PROJECT ENVIRONMENTAL REQUIREMENTS PROGRAM OVERVIEW

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ENVIRONMENTAL REQUIREMENTS PROGRAM

- **Objective**: Provide Confidence That the Spacecraft and Payload Will Perform As Required Throughout the Mission Life Cycle Environmental Exposures
- **Content**: Environmental Design and Verification Requirements
  - Verification Accomplished by Test or Analyses
  - Analyses Acceptable When Testing Would Damage or Degrade Flight Equipment Such As Radiation Damage to Flight Electronics
  - Testing Performed at Flight Equipment Assembly, Subsystem and System Levels
- **Development Life Cycle**: Requirements Are Tailored to the Specific Project Mission Characteristics in the Formulation Phase Well in Advance of the Project PDR

ENVIRONMENTAL REQUIREMENTS

Environmental Parameters

Dynamics: Acoustics, Vibration, Shock, Quasi-Static Loads

Sources:

- Ground Handling and Transportation: (Vibration and Shock) Note: Should be Controlled to Avoid Driving Flight Design
- Launch Events Including Liftoff, Launch Vehicle Staging and Spacecraft Separation: (Acoustics, Vibration and Shock)
- Spacecraft Pyrotechnic Actuated Events: (Shock)
- Combined Launch Vehicle Thrust and Low Frequency Vibrations From Launch Vehicle Staging: (Quasi Static Loads)

Design And Verification Requirements: Acoustics, Sine and Random Vibration And Shock Spectra And Static Loads

Environmental Parameters

Dynamics: Some *typical* values

- Acoustics: 144 Db Overall for Protoflight (PF) (Table 3-1 MRO Preliminary Environmental Requirements (ER))
- Vibration of Spacecraft (S/C) System: 2.3G RMS Overall
- Vibration of (S/C) Assemblies: 16.1 G RMS Overall (PF)
- Pyrotechnic Shock: 5,000g Peak Response (See Table 3-7, MRO ER)
- Quasi-static Loads: $\pm$ 3 G Lateral Axis, + 6.5 G Thrust Axis (See Table 3-8, MRO ER)

Table 3-1 MRO Launch Acoustics Spectrum

1/3 Oct. Band Center Frequency, Hz	Flight SPL, dB (Ref. 2 x 10^{-5} Pascal)	Protoflight SPL, dB (Ref. 2 x 10^{-5} Pascal)
31.5	121	124
40	124	127
50	125.5	128.5
63	126.5	129.5
80	128	131
100	129	132
125	130	133
160	130	133
200	131	134
250	130.5	133.5
315	130	133
400	130	133
500	129.5	132.5
630	128	131
800	127	130
1000	124	127
1250	122	125
1600	121.5	124.5
2000	121	124
2500	118	121
3150	117	120
4000	116	119
5000	115	118
6300	115	118
8000	115	118
10000	115	118
Overall	141	144

From D-DOC 20241 Previously Cleared

Table 3-7. Orbiter Pyrotechnic Shock Environments

Frequency, Hz	Peak SRS Response (Q=10)
100	50 g
100 - 1,600	+ 10.0 dB / Oct.
1,600 - 10,000	5,000 g

1g = standard acceleration due to gravity = 9.81 m/s^2

Table 3-8. Orbiter Preliminary Design Limit-Load Accelerations (Unit: g) (1)

Load Condition (2)	Lift-off/Transonic/1st Stage Burnout			
	Case 1	Case 2	Case 3	Case 4
Lateral Axes Thrust Axis (3)	± 0.5 +6.5	± 3.0 +3.5	± 3.0 -1.0	± 0.5 -1.0

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(1) Limit load accelerations should be multiplied by appropriate safety factors to obtain structural design loads.
(2) Lateral and longitudinal loading may act simultaneously during any flight event.
(3) Plus indicates compression loads and minus indicates tension load.

