wave)
LEO	1290 to 1420 W/m^2	0.275 to 0.375	222 to 243 W/m^2
GEO		Insignificant	Insignificant

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.4	Operational Environment Radiation Design Margin	Every hardware component of the Instrument should have a minimum RDM value of two.	Exposure to radiation degrades many materials and will require mitigation to assure full instrument function over the design mission lifetime. This guidance defines the need to carry 100% margin against the estimated amount of radiation exposure that will be experienced in Earth orbit in support of said mitigation. A Radiation Design Margin (RDM) for a given electronic part (with respect to a given radiation environment) is defined as the ratio of that part's capability (with respect to that environment and its circuit application) to the environment level at the part's location.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.5	Operational Environment Total Ionizing Dose	[LEO] The Instrument should function according to its operational specifications during and after exposure to the Total Ionizing Dose (TID) radiation environment of Table 8-9 over a two year mission life. The TID of Table 8-9 contains no margin or uncertainty factors. [GEO] The Instrument should function according to its operational specifications during and after exposure to the TID radiation environment of Table 8-10 over a two year mission life. Table 8-10 contains no margin or uncertainty factors.	Exposure to ionizing radiation degrades many materials and electronics in particular, and will require mitigation to assure full instrument function over the design mission lifetime. Mitigation is typically achieved through application of the appropriate thickness of shielding. The LEO TID radiation environment is representative of exposure from an 813 km, sun-synchronous orbit. GEO data come from the *CII RFI for GEO Hosted Payload Opportunities responses and The Radiation Model for Electronic Devices on GOES-R Series Spacecraft (417-R-RPT-0027).* The TID varies linearly with respect to time and may be scaled to be representative of both shorter and longer mission durations.

Environmental L2 Guidelines

Table 8-9: [LEO] Total Ionizing Dose Radiation Environment

Shield Thickness (mil)	Trapped Electrons Rad [Si]	Bremsstrahlung Rad [Si]	Trapped Protons Rad [Si]	Solar Protons Rad [Si]	Total Rad [Si]
1	1.09E+06	1.84E+03	5.24E+04	6.52E+04	1.21E+06
3	5.23E+05	1.03E+03	1.70E+04	2.81E+04	5.69E+05
4	3.99E+05	8.30E+02	1.29E+04	2.18E+04	4.35E+05
6	2.44E+05	5.70E+02	8.86E+03	1.48E+04	2.68E+05
7	1.98E+05	4.87E+02	7.70E+03	1.29E+04	2.19E+05
9	1.38E+05	3.72E+02	6.30E+03	1.04E+04	1.55E+05
10	1.18E+05	3.32E+02	5.79E+03	9.47E+03	1.34E+05
12	9.04E+04	2.70E+02	5.01E+03	7.92E+03	1.04E+05
13	8.03E+04	2.46E+02	4.72E+03	7.31E+03	9.25E+04
15	6.45E+04	2.08E+02	4.28E+03	6.28E+03	7.53E+04
29	2.31E+04	9.80E+01	2.80E+03	2.96E+03	2.90E+04
44	1.23E+04	6.33E+01	2.18E+03	1.94E+03	1.65E+04
58	7.93E+03	4.75E+01	1.89E+03	1.47E+03	1.13E+04
73	5.24E+03	3.71E+01	1.70E+03	1.14E+03	8.12E+03
87	3.66E+03	3.06E+01	1.57E+03	9.30E+02	6.19E+03
117	1.81E+03	2.22E+01	1.39E+03	6.40E+02	3.86E+03
146	9.59E+02	1.76E+01	1.28E+03	4.52E+02	2.71E+03
182	4.38E+02	1.40E+01	1.19E+03	3.13E+02	1.95E+03
219	1.90E+02	1.17E+01	1.12E+03	2.47E+02	1.56E+03
255	8.38E+01	1.01E+01	1.06E+03	2.20E+02	1.38E+03
292	3.55E+01	8.97E+00	1.02E+03	1.98E+02	1.26E+03
365	5.72E+00	7.43E+00	9.34E+02	1.61E+02	1.11E+03
437	6.98E-01	6.46E+00	8.76E+02	1.38E+02	1.02E+03
510	4.96E-02	5.77E+00	8.32E+02	1.22E+02	9.60E+02
583	7.76E-04	5.26E+00	7.77E+02	1.05E+02	8.87E+02
656	1.06E-05	4.85E+00	7.38E+02	9.35E+01	8.36E+02
729	1.37E-07	4.49E+00	7.06E+02	8.50E+01	7.95E+02
875	0.00E+00	3.92E+00	6.42E+02	7.02E+01	7.16E+02
1167	0.00E+00	3.14E+00	5.42E+02	5.09E+01	5.96E+02
1458	0.00E+00	2.61E+00	4.67E+02	3.90E+01	5.09E+02

Table 8-10: [GEO] Total Ionizing Dose Radiation Environment

Aluminum Sheild Thickness (mils)	Total Dose Rad (SI)
0	2.09E+08
10	2.62E+07
20	9.64E+06
30	4.78E+06
40	2.70E+06
50	1.60E+06
60	1.01E+06
70	6.60E+05
80	4.44E+05
90	3.19E+05
100	2.31E+05
110	1.69E+05
120	1.26E+05
130	9.37E+04
140	6.67E+04
150	5.26E+04
160	3.94E+04
170	2.87E+04
180	2.36E+04
190	1.88E+04
200	1.43E+04
210	1.17E+04
220	1.01E+04
230	8.57E+03
240	7.10E+03
250	5.96E+03
260	5.28E+03
270	4.63E+03
280	4.01E+03
290	3.41E+03
300	2.90E+03

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.6	Operational Environment Single Event Effects	[LEO] The Instrument should function according to its specifications in its operational environment when exposed to multi-proton nuclei from galactic cosmic rays as defined by Figure 8-9 and Table 8-11.	Exposure to galactic cosmic rays and high energy protons may cause single events (*i.e. single event latch-up, single event upset, and single event burn-out) to occur in sensitive* electronics. This guidance defines the need for the hosted payload instrument to operate during exposure to galactic cosmic rays and high energy protons. This guidance also provides information required for the prediction of the single events induced by exposure of sensitive electronics to galactic cosmic rays and high energy protons. Predictions of single events (*i.e. single event latch-up, single event upset, and single event burn* out) induced by galactic cosmic ray ions and high energy protons should be performed separately and the results combined. The integral Galactic Cosmic Ray Linear Energy Transfer (LET) spectrum provided in Figure 8-9 and Table 8-11 should be used to predict ion-induced single events. The difference proton fluence in Figure 8-10 and Table 8-12, which consists of trapped protons and galactic cosmic ray protons, should be used to predict proton-induced single events in the absence of solar flares. The difference proton fluence in Figure 8-11 and Table 8-13, which consists of trapped protons, galactic cosmic ray protons, and solar flare protons, should be used to predict proton-induced single events with solar flares.

Environmental L2 Guidelines

Table 8-11: [LEO] Total Integral Galactic Cosmic Ray LET Spectrum

INTEGRAL COSMIC RAY LET SPECTRA FOR ELEMENTS Z > 1
I=98 DEG, H=705/705 KM (SINGLY IONIZED WITH SHADOW)
SOLID ALUMINUM SPHERE SHIELDING

