EUROPA CLIPPER MISSION

Environmental Requirements Document (Preliminary DRAFT)

JPL D-80302

Document Custodian: **David E. Brinza**

Date: **April 1, 2014**

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

NASA has not decided whether to proceed with the proposed Europa Clipper mission. Any such decision would be made after completion of the National Environmental Policy Act (NEPA) process for the proposed mission.

EUROPA CLIPPER
Environmental Requirements Document

Prepared by:	3/25/2014 David E. Brinza Europa Clipper Environmental Requirements Engineer (Acting)
Concurred by:	3/25/2014 John C. Forgrave Mission Environmental Assurance Supervisor
Approved by:	3/25/2014 Genji A. Arakaki Europa Clipper Mission Assurance Manager
Approved by:	3/25/2014 Brian C. Cooke Europa Clipper Project Systems Engineer
Approved by:	Thomas Magner Europa Clipper Assistant Project Manager
Approved by:	Barry G. Goldstein Europa Clipper Project Manager

DOCUMENT CHANGE LOG

CHANGE LETTER	CHANGE DATE	SECTIONS AFFECTED	CHANGES/ NOTES
Draft	11-07-13	All	
Prelim Draft	02-13-14	All	Peer Review copy
Preliminary	03-05-14	All	For Unlimited Release

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1.0 INTRODUCTION

1.1 PURPOSE

This document defines environmental design and verification requirements for the proposed Europa Clipper Mission. Successful definition and implementation of the environmental requirements is expected to result in flight hardware that is fully compatible with all anticipated natural or induced ground, launch and mission environments.

The following definitions are used throughout this document:

"**Shall**" = required
"Should" = recommended
"Will" = planned to be carried out

1.2 APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the current issue of the document applies.

1.2.1 GOVERNMENT DOCUMENTS

MIL-STD 461C Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference

MIL-STD-462 Electromagnetic Interference Characteristics, Measurement of

1.2.2 LAUNCH SYSTEM USER GUIDES

Atlas-V Atlas Launch Services User's Guide, United Launch Alliance, Centennial, CO, Rev 11, March 2010

SLS Space Launch System Payload Planner's Guide, TBD

1.3 NASA REFERENCE DOCUMENTS

The following reference documents include various NASA guidelines which are called out in this document for further information on design or test guidance. Others are NASA standards, upon which some of the requirements in this document are based.

NASA-HDBK-4002A Mitigating In-Space Charging Effects – A Guideline, Mar. 3, 2011

NASA-STD-7001 Payload Vibroacoustic Test Criteria

NASA-STD-7003 Pyroshock Test Criteria

NASA-HDBK-7004B Force Limited Vibration Testing Handbook

2.0 ENVIRONMENTAL PROGRAM AND VERIFICATION REQUIREMENTS

2.1 GENERAL

The environmental design and verification program is intended to demonstrate, through rigorous test and analysis methods, the ability of the Europa Clipper Flight System design to successfully survive and operate within specification over the natural or induced ground, launch, cruise and mission operations environments with sufficient margins.

2.2 EUROPA CLIPPER ENVIRONMENTAL VERIFICATION REQUIREMENTS

The Europa Clipper Flight System, instruments, and assemblies/subsystems **shall** be verified to be compatible with the environmental design and test levels presented in Section 4 of this document.

The environmental verification process is outlined in Figure 2.2-1 below and includes both test and analysis methods. Aspects of this flow are described in the sections that follow.

The verification activities (test & analysis) **shall** comply with the project required margins, levels and durations as specified in Table 2.2-1 (Environmental Design & Test Margin Requirements), unless explicitly specified in Section 4 of this document.