ENVIRONMENTAL REQUIREMENTS

Environmental parameters

Thermal/Vacuum: Temperature Ambient, Humidity, Thermal Radiation, Ambient Pressure

Sources:

- Ground Handling and Transportation: (Temperature Ambient, Humidity) Note: Should be controlled to avoid driving flight design
- Launch, Cruise, Planet Encounter/Orbit: (Thermal Radiation From Direct and Reflected Solar Radiation, Launch Pressure Profile, Space Vacuum)

Design and Verification Requirements: Equipment Temperature Extremes for Hot and Cold, Launch Pressure Profile, Thermal Radiation Intensities vs. mission phases, Solar-Spectral-Irradiance Data

Environmental parameters

Thermal/vacuum: Some *Typical* Values

- Controlled Ground Temp Limits: +5deg C to +45deg C
- Uncontrolled Ground Temp Limits: -40deg C to +70deg C
- S/C Assemblies –35deg C to +70deg C for PF Design/test
- Test Duration: 144 Hours Hot, 24 Hours Cold
- Protoflight (Pf)/Flight Acceptance (FA)/ Allowable Flight Temp (AFT) Margins Are: PF/FA= 20deg, FA/AFT =5deg
- Thermal Radiation Environments: See Table 4-1, MRO ER

Table 4-1 Thermal Radiation Environments

Mission Phase	Direct Solar	Reflected Solar (albedo)	Planetary IR (LW Radiation)
Earth Orbit:	0 to 1400 W/m^2 (5770K effective blackbody temperature)	0 to 0.32 0 to 450 W/m^2 (global annual mean) 0 to 0.70 (polar regions)	0 to 270 W/m^2 (206K to 262K effective blackbody temperature)
Earth/Mars Cruise:			
Near Earth	0 to 1414 W/m^2 (at earth perihelion)	Negligible beyond 4 earth radii	Negligible beyond 4 earth radii
Mars Perihelion	0 to 710 W/m^2	Negligible beyond 4 Mars radii	Negligible beyond 4 Mars radii
Mars Aphelion	0 to 490 W/m^2	Negligible beyond 4 Mars radii	Negligible beyond 4 Mars radii
Mars Orbit:			
Mars Perihelion	0 to 710 W/m^2	See Table 5-1	128 W/m^2
Mars Aphelion	0 to 490 W/m^2	See Table 5-1	99 W/m^2
Mars Occultation	0	0	as above

Note: Due to Orbiter orientation, a surface may not see direct solar, reflected solar or planetary infrared. The percentage of the solar constant associated with wavelengths in the range of 0.085 to 7.0 micrometers is given in Table 4-2. The percentages are expected to remain unchanged for planetary reflected solar radiation. The relative spectral distribution for planetary infrared (IR) is represented by a Planck distribution consistent with the provided planetary IR fluxes.

Environmental Parameters

High Energy Radiation Environments:

Ionizing Radiation: Result in Total Ionizing Effects, Single Event Effects and Damage Displacement

Sources: Solar Proton Events (Solar Flares) and Galactic Cosmic Rays

Design and Verification Requirements: Solar Proton Fluence, And Total Ionizing Dose / Shield Thickness plots,

Linear Energy Transfer (LET) Requirements for SEE

ENVIRONMENTAL REQUIREMENTS

Environmental Parameters

High Energy Radiation Environments: Some *Typical* Values:

- Total Ionizing Dose Requirements for Electronics: ~36 Krad for 10 Year Mission With Radiation Design Margin of 2 and 100 Mils Spherical Shell Al Shielding
- Solar Flare Proton Total Fluence From Launch: See Figure 4-1, MRO ER
- Electronic Parts LET Threshold Requirement: LET =15 Mev-cm2/mg