LET				LET SPECTRA		
MEV/CM	MEV*SQCM/MG	PC/CM	PC*SQCM/MG	0.03 inches #/SQCM/DAY	0.15 inches #/SQCM/DAY	0.50 inches #/SQCM/DAY
1.00E+00	4.10E-04	4.55E-02	1.86E-05	1.39E+04	1.38E+04	1.38E+04
1.26E+00	5.16E-04	5.73E-02	2.35E-05	1.39E+04	1.38E+04	1.38E+04
1.58E+00	6.48E-04	7.18E-02	2.94E-05	1.39E+04	1.38E+04	1.38E+04
2.00E+00	8.20E-04	9.09E-02	3.73E-05	1.39E+04	1.38E+04	1.38E+04
3.98E+00	1.63E-03	1.81E-01	7.41E-05	1.44E+04	1.44E+04	1.44E+04
5.01E+00	2.05E-03	2.28E-01	9.33E-05	1.36E+04	1.36E+04	1.35E+04
6.31E+00	2.59E-03	2.87E-01	1.18E-04	1.47E+04	1.46E+04	1.45E+04
7.94E+00	3.25E-03	3.61E-01	1.48E-04	1.60E+04	1.60E+04	1.58E+04
1.00E+01	4.10E-03	4.55E-01	1.86E-04	1.70E+04	1.70E+04	1.67E+04
1.26E+01	5.16E-03	5.73E-01	2.35E-04	1.75E+04	1.75E+04	1.72E+04
1.58E+01	6.48E-03	7.18E-01	2.94E-04	1.43E+04	1.42E+04	1.40E+04
2.00E+01	8.20E-03	9.09E-01	3.73E-04	7.49E+03	7.38E+03	7.23E+03
3.98E+01	1.63E-02	1.81E+00	7.41E-04	2.69E+03	2.64E+03	2.55E+03
5.01E+01	2.05E-02	2.28E+00	9.33E-04	2.14E+03	2.10E+03	2.02E+03
6.31E+01	2.59E-02	2.87E+00	1.18E-03	1.81E+03	1.78E+03	1.69E+03
7.94E+01	3.25E-02	3.61E+00	1.48E-03	1.61E+03	1.57E+03	1.51E+03
1.00E+02	4.10E-02	4.55E+00	1.86E-03	1.44E+03	1.39E+03	1.34E+03
1.26E+02	5.16E-02	5.73E+00	2.35E-03	1.30E+03	1.28E+03	1.23E+03
1.58E+02	6.48E-02	7.18E+00	2.94E-03	1.05E+03	1.03E+03	9.82E+02
2.00E+02	8.20E-02	9.09E+00	3.73E-03	8.85E+02	8.63E+02	8.32E+02
3.98E+02	1.63E-01	1.81E+01	7.41E-03	4.06E+02	3.97E+02	3.78E+02
5.01E+02	2.05E-01	2.28E+01	9.33E-03	3.27E+02	3.21E+02	3.05E+02
6.31E+02	2.59E-01	2.87E+01	1.18E-02	2.47E+02	2.44E+02	2.31E+02
7.94E+02	3.25E-01	3.61E+01	1.48E-02	1.81E+02	1.78E+02	1.68E+02
1.00E+03	4.10E-01	4.55E+01	1.86E-02	1.32E+02	1.30E+02	1.22E+02
1.26E+03	5.16E-01	5.73E+01	2.35E-02	1.02E+02	1.00E+02	9.42E+01
1.58E+03	6.48E-01	7.18E+01	2.94E-02	8.14E+01	8.01E+01	7.55E+01
2.00E+03	8.20E-01	9.09E+01	3.73E-02	6.51E+01	6.41E+01	6.04E+01
3.98E+03	1.63E+00	1.81E+02	7.41E-02	1.11E+01	1.06E+01	9.50E+00
5.01E+03	2.05E+00	2.28E+02	9.33E-02	6.09E+00	5.84E+00	5.26E+00
6.31E+03	2.59E+00	2.87E+02	1.18E-01	3.49E+00	3.31E+00	3.02E+00
7.94E+03	3.25E+00	3.61E+02	1.48E-01	2.07E+00	1.94E+00	1.77E+00
1.00E+04	4.10E+00	4.55E+02	1.86E-01	1.24E+00	1.12E+00	1.03E+00
1.26E+04	5.16E+00	5.73E+02	2.35E-01	7.04E-01	6.38E-01	5.88E-01
1.58E+04	6.48E+00	7.18E+02	2.94E-01	4.12E-01	3.62E-01	3.39E-01
2.00E+04	8.20E+00	9.09E+02	3.73E-01	2.44E-01	2.07E-01	1.93E-01
3.98E+04	1.63E+01	1.81E+03	7.41E-01	3.84E-02	2.90E-02	2.67E-02
5.01E+04	2.05E+01	2.28E+03	9.33E-01	1.73E-02	1.27E-02	1.17E-02
6.31E+04	2.59E+01	2.87E+03	1.18E+00	4.48E-03	3.12E-03	2.83E-03
7.94E+04	3.25E+01	3.61E+03	1.48E+00	1.11E-05	1.22E-05	9.94E-06
1.00E+05	4.10E+01	4.55E+03	1.86E+00	4.44E-06	4.99E-06	3.90E-06
1.26E+05	5.16E+01	5.73E+03	2.35E+00	1.81E-06	2.06E-06	1.62E-06
1.58E+05	6.48E+01	7.18E+03	2.94E+00	5.51E-07	6.46E-07	4.91E-07
2.00E+05	8.20E+01	9.09E+03	3.73E+00	1.28E-07	1.49E-07	1.12E-07
1.00E+06	4.10E+02	4.55E+04	1.86E+01	0.00E+00	0.00E+00	0.00E+00

Environmental L2 Guidelines

Table 8-12: [LEO] Total Differential Fluence of Trapped Protons and Galactic Cosmic Ray Protons

Surface Incident Energy (MeV)	Surface Incident Fluence (p/sqcm*MeV)	Emerging Energy (MeV)	Particles Emerging Behind Tantalum Spheres			Aluminum Spheres
			30 mils-TA (p/sqcm*MeV*5yrs)	150 mils-TA (p/sqcm*MeV*5yrs)	500 mils-TA (p/sqcm*MeV*5yrs)	100 mils-AL (p/sqcm*MeV*5yrs)
4.00E-02	1.41E+13	1.30E-01	-	2.07E+07	5.91E+06	1.12E+07
7.00E-02	1.10E+13	1.60E-01	8.20E+07	1.84E+07	5.27E+06	1.20E+07
1.00E-01	8.31E+12	2.00E-01	7.31E+07	1.64E+07	4.70E+06	1.29E+07
5.00E-01	6.11E+11	4.00E-01	5.17E+07	1.16E+07	3.33E+06	1.70E+07
1.00E+00	1.31E+10	5.00E-01	4.61E+07	1.04E+07	2.97E+06	1.93E+07
2.00E+00	3.36E+10	6.30E-01	4.23E+07	9.50E+06	2.72E+06	2.19E+07
3.00E+00	9.87E+09	7.90E-01	4.19E+07	9.41E+06	2.70E+06	2.49E+07
4.00E+00	8.10E+09	1.00E+00	4.35E+07	9.77E+06	2.80E+06	2.86E+07
5.00E+00	4.94E+09	2.00E+00	4.99E+07	1.28E+07	3.66E+06	4.53E+07
6.00E+00	3.12E+09	3.98E+00	7.39E+07	1.89E+07	5.41E+06	7.45E+07
8.00E+00	1.48E+09	5.01E+00	8.56E+07	2.19E+07	6.27E+06	8.35E+07
1.00E+01	1.06E+09	6.31E+00	8.56E+07	2.55E+07	7.30E+06	9.25E+07
2.00E+01	3.02E+08	7.94E+00	8.89E+07	2.99E+07	8.55E+06	1.10E+08
3.00E+01	1.66E+08	1.00E+01	1.01E+08	3.51E+07	1.00E+07	9.91E+07
4.00E+01	1.34E+08	2.00E+01	1.05E+08	4.58E+07	1.66E+07	1.08E+08
5.00E+01	1.21E+08	3.98E+01	1.03E+08	6.08E+07	2.12E+07	1.07E+08
6.00E+01	1.16E+08	5.01E+01	1.03E+08	5.99E+07	2.37E+07	1.04E+08
8.00E+01	8.79E+07	6.31E+01	8.67E+07	5.97E+07	2.54E+07	8.96E+07
1.00E+02	7.25E+07	7.94E+01	7.18E+07	5.11E+07	2.37E+07	7.35E+07
2.00E+02	2.44E+07	1.00E+02	5.66E+07	4.10E+07	2.33E+07	5.78E+07
3.00E+02	8.82E+06	2.00E+02	1.91E+07	1.54E+07	1.05E+07	1.92E+07
4.00E+02	3.39E+06	3.98E+02	2.82E+06	2.07E+06	1.49E+06	2.64E+06
5.00E+02	1.40E+06	5.01E+02	8.43E+05	3.94E+05	2.65E+05	6.37E+05
6.00E+02	1.58E+05	6.31E+02	1.51E+05	1.47E+05	1.43E+05	1.50E+05
8.00E+02	1.37E+05	7.94E+02	1.34E+05	1.28E+05	1.23E+05	1.31E+05
1.00E+03	1.14E+05	1.00E+03	1.10E+05	1.03E+05	9.76E+04	1.07E+05
2.00E+03	5.15E+04	2.00E+03	4.97E+04	4.59E+04	4.27E+04	4.72E+04
3.00E+03	2.81E+04	3.98E+03	1.68E+04	1.52E+04	1.40E+04	1.59E+04
4.00E+03	1.77E+04	5.01E+03	1.18E+04	1.09E+04	1.01E+04	1.12E+04
5.00E+03	1.23E+04	6.31E+03	8.03E+03	7.40E+03	6.86E+03	7.62E+03
8.00E+03	5.84E+03	7.94E+03	5.60E+03	5.13E+03	4.58E+03	5.33E+03
1.00E+04	4.09E+03	1.00E+4	1.07E-11	-	-	-

Environmental L2 Guidelines

Table 8-13: [LEO] Total Differential Fluence of Trapped Protons, Galactic Cosmic Ray Protons, and Solar Flare Protons