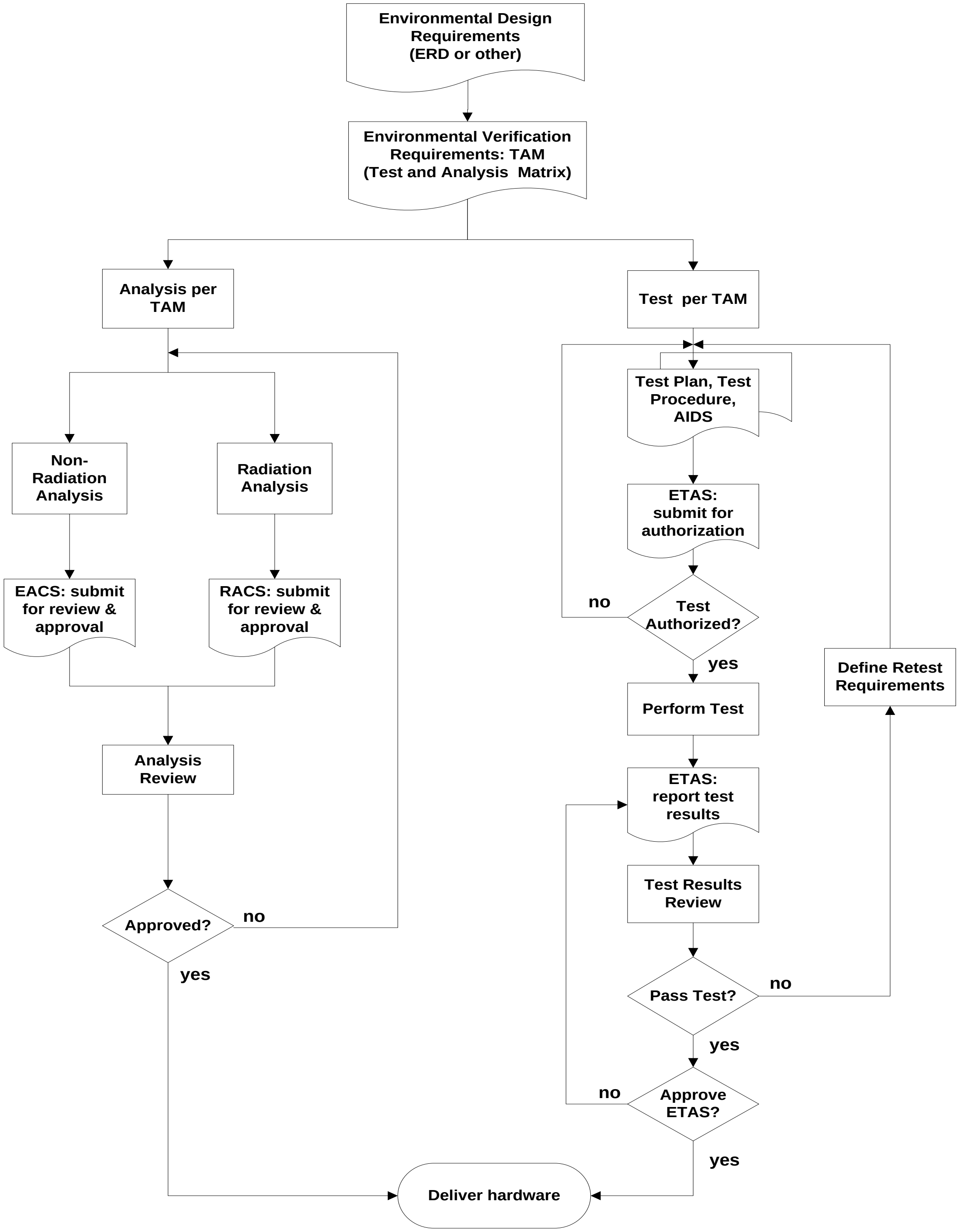


Figure 2.2-1. Environmental Program Flow

Table 2.2-1 Europa Clipper Project Environmental Design and Test Margin Requirements