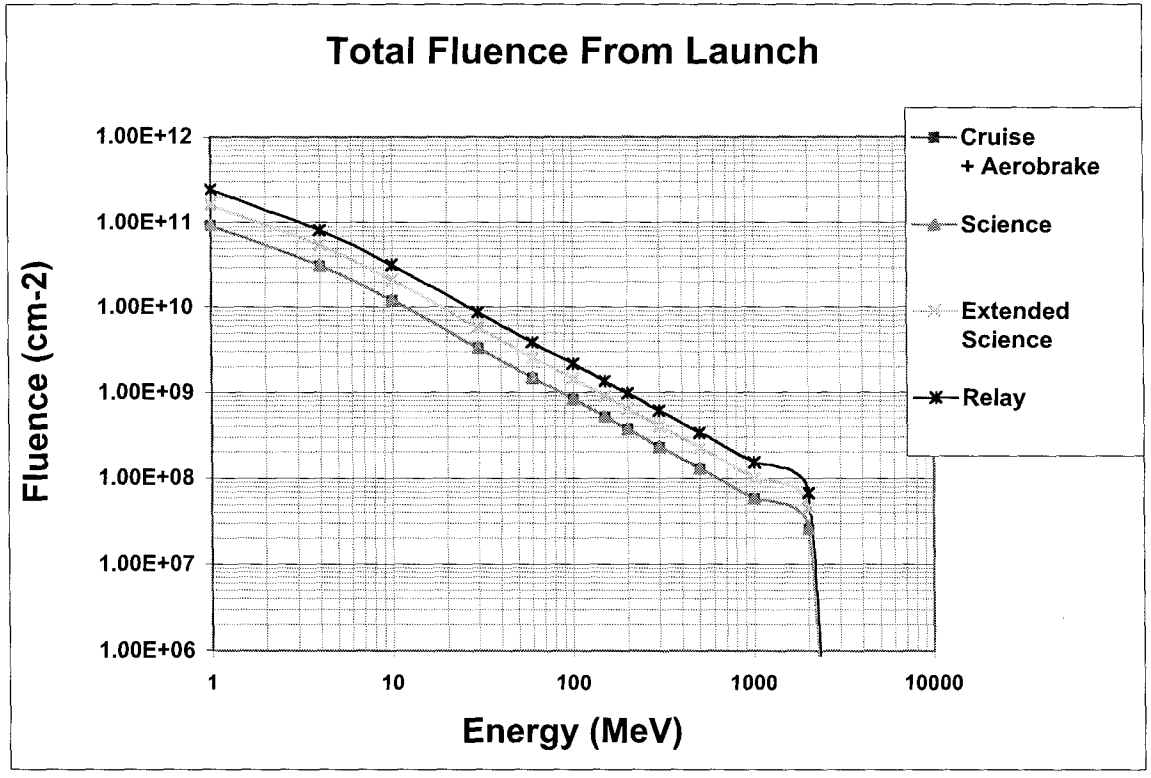


Figure 4-1 Total Solar Flare Proton Fluence at 95% Confidence Level

Environmental Parameters

Meteoroid Environments:

Sources: Interplanetary and Mars Orbit Meteoroids

Design and Verification Requirements: Meteoroid Mass/Fluence Chart

Some Typical Values: Micrometeoroid Environment, Mass/Mission Fluence, See Table 4-5, MRO ER

Table 4-5 Micrometeoroid Environment

Mass (grams)	Mission Omnidirectional Fluence (m^{-2})
1.E-12	1.34E+04
1.E-11	6.27E+04
1.E-10	2.84E+03
1.E-09	1.29E+03
1.E-08	5.13E+02
1.E-07	1.24E+02
1.E-06	2.04E+01
1.E-05	3.12E+00
1.E-04	4.71E-01
1.E-03	4.00E-02
1.E-02	2.26E-03
1.E-01	1.07E-04
1.E+00	5.00E-06
1.E+01	2.33E-07

ENVIRONMENTAL REQUIREMENTS

Environmental Parameters

Electromagnetic Compatibility (EMC): Conducted and Radiated Emissions and Susceptibility

Sources:

- Ground Sources Such As Launch Support Radars,
- Spacecraft/payload Induced Environments and
- Launch Vehicle Induced Environments

Design and Verification Requirements: Plots of Conducted Emission Limits, Radiated Emission Limits, Conducted Susceptibility Limits and Radiated Susceptibility Limits