Surface Incident Energy (MeV)	Surface Incident Fluence (p/sqcm*MeV)	Emerging Energy (MeV)	Particles Emerging Behind Tantalum Spheres			Aluminum Spheres
			30 mils-TA (p/sqcm*MeV *5yrs)	150 mils-TA (p/sqcm*MeV *5yrs)	500 mils-TA (p/sqcm*MeV *5yrs)	100 mils-AL (p/sqcm*MeV*5yrs)
4.00E-02	1.33E+13	1.30E-01	-	2.83E+07	5.11E+06	2.03E+07
7.00E-02	1.03E+13	1.60E-01	1.49E+08	2.52E+07	4.56E+06	2.17E+07
1.00E-01	7.64E+12	2.00E-01	1.33E+08	2.25E+07	4.06E+06	2.33E+07
5.00E-01	5.05E+11	4.00E-01	9.39E+07	1.59E+07	2.87E+06	3.09E+07
1.00E+00	8.22E+10	5.00E-01	8.37E+07	1.42E+07	2.56E+06	3.50E+07
2.00E+00	1.15E+10	6.30E-01	7.68E+07	1.30E+07	2.35E+06	3.98E+07
3.00E+00	5.64E+09	7.90E-01	7.61E+07	1.29E+07	2.33E+06	4.51E+07
4.00E+00	3.80E+09	1.00E+00	7.90E+07	1.34E+07	2.42E+06	5.20E+07
5.00E+00	2.54E+09	2.00E+00	9.44E+07	1.75E+07	3.16E+06	8.22E+07
6.00E+00	1.64E+09	3.98E+00	1.40E+08	2.59E+07	4.68E+06	1.35E+08
8.00E+00	1.28E+09	5.01E+00	1.62E+08	3.00E+07	5.42E+06	1.54E+08
1.00E+01	1.05E+09	6.31E+00	1.65E+08	3.49E+07	6.31E+06	1.75E+08
2.00E+01	5.19E+08	7.94E+00	1.74E+08	4.09E+07	7.39E+06	2.08E+08
3.00E+01	3.47E+08	1.00E+01	2.00E+08	4.81E+07	8.68E+06	1.94E+08
4.00E+01	2.62E+08	2.00E+01	2.12E+08	5.98E+07	1.43E+07	2.20E+08
5.00E+01	2.03E+08	3.98E+01	1.65E+08	6.99E+07	1.78E+07	1.76E+08
6.00E+01	1.61E+08	5.01E+01	1.41E+08	6.45E+07	1.96E+07	1.44E+08
8.00E+01	1.00E+08	6.31E+01	1.01E+08	5.80E+07	2.05E+07	1.07E+08
1.00E+02	6.80E+07	7.94E+01	7.15E+07	4.57E+07	1.84E+07	7.37E+07
2.00E+02	1.72E+07	1.00E+02	5.04E+07	3.43E+07	1.75E+07	5.16E+07
3.00E+02	5.97E+06	2.00E+02	1.34E+07	1.07E+07	7.19E+06	1.34E+07
4.00E+02	2.20E+06	3.98E+02	1.80E+06	1.30E+06	8.92E+05	1.68E+06
5.00E+02	8.51E+05	5.01E+02	4.30E+05	1.50E+05	8.60E+04	2.85E+05
6.00E+02	3.65E+04	6.31E+02	3.73E+04	3.77E+04	3.78E+04	3.76E+04
8.00E+02	3.83E+04	7.94E+02	3.82E+04	3.79E+04	3.76E+04	3.81E+04
1.00E+03	3.70E+04	1.00E+03	3.63E+04	3.52E+04	3.44E+04	3.59E+04
2.00E+03	2.57E+04	2.00E+03	2.52E+04	2.39E+04	2.28E+04	2.43E+04
3.00E+03	1.72E+04	3.98E+03	1.17E+04	1.08E+04	1.02E+04	1.12E+04
4.00E+03	1.22E+04	5.01E+03	8.85E+03	8.28E+03	7.77E+03	8.46E+03
5.00E+03	9.16E+03	6.31E+03	6.45E+03	6.02E+03	5.65E+03	6.17E+03
8.00E+03	4.93E+03	7.94E+03	4.76E+03	4.41E+03	3.98E+03	4.56E+03
1.00E+04	3.61E+03	1.00E+04	1.26E-11	-	-	-

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.7	Operational Environment [GEO] Single Event Effect Occurrence Rate	The Instrument should function according to its specifications in its operational environment with a critical Single Event Effect (SEE) rate of < 1 per 1000 years where "critical" is defined as any SEE requiring intervention by the ground for resolution.	This guidance supports the design and selection of electronic devices that are compatible with the environment that will be experienced during operation in GEO as defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities responses* and 417-R-RPT-0027.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.8	Operational Environment [GEO] Heavy Ion Induced Single Event Effects	The Instrument should function according to its specifications in its operational environment after being subjected to the LET spectra from galactic cosmic rays and solar heavy ions as defined in Table 8-14, Table 8-15, Figure 8-12 and Figure 8-13.	Some electronics are sensitive to heavy ion exposure because of the ability of such ions to penetrate into sensitive regions of electronics devices and directly deposit charge. Heavy ion populations that have sufficient numbers to represent a SEE hazard are those associated with Galactic Cosmic Rays (GCRs) and solar events. The quantity used most frequently to measure an ions ability to deposit charge in a device is LET. Heavy ion abundances are converted to total LET spectra. Once specific parts are selected, the LET spectra are integrated with device characterization to calculate SEE rates. This guidance supports the selection of electronic devices that are compatible with the heavy ion environment that will be experienced during operation in GEO as defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities responses and 417-R-RPT-0027.*

Environmental L2 Guidelines

Table 8-14: [GEO] Integral LET for Galactic Cosmic Rays (Z = 1-92)

100 mils Aluminum Shielding
Values Do Not Include Design Margins

LET	LET Fluence	LET	LET Fluence
MeV*sqcm/mg	#/sqcm/day	MeV*sqcm/mg	#/sqcm/day
	Solar Minimum		Solar Maximum
1.00E-03	4.25E+05	1.00E-03	1.54E+05
1.65E-03	4.24E+05	1.65E-03	1.54E+05
1.69E-03	3.29E+05	1.69E-03	1.07E+05
1.70E-03	3.04E+05	1.70E-03	9.42E+04
1.72E-03	2.84E+05	1.72E-03	8.46E+04
1.77E-03	2.54E+05	1.77E-03	7.02E+04
1.81E-03	2.30E+05	1.81E-03	5.98E+04
1.85E-03	2.12E+05	1.85E-03	5.20E+04
1.91E-03	1.90E+05	1.91E-03	4.34E+04
1.98E-03	1.72E+05	1.98E-03	3.75E+04
2.01E-03	1.67E+05	2.01E-03	3.59E+04
2.13E-03	1.46E+05	2.13E-03	3.05E+04
2.28E-03	1.27E+05	2.28E-03	2.69E+04
2.53E-03	1.07E+05	2.53E-03	2.39E+04
3.01E-03	8.29E+04	3.01E-03	2.11E+04
3.54E-03	6.87E+04	3.54E-03	1.98E+04
4.52E-03	5.55E+04	4.52E-03	1.88E+04
5.56E-03	4.90E+04	5.56E-03	1.83E+04
6.54E-03	4.58E+04	6.54E-03	1.82E+04
7.52E-03	2.76E+04	7.52E-03	7.46E+03
8.55E-03	2.13E+04	8.55E-03	5.04E+03
9.60E-03	1.75E+04	9.60E-03	3.97E+03
1.97E-02	7.02E+03	1.97E-02	1.88E+03
2.96E-02	5.07E+03	2.96E-02	1.63E+03
4.00E-02	4.33E+03	4.00E-02	1.55E+03
5.04E-02	3.81E+03	5.04E-02	1.43E+03
6.00E-02	3.50E+03	6.00E-02	1.36E+03
6.97E-02	2.91E+03	6.97E-02	1.08E+03
8.01E-02	2.66E+03	8.01E-02	1.01E+03
9.00E-02	2.40E+03	9.00E-02	9.12E+02
1.01E-01	2.23E+03	1.01E-01	8.74E+02
2.00E-01	9.84E+02	2.00E-01	3.59E+02
4.02E-01	4.33E+02	4.02E-01	1.52E+02

100 mils Aluminum Shielding
Values Do Not Include Design Margins

LET	LET Fluence	LET	LET Fluence
MeV*sqcm/mg	#/sqcm/day	MeV*sqcm/mg	#/sqcm/day
	Solar Minimum		Solar Maximum
6.03E-01	2.90E+02	6.03E-01	1.10E+02
7.96E-01	2.23E+02	7.96E-01	8.84E+01
1.00E+00	1.79E+02	1.00E+00	7.22E+01
2.01E+00	3.39E+01	2.01E+00	5.88E+00
3.02E+00	1.43E+01	3.02E+00	2.03E+00
3.99E+00	7.76E+00	3.99E+00	1.02E+00
5.03E+00	4.59E+00	5.03E+00	5.81E-01
5.99E+00	3.07E+00	5.99E+00	3.80E-01
8.00E+00	1.55E+00	8.00E+00	1.90E-01
1.01E+01	9.00E-01	1.01E+01	1.10E-01
1.11E+01	7.17E-01	1.11E+01	8.75E-02
1.20E+01	5.76E-01	1.20E+01	7.04E-02
1.30E+01	4.67E-01	1.30E+01	5.71E-02
1.40E+01	3.85E-01	1.40E+01	4.72E-02
1.50E+01	3.16E-01	1.50E+01	3.88E-02
1.60E+01	2.61E-01	1.60E+01	3.20E-02
1.70E+01	2.20E-01	1.70E+01	2.71E-02
1.80E+01	1.85E-01	1.80E+01	2.27E-02
1.91E+01	1.54E-01	1.91E+01	1.89E-02
2.00E+01	1.30E-01	2.00E+01	1.60E-02
2.49E+01	4.45E-02	2.49E+01	5.50E-03
3.00E+01	6.27E-04	3.00E+01	8.18E-05
3.49E+01	6.86E-05	3.49E+01	1.06E-05
4.01E+01	4.18E-05	4.01E+01	6.50E-06
4.50E+01	2.83E-05	4.50E+01	4.42E-06
5.00E+01	2.00E-05	5.00E+01	3.13E-06
5.06E+01	1.92E-05	5.06E+01	3.00E-06
5.55E+01	1.34E-05	5.55E+01	2.11E-06
6.02E+01	9.38E-06	6.02E+01	1.49E-06
6.53E+01	6.32E-06	6.53E+01	1.01E-06
7.00E+01	4.40E-06	7.00E+01	7.01E-07
7.50E+01	2.83E-06	7.50E+01	4.52E-07
8.04E+01	1.65E-06	8.04E+01	2.63E-07
8.52E+01	7.71E-07	8.52E+01	1.23E-07
9.03E+01	1.94E-07	9.03E+01	3.10E-08
9.57E+01	2.88E-08	9.57E+01	4.60E-09
1.00E+02	1.19E-08	1.00E+02	1.89E-09
1.01E+02	5.27E-09	1.01E+02	8.41E-10
1.03E+02	2.54E-09	1.03E+02	4.05E-10