	Assembly/Subsystem Level			**Flight System Level**
Environment	**Design/Qualification (Qual)**	**Protoflight (PF)**	**Flight Acceptance (FA)**	**Protoflight (PF)**
Acoustics: Level (note 1) Duration	Envelope of MEFL + 3dB and Minimum Workmanship level (note 10) 2 x FA duration	Envelope of MEFL + 3 dB and Minimum Workmanship level (note 10) FA duration	Envelope of MEFL and Minimum Workmanship level (note 10) 1 min minimum	Envelope of MEFL + 3 dB and Minimum Workmanship level (note 10) 1 min minimum
Random Vibration: Level Duration	FA level + 3dB 2 x FA duration	FA level + 3dB FA duration	Envelope of MEFL and Minimum Workmanship level (note 11) 1 min/axis	MEFL + 3dB 1 min/axis
Pyrotechnic Shock: Pyro Device Firings Simulated Pyro Shock	2 firings (notes 6 & 7) 1.4 x FA level 2 shocks/axis (note 8)	2 firings (notes 6 & 7) 1.4 x FA level 1 shocks/axis (note 8)	N/A (no test required) MEFL 1 shock/axis (note 8)	2 firings (dominant shock sources), 1 firing (other sources)
Quasi Static Loads:	per NASA-STD-5001A (see note 9)	per NASA-STD-5001A (see note 9)	per NASA-STD-5001A (see note 9)	
Thermal: Test Media (note 2)	• Thermal Vacuum: Flight System, Payload, Assemblies/Subsystems • Atmosphere/GN2: Assemblies, Payloads (on case-by-case basis, upon Project approval only)	• Thermal Vacuum: Flight System, Payload, Assemblies/Subsystems • Atmosphere/GN2: Assemblies, Payloads (on case-by-case basis, upon Project approval only)	• Thermal Vacuum: Flight System, Payload, Assemblies/Subsystems • Atmosphere/GN2: Assemblies, Payloads (on case-by-case basis, upon Project approval only)	• Thermal Vacuum: Flight System Thermal Balance Phase: -Simulate extreme Space Thermal Environments (per Section 4.5.1), along with worst-case power modes and interface boundary conditions. Flight System Thermal Margin Phase: Drive key assemblies to AFT limits for system functional margin demonstration Planetary Protection Dry-Heat Microbial Reduction: 125ºC for 255 hours (TBR)
Temp. Levels (Test Margins) (note 4)	• Electronics: **Cold**: AFTcold - 15ºC or -35ºC (whichever is colder) **Hot:** AFThot + 20ºC or +70 ºC (whichever is warmer) • Mechanisms without Electronics, Optics, Detectors, and Others: **Cold:** AFTcold - 15ºC **Hot:** AFThot + 20ºC	• Electronics: **Cold**: AFTcold - 15ºC or -35ºC (whichever is colder) **Hot:** AFThot + 20ºC or +70 ºC (whichever is warmer) • Mechanisms without Electronics, Optics, Detectors, and Others: **Cold:** AFTcold - 15ºC **Hot:** AFThot + 20ºC	• Electronics: **Cold**: AFTcold - 5ºC or -25ºC (whichever is colder) **Hot:** AFThot + 5ºC or +55ºC (whichever is warmer) • Mechanisms without Electronics, Optics, Detectors, and Others: **Cold:** AFTcold - 5ºC **Hot:** AFThot + 5ºC	
Thermal Test Duration (note 3)	• Flight System & Payload Electronics 24 hrs cold/72 hrs hot (Op) 6 hrs cold/6 hrs hot (Non-Op) • Non-Electronics Hot and cold dwell times as needed to run tests for all required functions	• Flight System & Payload Electronics 24 hrs cold/72 hrs hot (Op) 6 hrs cold/6 hrs hot (Non-Op) • Non-Electronics Hot and cold dwell times as needed to run tests for all required functions	• Flight System & Payload Electronics 8 hrs cold/60 hrs hot (Op) 6 hrs cold/ 6 hrs hot (Non-Op) • Non-Electronics Hot and cold dwell times as needed to run tests for all required functions	
Number of Thermal Cycles (note 5)	• 3 cycles minimum. 10 cycles maximum (cumulative)	• 3 cycles minimum. 10 cycles maximum (cumulative)	• 3 cycles minimum. 10 cycles maximum (cumulative)	
Temperature Ramp Rate	• $\lvert dT/dt \rvert \leq 5^oC$/min (T/Atmos) • $\lvert dT/dt \rvert \leq 2^oC$/min (T/Vac)	• $\lvert dT/dt \rvert \leq 5^oC$/min (T/Atmos) • $\lvert dT/dt \rvert \leq 2^oC$/min (T/Vac)	• $\lvert dT/dt \rvert \leq 5^oC$/min (T/Atmos) • $\lvert dT/dt \rvert \leq 2^oC$/min (T/Vac)	
Number of Thermal Startups	• 3 cold/3 hot (Op) • 3 cold (Non-Op)	• 3 cold/3 hot (Op) • 3 cold (Non-Op)	• 3 cold/3 hot (Op) • 3 cold (Non-Op)	