Environmental Parameters

Electromagnetic Compatibility (EMC): Some Typical Values

Conducted Emission Limits: See Figure 2-1, MRO ER

Radiated Emission Limits: See Figure 2-2, MRO ER

Radiated Susceptibility Limits: See Figure 2-3, MRO ER

Conducted Susceptibility Limits: See Figure 2-4, MRO ER

Figure 2-1 CE01/CE03 Limit – Narrowband

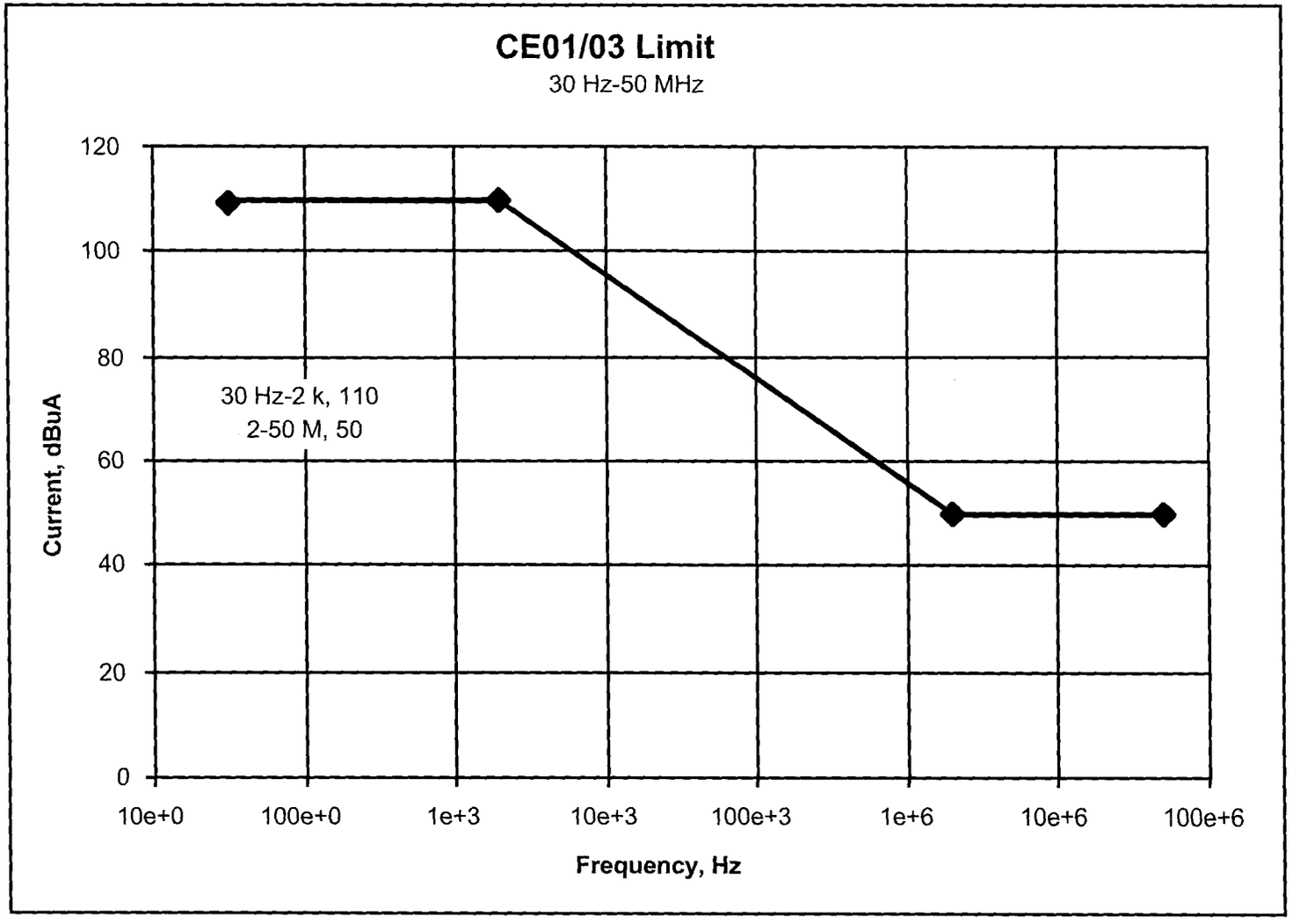