Environmental L2 Guidelines

Table 8-15: [GEO] Integral LET Solar Particles w/ 1989 Solar Particle Event Basis (Z = 1-92)

100 mils Aluminum Shielding
Values Do Not Include Design Margins

LET	LET Fluence	LET Fluence	LET Fluence
MeV*cm^2/mg	#/cm^2/s	#/cm^2/s	#/cm^2/s
	Average Over Peak	Average Over Worst Day	Average Over Worst Week
1.00E-03	1.93E+05	5.21E+04	1.15E+04
2.01E-03	1.93E+05	5.21E+04	1.15E+04
3.01E-03	1.93E+05	5.20E+04	1.14E+04
4.02E-03	1.92E+05	5.17E+04	1.13E+04
5.01E-03	1.90E+05	5.11E+04	1.11E+04
6.03E-03	1.86E+05	5.02E+04	1.08E+04
7.02E-03	1.82E+05	4.90E+04	1.05E+04
7.97E-03	1.77E+05	4.76E+04	1.01E+04
8.95E-03	1.71E+05	4.60E+04	9.68E+03
1.01E-02	1.64E+05	4.40E+04	9.19E+03
1.99E-02	9.60E+04	2.55E+04	5.07E+03
2.99E-02	5.39E+04	1.43E+04	2.78E+03
4.00E-02	3.23E+04	8.56E+03	1.65E+03
4.98E-02	2.11E+04	5.59E+03	1.07E+03
6.00E-02	1.45E+04	3.84E+03	7.33E+02
6.97E-02	1.06E+04	2.81E+03	5.34E+02
8.01E-02	7.91E+03	2.09E+03	3.96E+02
9.00E-02	6.16E+03	1.63E+03	3.08E+02
9.99E-02	4.90E+03	1.29E+03	2.44E+02
2.00E-01	9.50E+02	2.51E+02	4.67E+01
3.01E-01	3.15E+02	8.31E+01	1.53E+01
4.02E-01	1.25E+02	3.32E+01	6.08E+00
5.01E-01	3.82E+01	1.01E+01	1.80E+00
6.03E-01	1.86E+01	4.94E+00	8.78E-01
7.01E-01	1.35E+01	3.58E+00	6.52E-01
8.05E-01	9.85E+00	2.62E+00	4.91E-01
9.04E-01	7.55E+00	2.02E+00	3.87E-01
1.00E+00	5.88E+00	1.57E+00	3.10E-01
2.01E+00	7.49E-01	2.06E-01	5.99E-02
3.02E+00	4.11E-01	1.13E-01	3.33E-02
3.99E+00	2.64E-01	7.29E-02	2.14E-02
5.03E+00	1.74E-01	4.80E-02	1.42E-02
6.06E+00	1.21E-01	3.36E-02	9.92E-03
7.04E+00	8.68E-02	2.40E-02	7.11E-03
8.00E+00	6.39E-02	1.77E-02	5.26E-03
8.99E+00	5.04E-02	1.40E-02	4.13E-03
1.01E+01	3.85E-02	1.07E-02	3.15E-03
2.00E+01	5.75E-03	1.60E-03	4.63E-04
2.52E+01	2.14E-03	5.95E-04	1.72E-04

100 mils Aluminum Shielding
Values Do Not Include Design Margins

LET	LET Fluence	LET Fluence	LET Fluence
MeV*cm^2/mg	#/cm^2/s	#/cm^2/s	#/cm^2/s
	Average Over Peak	Average Over Worst Day	Average Over Worst Week
3.00E+01	1.83E-05	5.10E-06	1.55E-06
3.53E+01	7.23E-07	2.01E-07	7.14E-08
4.01E+01	3.26E-07	9.08E-08	3.43E-08
4.50E+01	1.95E-07	5.44E-08	2.12E-08
5.00E+01	1.36E-07	3.78E-08	1.48E-08
5.55E+01	8.43E-08	2.35E-08	9.31E-09
6.02E+01	4.92E-08	1.37E-08	5.58E-09
6.53E+01	3.28E-08	9.12E-09	3.75E-09
7.00E+01	2.49E-08	6.92E-09	2.84E-09
7.50E+01	1.80E-08	5.00E-09	2.04E-09
8.04E+01	1.20E-08	3.34E-09	1.36E-09
8.52E+01	6.69E-09	1.86E-09	7.56E-10
9.03E+01	2.03E-09	5.64E-10	2.29E-10
9.46E+01	1.33E-10	3.71E-11	1.51E-11
1.00E+02	5.01E-11	1.39E-11	5.66E-12
1.01E+02	2.22E-11	6.19E-12	2.51E-12
1.03E+02	1.07E-11	2.99E-12	1.21E-12

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.9	Operational Environment [GEO] Proton Induced Single Event Effects	The Instrument should function according to specification in the operational environment when exposed to protons from the trapped radiation belts and solar events defined by Table 8-16 and Figure 8-14.	Protons from the trapped radiation belts and from solar events do not generate sufficient ionization energy to produce the critical charge necessary for SEEs to occur in most electronics. However, some electronics are sensitive to proton exposure because of the ability of protons to produce the critical charge necessary to induce SEEs through secondary particles via nuclear interactions such as spallation and fractionation products. Electronics device sensitivity secondary particles is typically expressed as a function of Proton energy (and not LET) because proton energy is the important quantity in production of secondary particles. Please note that at GEO, trapped protons are not a significant factor in producing interference or damage to electronics due to energies of < 2 MeV. This guidance supports the selection of electronic devices that are compatible with the proton environment that will be experienced during operation in GEO as defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities responses and 417-R-RPT-0027.*

Environmental L2 Guidelines

Table 8-16: [GEO] Differential Fluxes from Solar Proton Events @ 1 AU w/ 1989 Solar Particle Event Basis

100 mils Aluminum Shielding, CREME96
Note: Spectra were cut off at E =1 MeV and E=1000 MeV
Values Do Not Include Design Margins

Energy	Proton Flux	Proton Flux	Proton Flux
MeV	$\#/cm^2/s$	$\#/cm^2/s$	$\#/cm^2/s$
	Average Over Peak	Average Over Worst Day	Average Over Worst Week
1.00	1.75E+03	4.62E+02	8.85E+01
2.00	2.68E+03	7.09E+02	1.36E+02
3.02	3.47E+03	9.17E+02	1.76E+02
4.04	4.11E+03	1.09E+03	2.09E+02
5.04	4.62E+03	1.22E+03	2.36E+02
6.03	5.03E+03	1.33E+03	2.58E+02
7.02	5.33E+03	1.41E+03	2.75E+02
8.06	5.56E+03	1.47E+03	2.88E+02
9.00	5.69E+03	1.51E+03	2.96E+02
10.05	5.76E+03	1.53E+03	3.01E+02
14.99	5.41E+03	1.44E+03	2.92E+02
20.03	4.50E+03	1.21E+03	2.52E+02
24.98	3.57E+03	9.65E+02	2.07E+02
30.31	2.73E+03	7.40E+02	1.64E+02
35.27	2.11E+03	5.75E+02	1.31E+02
40.49	1.61E+03	4.42E+02	1.04E+02
50.50	9.91E+02	2.73E+02	6.79E+01
60.43	6.33E+02	1.75E+02	4.58E+01
70.33	4.20E+02	1.17E+02	3.20E+01
79.63	2.94E+02	8.18E+01	2.33E+01
90.17	2.03E+02	5.65E+01	1.68E+01
100.69	1.44E+02	4.01E+01	1.24E+01
150.25	3.84E+01	1.06E+01	3.80E+00
200.77	1.39E+01	3.79E+00	1.50E+00
299.59	3.32E+00	8.62E-01	3.88E-01
400.31	1.16E+00	2.85E-01	1.39E-01
499.23	4.97E-01	1.16E-01	5.96E-02
605.64	2.07E-01	4.64E-02	2.34E-02
704.94	1.10E-01	2.48E-02	1.44E-02
798.17	6.61E-02	1.48E-02	9.03E-03
903.74	3.95E-02	8.88E-03	5.66E-03
995.41	2.65E-02	5.96E-03	3.94E-03

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.10	Operational Environment [GEO] Instrument Interference	The Instrument should function according to specification in the operational environment when exposed to the particle fluxes defined by Table 8-17.	The particle background causes increased noise levels in instruments and other electronics. No long term flux is included for solar particle events because of their short durations. This guidance is based upon *CII RFI for GEO Hosted Payload Opportunities* responses and 417-R-RPT-0027.

Table 8-17: [GEO] Particle fluxes in GEO w/ 100 mils of Aluminum Shielding

Radiation:	Long-term flux (#/cm^2/s)	Worst-case flux (#/cm^2/s)
Galactic Cosmic Rays	2.5	4.6
Trapped Electrons	6.7×10^4	1.3×10^6
Solar Particle Events		2.0×10^5

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.11	Operational Environment Electrostatic Discharge Prevention	The Instrument should preclude Electrostatic Discharge (ESD) by complying with the design principles in NASA-HDBK-4002A.	NASA-HDBK-4002A provides established design principles that will reduce and potentially prevent ESD.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.12	Operational Environment External Potential Difference	The voltage between any Instrument surface area greater than 0.5 cm^2 and the Instrument structure should be less than or equal to 200 V, when exposed to a 5 nA/cm^2 flux level of electrons with 20 keV energy.	Exposure to an external potential difference could initiate an electrostatic discharge which could cause permanent degradation or damage in sensitive electronics. This guidance defines the need for the hosted payload instrument to mitigate ESD events induced by externally induced potential differences through the equalization of accumulated charge between the instrument surface and the instrument chassis at a defined rate.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.13	Operational Environment Electrostatic Discharge Testing	The Instrument should function according to its operational specifications following electrostatic discharge testing for both single point discharge and structural current in accordance with NASA-HDBK-4002.	NASA-HDBK-4002 provides procedures to verify that the Instrument will successfully operate in an environment capable of generating ESD events.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.14	Operational Environment Electrostatic Discharge Radiated Field Susceptibility	The Instrument should function according to its operational specifications following a 6 mJ discharge applied at a distance of 25 cm from any exterior surface of the Instrument.	Exposure to an external potential difference could initiate an electrostatic discharge which could cause permanent degradation or damage in sensitive electronics. This guidance defines the need for the hosted payload instrument to mitigate ESD events induced by externally induced potential differences through the equalization of accumulated charge.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.15	Operational Environment Induced Charging	Metallic elements, including wires, unused conductors of cable, connectors, circuit board traces, and spot shields greater than 3 cm^2 in area or 25 cm in length should have a conductive path to ground of less than 10^8 Ω when measured in air and less than 10^{12} Ω when measured in vacuum. Flight hardware that is shielded from the external radiation environment by greater than 0.32 cm (125 mils) of aluminum (or equivalent) need not be grounded.	This guidance defines the need for the hosted payload instrument to mitigate induced charging of metallic elements, and in particular unused electrical/electronic elements, via a conductive path(s) to ground.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.16	Operational Environment Micrometeoroids	The Instrument should function according to its specifications after exposure to a flux of micrometeoroids as defined in Table 8-18 and Figure 8-15.	Impacts from micrometeoroids may cause permanently degraded performance or damage to the hosted payload instrument. This guidance provides estimates of the worst-case scenarios of micrometeoroid particle size and associated flux over the LEO and GEO domains. The data come from the Grün flux model assuming a meteoroid mean speed of 20 km/s. Of note, the most hazardous micrometeoroid environment in LEO is at an altitude of 2000 km.

Environmental L2 Guidelines

Table 8-18: Worst-case Micrometeoroid Environment

Particle mass (grams)	Particle diameter (cm)	Flux (particles/m²/year) LEO	Flux (particles/m²/year) GEO
1.00E-18	9.14E-07	1.20E+07	9.53E+06
1.00E-17	1.97E-06	1.75E+06	1.39E+06
1.00E-16	4.24E-06	2.71E+05	2.15E+05
1.00E-15	9.14E-06	4.87E+04	3.85E+04
1.00E-14	1.97E-05	1.15E+04	9.14E+03
1.00E-13	4.24E-05	3.80E+03	3.01E+03
1.00E-12	9.14E-05	1.58E+03	1.25E+03
1.00E-11	1.97E-04	6.83E+02	5.40E+02
1.00E-10	4.24E-04	2.92E+02	2.31E+02
1.00E-09	9.14E-04	1.38E+02	1.09E+02
1.00E-08	1.97E-03	5.41E+01	4.28E+01
1.00E-07	4.24E-03	1.38E+01	1.09E+01
1.00E-06	9.14E-03	2.16E+00	1.71E+00
1.00E-05	1.97E-02	2.12E-01	1.68E-01
1.00E-04	4.24E-02	1.50E-02	1.19E-02
1.00E-03	9.14E-02	8.65E-04	6.84E-04
1.00E-02	1.97E-01	4.45E-05	3.52E-05
1.00E-01	4.24E-01	2.16E-06	1.71E-06
1.00E+00	9.14E-01	1.02E-07	8.05E-08
1.00E+01	1.97E+00	4.72E-09	3.73E-09
1.00E+02	4.24E+00	2.17E-10	1.72E-10

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.17	Operational Environment Artificial Space Debris	[LEO] The Instrument should function according to its specifications after exposure to a flux of artificial space debris, as defined in Table 8-19 and Figure 8-16, over the lifetime of its primary mission.	[LEO] Impacts from artificial space debris may cause permanently degraded performance or damage to the hosted payload instrument. This guidance estimates the maximum artificial space debris flux and impact velocities an Instrument can expect to experience while at altitudes from 200 to 2000 km and orbital inclinations between 0 and 180 degrees. The ORDEM2000 model, developed by the NASA Orbital Debris Program Office at Johnson Space Center, is the source of the data.

Table 8-19: [LEO] Worst-case Artificial Space Debris Environment

Object Size (m)	Flux (objects/m^2/year)	Object Velocity (km/s)
1.00E-05	4.14E+03	12.02
1.00E-04	4.10E+02	9.25
1.00E-03	3.43E-01	10.63
1.00E-02	1.50E-04	10.53
1.00E-01	6.64E-06	9.10
1.00E+00	2.80E-06	9.34
	Average Velocity:	10.15

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.17	Operational Environment Artificial Space Debris	[GEO] The Instrument should function according to its specifications after exposure to a flux of artificial space debris, as defined in Table 8-20 and Figure 8-17, over the lifetime of its primary mission.	[GEO] Impacts from artificial space debris may cause permanently degraded performance or damage to the hosted payload instrument. Based upon analysis of ESA's 2009 MASTER (Meteoroid and Space Debris Environment) model, this guidance aggregates the maximum expected artificial space debris flux, sampled at 20° intervals around the GEO belt.

Environmental L2 Guidelines

Table 8-20: [GEO] Worst-case Artificial Space Debris Environment

Object Diameter (m)	Flux (objects/m^2/year)	Object Diameter (m)	Flux (objects/m^2/year)	Object Diameter (m)	Flux (objects/m^2/year)
1.00000E-03	2.08800E-05	2.06200E-02	1.56300E-08	4.25179E-01	3.93000E-09
1.14100E-03	1.58800E-05	2.35200E-02	1.40200E-08	4.84969E-01	3.89700E-09
1.30100E-03	9.74700E-06	2.68270E-02	1.13500E-08	5.53168E-01	3.85700E-09
1.48400E-03	6.06200E-06	3.05990E-02	1.02900E-08	6.30957E-01	3.83000E-09
1.69300E-03	4.70300E-06	3.49030E-02	9.74100E-09	7.19686E-01	3.81700E-09
1.93100E-03	3.38900E-06	3.98110E-02	8.92500E-09	8.20891E-01	3.76600E-09
2.20200E-03	2.32700E-06	4.54090E-02	8.07400E-09	9.36329E-01	3.75200E-09
2.51200E-03	1.55700E-06	5.17950E-02	7.06300E-09	1.06800E+00	3.73800E-09
2.86500E-03	1.10200E-06	5.90780E-02	6.36200E-09	1.21819E+00	3.73800E-09
3.26800E-03	7.81600E-07	6.73860E-02	5.88900E-09	1.38949E+00	3.73800E-09
3.72800E-03	5.16800E-07	7.68620E-02	5.52200E-09	1.58489E+00	3.73800E-09
4.25200E-03	3.73600E-07	8.76710E-02	5.30700E-09	1.80777E+00	3.73800E-09
4.85000E-03	2.88600E-07	1.00000E-01	4.91200E-09	2.06199E+00	3.38500E-09
5.53200E-03	2.15600E-07	1.14062E-01	4.66500E-09	2.35195E+00	3.38500E-09
6.31000E-03	1.60200E-07	1.30103E-01	4.56000E-09	2.68270E+00	3.38500E-09
7.19700E-03	1.20300E-07	1.48398E-01	4.39400E-09	3.05995E+00	3.38000E-09
8.20900E-03	8.21500E-08	1.69267E-01	4.27400E-09	3.49025E+00	3.37800E-09
9.36300E-03	6.42500E-08	1.93070E-01	4.18300E-09	3.98107E+00	1.95200E-09
1.06800E-02	5.00200E-08	2.20220E-01	4.14700E-09	4.54091E+00	1.95000E-09
1.21820E-02	4.05400E-08	2.51189E-01	4.08200E-09	5.17948E+00	1.94900E-09
1.38950E-02	3.00300E-08	2.86512E-01	4.02900E-09	5.90784E+00	1.94800E-09
1.58490E-02	2.36300E-08	3.26803E-01	3.99300E-09	6.73863E+00	1.94800E-09
1.80780E-02	1.92000E-08	3.72759E-01	3.96000E-09	7.68625E+00	1.36900E-13
				Average Velocity (km/s)	1.3333

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.18	Operational Environment Atomic Oxygen Environment	[LEO] The Instrument should function according to its specifications following exposure to a cumulative atomic oxygen fluence of 3.3 x 10^{20} atoms/cm^2. [GEO] The Instrument should provide either self-protection or design resilience for the cumulative exposure to atomic oxygen at the fluence required by the hosting mission such that the instrument functions according to its specifications following exposure.	[LEO] Exposure to Atomic Oxygen degrades many materials and will require mitigation to assure full instrument function over the design mission lifetime. The defined fluence is equivalent to an exposure in a 705 km circular polar orbit over two years. [GEO] Exposure to Atomic Oxygen degrades many materials and will require mitigation to assure full instrument function over the design mission lifetime. The exposure fluence is undefined because the atomic oxygen levels in GEO are considered to be negligible. Exposure concerns for GEO instruments are typically limited to exceptional circumstances or mission requiring extended periods in Low Earth Orbit prior to transfer to GEO.