Figure 2-2 RE02 Limit – Narrowband

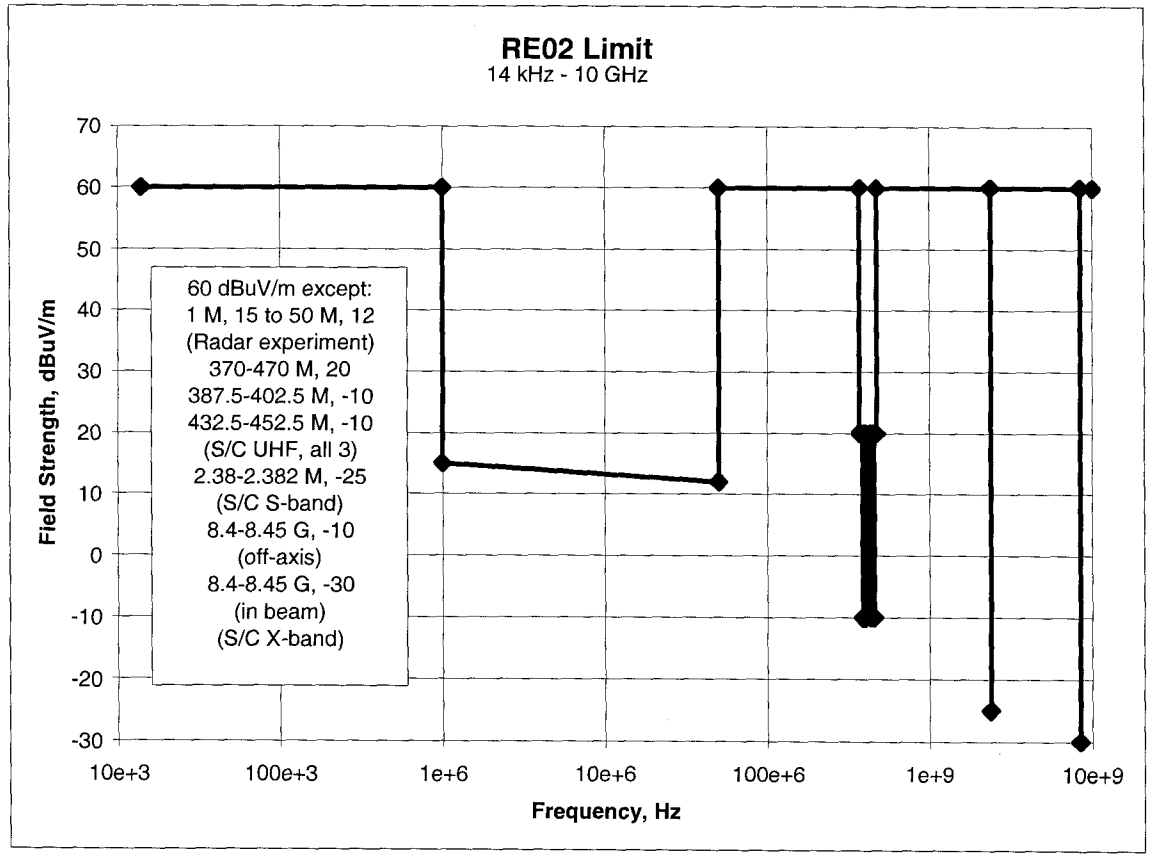


Figure 2-3 RS03 Radiated Susceptibility Limits

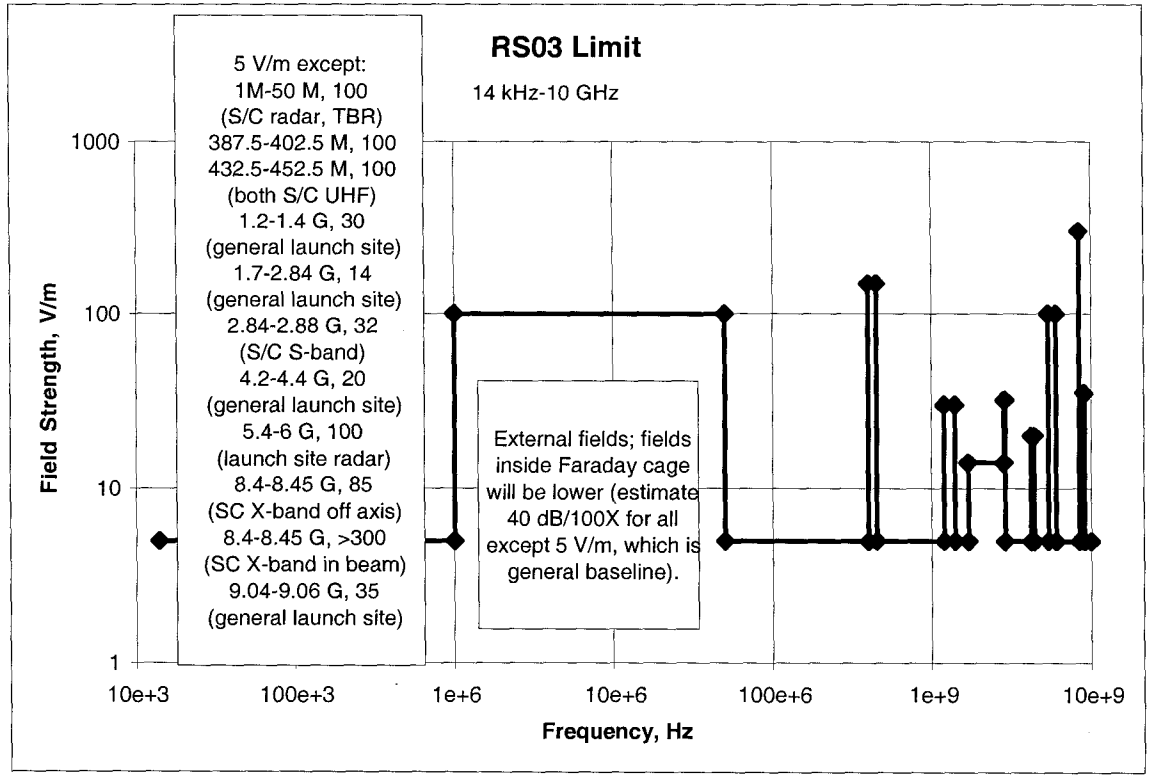
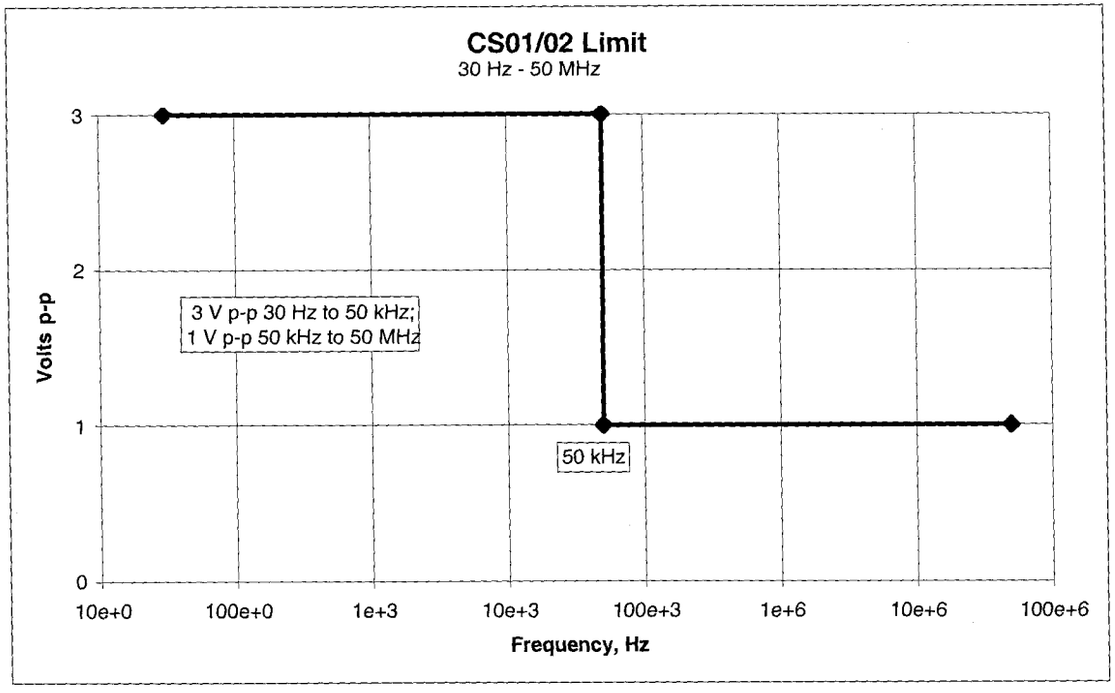