Environmental L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
8.5.19	Operational Environment Electromagnetic Interference & Compatibility Environment	The Instrument should function according to its specification following exposure to the Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC) environments as defined in Sections 9.5.3 and 9.5.4 of this document and as tailored in accordance with the Host Spacecraft, launch vehicle and launch range requirements.	Exposure of the hosted payload instrument to electromagnetic fields may induce degraded performance or damage in the instrument electrical and/or electronic subsystems. The application of the appropriate environments as described in the above noted sections of this document in accordance with those test procedures defined in, or superior to, MIL-STD-461 or MIL-STD-462, will result in an instrument that is designed and verified to assure full instrument function in the defined EMI/EMC environments. The provided guidance is based upon an analysis of limits supplied in MIL-STD-461, the CII HPO RFI and all available Launch Vehicle Payload Planning Guidebooks. These values are considered to be baseline and should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle and Launch Range.

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.2.1	Radiation-Induced SEE *Temporary Loss of Function or Loss of Data*	Temporary loss of function or loss of data is permitted, provided that the loss does not compromise instrument health and full performance can be recovered rapidly.	Identifies that a temporary loss of function and/or data is permissible in support of correcting anomalous operations. This includes autonomous detection and correction of anomalous operations as well as power cycling.

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.2.2	Radiation-Induced SEE *Restoration of Normal Operation and Function*	To minimize loss of data, normal operation and function should be restored via internal correction methods without external intervention.	Identifies that autonomous fault detection and correction should be implemented.
9.5.2.3	Radiation-Induced SEE *Restoration of Normal Operation and Function*	Irreversible actions should not be permitted. The hardware design should have no parts which experience radiation induced latch-up to an effective LET of 75 $MeV/mg/cm^2$ and a fluence of 10^7 $ions/cm^2$.	Identifies limitations for radiation induced latch-up and prescribes both a LET and an ion fluence immunity level

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.3.1	Instrument Electromagnetic Emissions *Magnetic Field Emissions (RE04)*	The Instrument should limit its magnetic field emissions to the values as specified in Table 9-2.	Table 9-2 is based on MIL-STD-461 requirement RE04, which prescribes limits for the magnetic field emissions. These test values are a composite of the noted test specification and limits defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities* responses. The supplied limits should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Table 9-2: Magnetic Field Emissions (RE04)

Magnetic Field Emissions
AC Magnetic Field Emissions: The radiated AC magnetic field levels from the instrument should be limited to 60 dB above 1 pT between 20 Hz and 50 kHz using the RE04 test method of MIL-STD-462. The measurement bandwidth should be 10 Hz between 20 Hz and 200 Hz; 100 Hz between 200 Hz and 20kHz; and 1 kHz between 20 kHz and 50 kHz.
DC Magnetic Field Emissions: The residual magnetic dipole moment of the instrument should be less than 0.05 $A \cdot m^2$

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.3.2	Instrument Electromagnetic Emissions *Conducted Emissions (CE102)*	The Instrument should limit its conducted emissions along the power leads and/or power return to the values as specified in Table 9-3	The values presented in the provided table are based upon an analysis of limits supplied in MIL-STD-461, the CII HPO RFI and all available Launch Vehicle Payload Planning Guidebooks. These values are considered to be baseline and should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Table 9-3: Conducted Emissions Environment (CE102)

"Conducted Frequency (Hz)"	"Design/Qual/Protoflight (dBµA)"	"Acceptance (dBµA)"
1.0000E+00	–	–
1.0000E+01	93.96	87.96
1.0000E+04	93.96	87.96
1.0001E+04	48.50	42.50
5.0000E+05	14.50	8.50
5.0000E+07	14.50	8.50
1.0000E+08	–	–

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.3.3	Instrument Electromagnetic Emissions *Radiated Emissions (RE102)*	The Instrument should limit its radiated emissions to the values as specified in Table 9-4.	The values presented in the provided table are based upon an analysis of limits supplied in MIL-STD-461, the CII HPO RFI and all available Launch Vehicle Payload Planning Guidebooks. These values are considered to be baseline and should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Environmental Best Practices

Table 9-4: Radiated Emissions Environment (RE102)

Radiated Frequency (Hz)	Design/Qual/ Protoflight (dBμV/m)	Acceptance (dBμV/m)	Radiated Frequency (Hz)	Design/Qual/ Protoflight (dBμV/m)	Acceptance (dBμV/m)
1.0000E+03	–	–	1.9800E+09	24.0000000	30.0000000
1.0000E+04	18.0000000	24.0000000	2.0250E+09	24.0000000	30.0000000
1.0000E+08	18.0000000	24.0000000	2.0250E+09	14.0000000	20.0000000
2.9000E+08	27.2479599	33.2479599	2.1100E+09	14.0000000	20.0000000
2.9000E+08	24.0000000	30.0000000	2.1100E+09	24.0000000	30.0000000
3.2200E+08	24.0000000	30.0000000	2.1200E+09	24.0000000	30.0000000
3.2200E+08	28.1571175	34.1571175	2.1200E+09	44.5267172	50.5267172
4.0000E+08	30.0411998	36.0411998	5.5800E+09	52.9326840	58.9326840
4.0000E+08	24.0000000	30.0000000	5.5800E+09	29.0000000	35.0000000
4.1000E+08	24.0000000	30.0000000	5.7250E+09	29.0000000	35.0000000
4.1000E+08	14.0000000	20.0000000	5.7250E+09	14.0000000	20.0000000
4.3000E+08	14.0000000	20.0000000	7.0750E+09	14.0000000	20.0000000
4.3000E+08	24.0000000	30.0000000	7.0750E+09	24.0000000	30.0000000
5.0000E+08	24.0000000	30.0000000	7.1000E+09	24.0000000	30.0000000
5.0000E+08	31.9794001	37.9794001	7.1000E+09	55.0251670	61.0251670
5.5000E+08	32.8072538	38.8072538	7.9000E+09	55.9525418	61.9525418
5.5000E+08	9.0000000	15.0000000	7.9000E+09	14.0000000	20.0000000
7.5000E+08	9.0000000	15.0000000	8.4000E+09	14.0000000	20.0000000
7.5000E+08	35.5012253	41.5012253	8.4000E+09	56.4855857	62.4855857
7.6200E+08	35.6390994	41.6390994	1.2750E+10	60.1102037	66.1102037
7.6200E+08	24.0000000	30.0000000	1.2750E+10	14.0000000	20.0000000
7.7600E+08	24.0000000	30.0000000	1.4800E+10	14.0000000	20.0000000
7.7600E+08	35.7972344	41.7972344	1.4800E+10	61.4052343	67.4052343
1.5000E+09	41.5218252	47.5218252	1.7300E+10	62.7609221	68.7609221
1.5000E+09	4.0000000	10.0000000	1.7300E+10	14.0000000	20.0000000
1.7000E+09	4.0000000	10.0000000	1.8100E+10	14.0000000	20.0000000
1.7000E+09	42.6089784	48.6089784	1.8100E+10	63.0000000	69.0000000
1.5700E+09	41.9179930	47.9179930	2.7000E+10	63.0000000	69.0000000
1.5700E+09	24.0000000	30.0000000	2.7000E+10	14.0000000	20.0000000
1.6265E+09	24.0000000	30.0000000	3.1000E+10	14.0000000	20.0000000
1.6265E+09	14.0000000	20.0000000	3.1000E+10	63.0000000	69.0000000
1.6750E+09	14.0000000	20.0000000	1.0000E+11	63.0000000	69.0000000
1.6750E+09	42.4802962	48.4802962	1.0000E+12	–	–

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.1	Susceptibility to Electromagnetic *Magnetic Field Susceptibility (RS01)*	The instrument should function according to its operational specification after being subjected to a magnetic field as defined in Table 9-5.	Table 9-5 is based upon requirement RS01 of MIL-STD-461, which prescribes limits for magnetic field susceptibility. These test values are a composite of the noted test specification and limits defined from the information provided in the *CII RFI for GEO Hosted Payload Opportunities* responses. The supplied limits should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Table 9-5: Magnetic Field Susceptibility (RS01)

Magnetic Field Susceptibility
AC Magnetic Field Susceptibility: The Instrument should operate within specification after being subjected to an AC magnetic field level of 124 dB above 1 pT between 30 Hz and 200 kHz. The RS01 test method of MIL-STD-462 should be used for measurement.
DC Magnetic Field Susceptibility: The Instrument should operate within specification after being subjected to an ambient magnetic field consisting of the Earth's field (15 to 50 μT), the fields generated by neighboring instruments (3 μT maximum), and the field produced by the spacecraft magnetic torquers (1000 μT maximum).

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.2	Susceptibility to Electromagnetic *Conducted Susceptibility (CS101)*	The Instrument should function according to its operational specifications after being subjected to the electromagnetic environment specified in Table 9-6.	The values presented in the provided table are based upon an analysis of limits supplied in MIL-STD-461, the CII HPO RFI and all available Launch Vehicle Payload Planning Guidebooks. These values are considered to be baseline and should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Table 9-6: Conducted Susceptibility Voltage Limits (CS101)

Conducted Frequency (Hz)	Design/Qual/Protoflight (dBμV)	Acceptance (dBμV)
1.0000E+00	–	–
1.0000E+01	126	120
3.0000E+01	147.4213562	141.4213562
1.0000E+04	147.4213562	141.4213562
1.0000E+05	138.9360749	132.9360749
5.0000E+05	129.5218252	123.5218252
5.0000E+07	129.5218252	123.5218252
1.0000E+08	–	–

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.3	Susceptibility to Electromagnetic *Conducted Susceptibility (CS114)*	The Instrument should function according to its operational specifications after being subjected to conducted RF disturbances as defined in Figure 9-5.	Figure 9-5 is based upon requirement CS114 of MIL-STD-461F, which prescribes limits for conducted susceptibility. These are baseline values which should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Environmental Best Practices

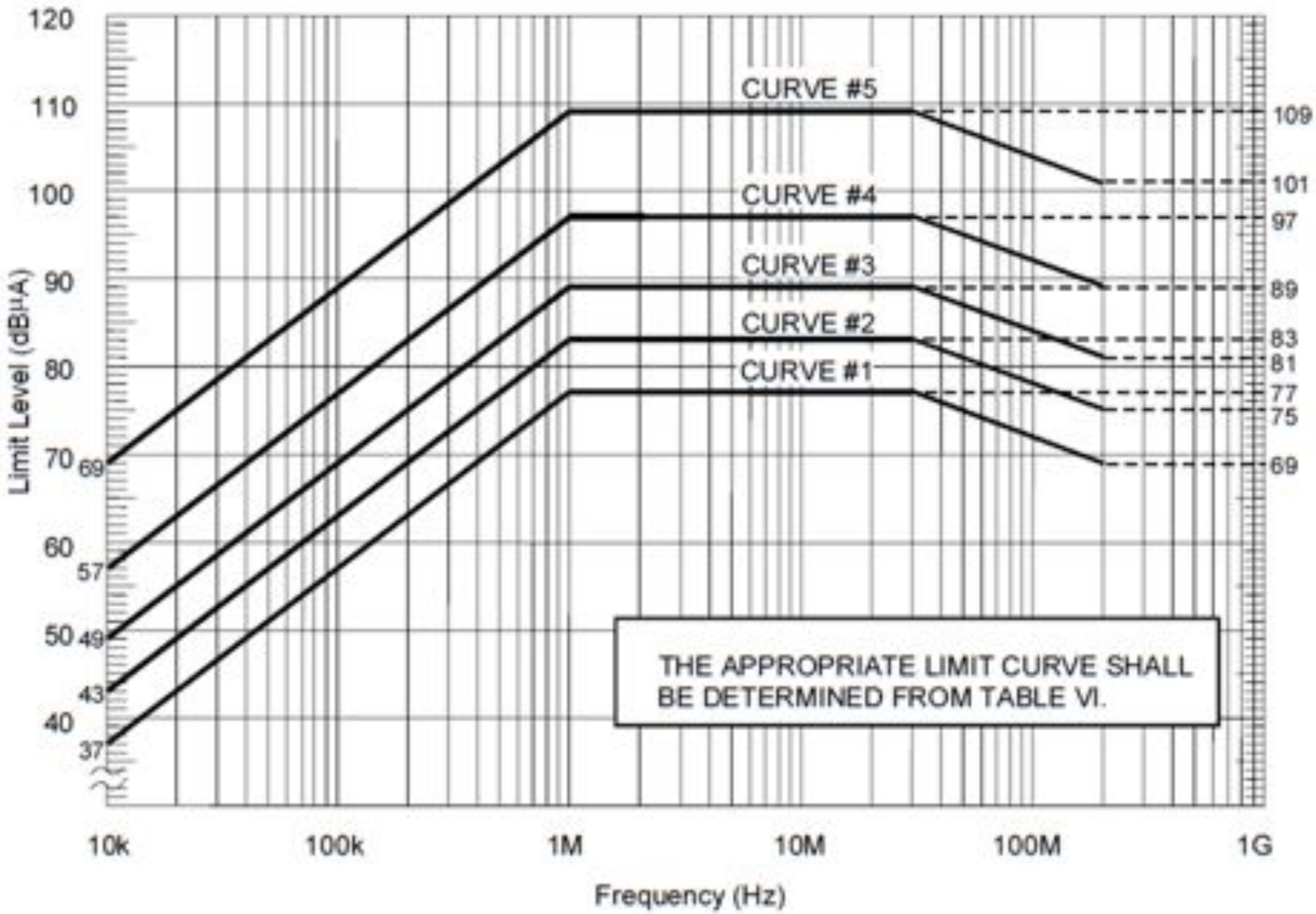


Figure 9-5: Conducted Susceptibility Current Limits (Reference)

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.4	Susceptibility to Electromagnetic *Conducted Susceptibility (CS115)*	The Instrument should function according to its operational specifications after being subjected to a pre-calibrated signal having rise and fall times, pulse width, and amplitude as specified in Figure 9-6.	Figure 9-6 is based upon requirement CS115 of MIL-STD-461F, which prescribes limits for conducted susceptibility. These are baseline values which should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Environmental Best Practices

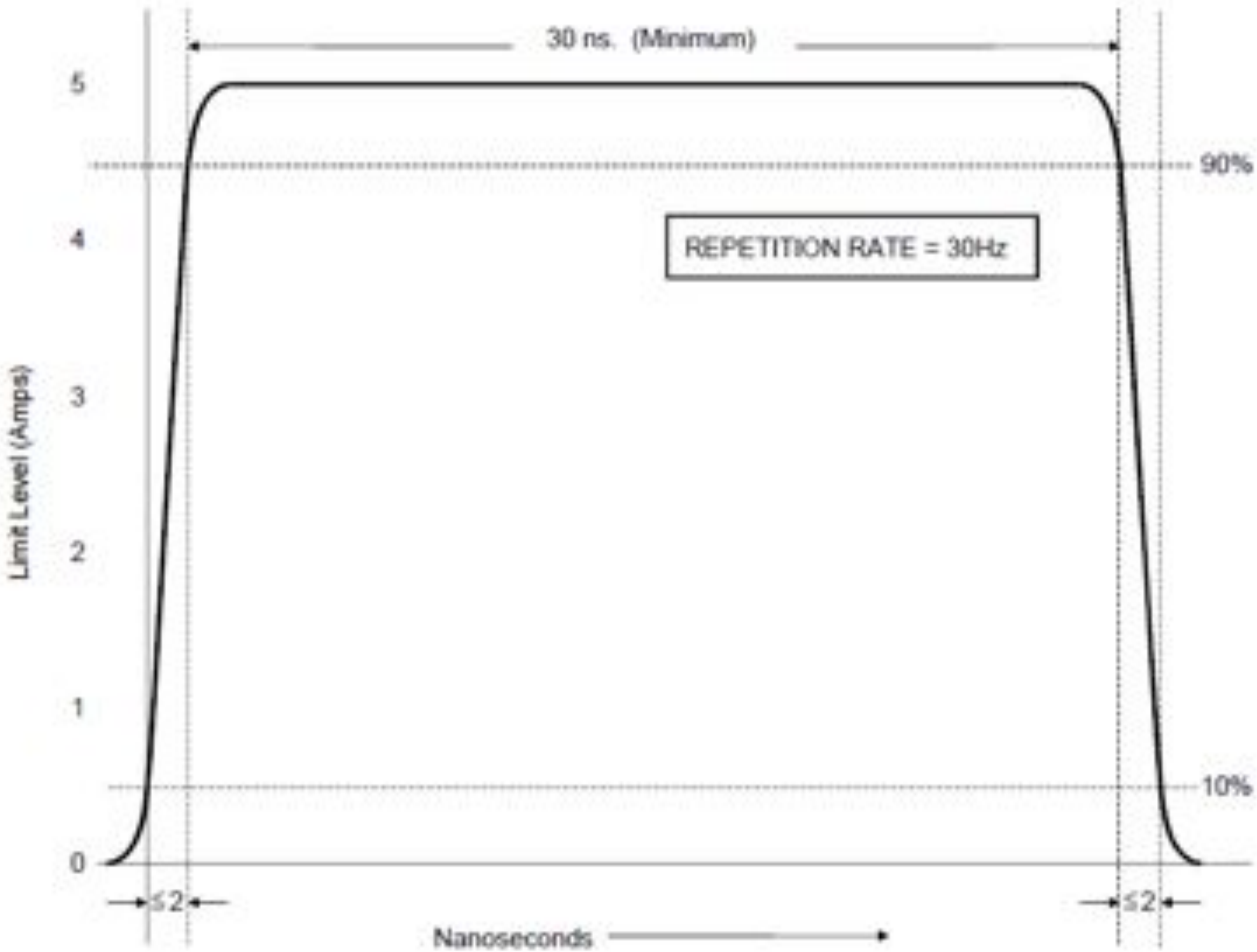
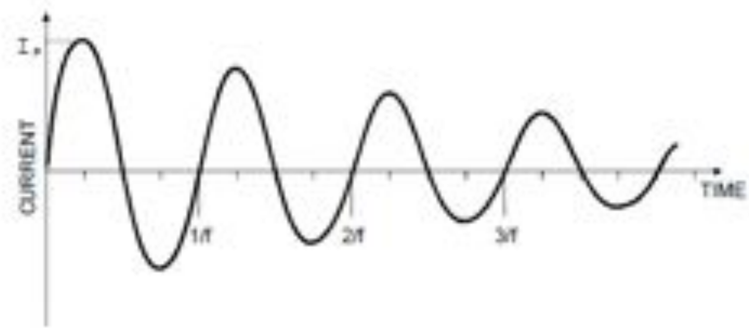