Figure 2-4 CS01 / CS02 Narrowband Injected Ripple



ENVIRONMENTAL REQUIREMENTS

Environmental Parameters

Environmental Requirements Margins

Definition: Environmental Design and Verification Requirements / Predicted Mission Environments

Margins Are Robust to Cover Environmental Prediction and Verification Uncertainties and Unexpected Flight Anomalies

Typical Margins: See Table A-1, MRO ER

	Orbiter System	Assembly Level and Payload		
	Protoflight	**Design/-Qualification**	**Protoflight**	**Flight Acceptance**
Acoustics (1) Level Duration	MEFL + 3 dB 1 min	MEFL + 3 dB 2 min	MEFL + 3 dB 1 min	MEFL 1 min
Random Vibration (1) Level Duration	Low Frequency Random Vibration 1 minute	MEFL + 3 dB 2 min/axis	MEFL + 3 dB 1 min/axis	MEFL 1 min/axis
Sine Vibration Level Duration	No test	1.4 x FA level 2 octaves/min	1.4 x FA level 4 octaves/min	MEFL 4 octaves/min
Pyro Shock (2) Level or Firings	2 actual device firings	1.4 x MEFL (2 shocks/axis) or 2 firings	1.4 x MEFL (1 shock/axis) or 2 firings	Normally performed to PF levels
Thermal: Orbiter bus electronics (3)	Within AFT and not to exceed assembly PF	-35°C to +70°C or AFT-15°C to AFT+20°C [whichever is greater] Duration: 144 hrs hot; 24 hrs cold	-35°C to +70°C or AFT-15°C to AFT+20°C [whichever is greater] Duration: 144 hrs hot; 24 hrs cold	AFT-5°C to AFT+5°C Duration: 60 hrs hot; 8 hrs cold
Thermal: Orbiter mechanisms (3)	Within AFT and not to exceed assembly PF	AFT-15°C to AFT+20°C	AFT-15°C to AFT+20°C	AFT-5°C to AFT+5°C
Thermal: Payload electronics (3)	Within AFT and not to exceed assembly PF	-35°C to +70°C or AFT-15°C to AFT+20°C [whichever is greater] Duration: 144 hrs hot; 24 hrs cold	-35°C to +70°C or AFT-15°C to AFT+20°C [whichever is greater] Duration: 144 hrs hot; 24 hrs cold	AFT-5°C to AFT+5°C Duration: 60 hrs hot; 8 hrs cold
Thermal: Payload detectors, optics (3)	Within AFT and not to exceed assembly PF	AFT-15°C to AFT+20°C Duration: 144 hrs hot; 24 hrs cold	AFT-15°C to AFT+20°C Duration: 144 hrs hot; 24 hrs cold	AFT-5°C to AFT+5°C Duration: 60 hrs hot; 8 hrs cold
Total Ionizing Dose & Displacement Damage	RDF = 2			
Single Event Effects	RDF = 1 (applied to environments)			
EMC Susceptibility	Expected Levels + 6 dB (for pyrotechnic devices, +20 dB if by analysis)			
EMC Emissions	Expected Levels − 6 dB (for pyrotechnic devices, -20 dB if by analysis)			

Table A-1 Orbiter and Payload Environmental Design/Test Margin Requirements

RDF = Radiation Design Factor = Radiation Design Margin (RDM)
EMC = Electromagnetic Compatibility
MEFL = Maximum Expected Flight Level
FA = Flight Acceptance
AFT = Allowable Flight Temperature
PF = Protoflight

(1) = NASA-STD-7001, Payload Vibroacoustic Test Criteria
(2) = NASA-STD-7003, Pyroshock Test Criteria
(3) = Design, Verification/Validation and Operations Principles for Flight Systems, JPL D-17868, 6-15-99