Figure 9-6: Conducted Susceptibility Current Limits (Reference)

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.5	Susceptibility to Electromagnetic *Conducted Susceptibility (CS116)*	The Instrument should function according to its operational specifications after being subjected to a damped sinusoidal signal as specified in Figure 9-7 and Figure 9-8.	Figure 9-7, which depicts the test signal waveform, and 1951 Figure 9-8, which specifies the maximum current, are based upon requirement CS116 of MIL-STD-461F, which prescribes limits for conducted susceptibility. The current limit is applicable across the entire specified frequency range. These are baseline values which should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.



NOTES: 1. Normalized waveform: $e^{-(\pi f t)/Q} \sin(2\pi f t)$

Where:
f = Frequency (Hz)
t = Time (sec)
Q = Damping factor, 15 ±5

2. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N-1)}{\ln(I_P/I_N)}$$

Where:
Q = Damping factor
N = Cycle number (i.e. N = 2, 3, 4, 5,...)
I_P = Peak current at 1[st] cycle
I_N = Peak current at cycle closest to 50% decay
ln = Natural log

3. I_P as specified in Figure CS116-2

Figure 9-7: Conducted Susceptibility Waveform (Reference)

Environmental Best Practices

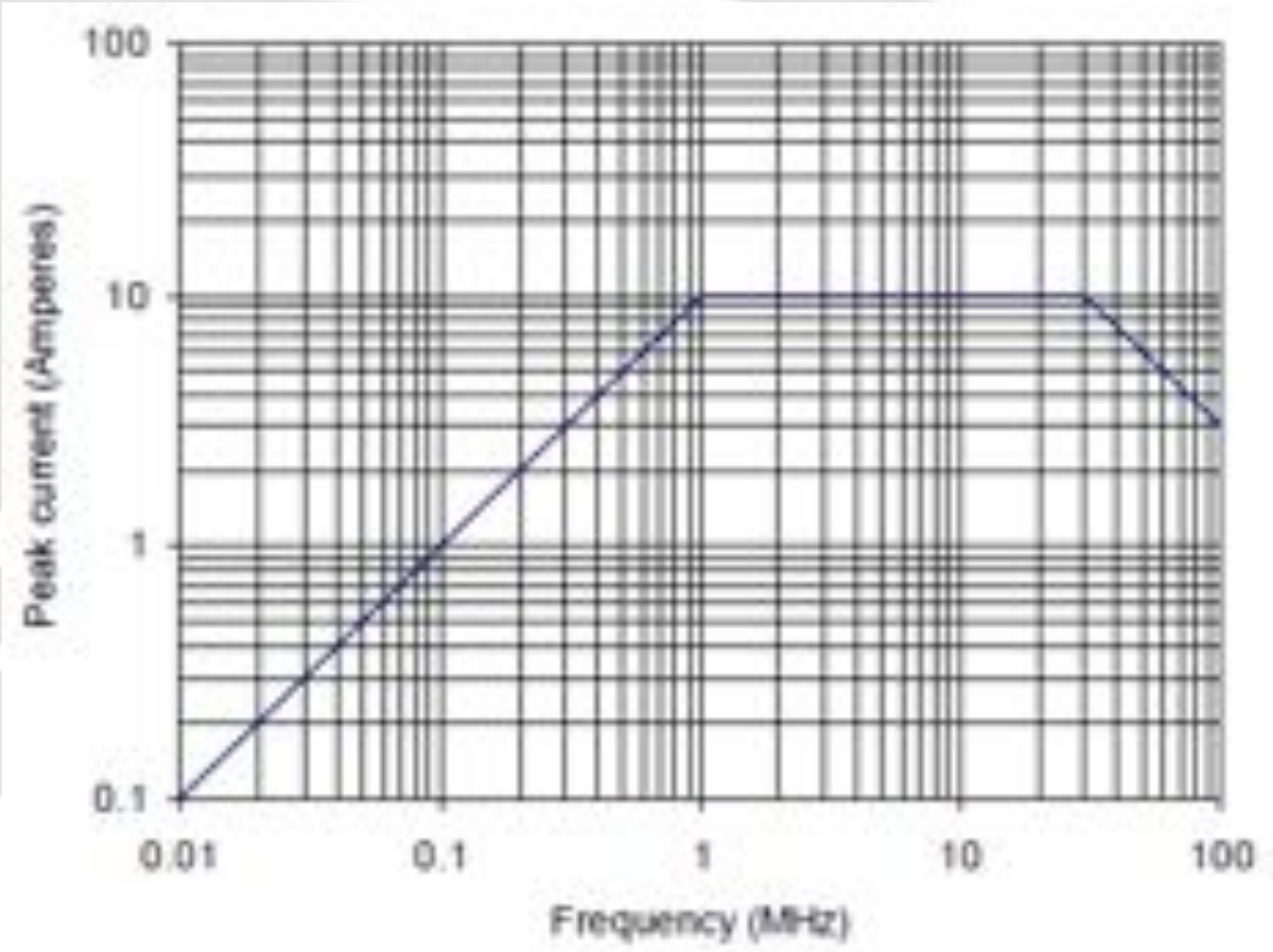


Figure 9-8: Conducted Susceptibility Current Limits (Reference)

Environmental Best Practices

ID	Function	Guidelines	Rationale/Comment
9.5.4.6	Susceptibility to Electromagnetic *Radiated Susceptibility (RS103)*	The Instrument should function according to its operational specifications after being subjected to the radiated electric field specified in Table 9-7	The values presented in the provided table are based upon an analysis of limits supplied in MIL-STD-461, the CII HPO RFI and all available Launch Vehicle Payload Planning Guidebooks. These values are considered to be baseline and should be tailored once the Instrument is paired with a Host Spacecraft and Launch Vehicle.

Table 9-7: Radiated Susceptibility (RS103)

Radiated Frequency(Hz)	Design/Qual/Protoflight (dBμV/m)	Acceptance (dBμV/m)
1.0000E+03	–	–
1.0000E+04	152.0205999	146.0205999
9.9999E+04	152.0205999	146.0205999
1.0000E+05	152.8484536	152.8484536
1.0000E+06	152.8484536	152.8484536
1.0000E+06	159.9794001	153.9794001
1.0000E+09	159.9794001	153.9794001
1.0000E+09	172.0205999	166.0205999
3.0494E+09	172.0205999	166.0205999
3.0494E+09	174.8219573	168.8219573
3.0494E+09	172.0205999	166.0205999
5.2300E+09	172.0205999	166.0205999
5.2300E+09	177.0000000	171.0000000
5.4000E+09	177.0000000	171.0000000
5.4000E+09	178.6187224	172.6187224
5.8400E+09	178.6187224	172.6187224
5.8400E+09	191.9394432	185.9394432
5.8400E+09	178.6187224	172.6187224
5.9000E+09	178.6187224	172.6187224
5.9000E+09	172.0205999	166.0205999
9.4100E+09	172.0205999	166.0205999
9.4100E+09	182.1941564	176.1941564
9.4100E+09	172.0205999	166.0205999
4.0000E+10	172.0205999	166.0205999
4.0000E+10	152.0205999	146.0205999
1.0000E+11	152.0205999	146.0205999
1.0000E+12	–	–

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    - 2.2.10 [GEO] Attitude Determination System Pointing Knowledge Accommodation
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Summary of Environmental Guidelines

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    - 9.5.4 Susceptibility to Electromagnetic Interference (continued)
      - 9.5.4.3 *Conducted Susceptibility (CS114)*
      - 9.5.4.4 *Conducted Susceptibility (CS115)*
      - 9.5.4.5 *Conducted Susceptibility (CS116)*
      - 9.5.4.6 *Radiated Susceptibility (RS103)*