	Assembly/Subsystem Level			Flight System Level
Environment	**Design/Qualification (Qual)**	**Protoflight (PF)**	**Flight Acceptance (FA)**	**Protoflight (PF)**
EMC (RE, RS, CE, CS)	MEFL + 6 dB (susceptibility) MinEFL - 6 dB (emissions)	MEFL + 6 dB (susceptibility) MinEFL - 6 dB (emissions) (see note 6)	N/A (grounding/isolation testing only)	Launch Sources: Minimum Expected Flight Level – 6 dB (emissions) Maximum Expected Flight Level + 6dB (susceptibility) Flight System Self - Compatibility at Maximum Expected Flight Level
Internal Electro-Static Discharge (note 12)	Electron fluence: $>10^{10}$ cm^{-2} Current Density: 0.1 $nAcm^{-2}$ to 10 $nAcm^{-2}$ Electron energy range: mid-way into the insulator.			
Charge Particle Radiation (TID/DDD)	Radiation Design Factor (RDF) = 2			

Notes for Table 2.2-1

1. MEFL = Maximum Expected Flight Level; MinEFL= Minimum Expected Flight Level
2. All assemblies will be tested in vacuum ($<10^{-5}$ Torr) unless otherwise exempted;
3. Test duration requirement is cumulative of the test duration employed during thermal cycling.
4. AFT = Allowable Flight Temperature, typically includes both operational and non-operational limits. The number of thermal cycles performed on flight hardware (PF or FA) will be sufficient to detect workmanship defects, mechanical problems or electrical hysteresis.
5. Typically this is 3 to 10 cycles (except for purely mechanical/structural assemblies). Unless otherwise approved by the Project Environmental Requirements Engineer (ERE), no more than 10 cycles (inclusive of all retest activities) will be performed on flight hardware prior to ATLO (Assembly, Test, and Launch Operations) delivery.
6. For pyrotechnic shock and EMC testing, if there is no EM available for Qualification, then a Protoflight test will be performed on a single PF unit. No test required for remaining flight units.
7. Each pyrotechnic device contained within protoflight or qualification hardware shall be fired a minimum of two times in order to characterize the device functionality and the resultant shock responses. Shock levels generated by firings of flight or flight-like pyro devices will not provide a 3 dB Design/Qual/PF level margin and therefore is not a valid PF or Qual Pyroshock test. Shock-sensitive subassemblies within the assembly/subsystem should be assessed for possible Qual/PF level pyroshock testing.
8. For assemblies/subsystems not containing shock-producing devices, shock testing is to be performed at PF test level of 3 dB above FA level with one shock in each of the three orthogonal axes. Qualification tests are the same level as PF tests but with 2 shocks per axis. If performed, FA test levels are at MEFL.
9. JPL takes exception to the NASA-STD 5001A factor of safety for glass. The JPL required ultimate factor of safety for glass shall be a minimum of 2.0, and the acceptance proof test factor shall be 1.2 or greater.
10. Minimum Workmanship Acoustics Level is 138 dB Overall SPL
11. Minimum Workmanship Random Vibration Level is 6.8 Grms Overall
12. IESD test articles are representative PWA and cables with isolated conductors with length >15 cm or area > 3 cm^2

2.3 ENVIRONMENTAL TESTING

Environmental tests approaches are categorized for the purpose of hardware quality verification as Qualification (Qual), Protoflight (PF), and Flight Acceptance (FA).

2.3.1 QUALIFICATION TEST APPROACH

Qualification testing is performed on a dedicated Qualification (or Engineering) Model of the flight hardware that is not intended to fly, in order to qualify the hardware design for the maximum expected flight environment plus margin, including margin on environment duration or cycles.

If approved by the Project ERE, an engineering model of an assembly may be used as a qualification unit and be subjected to qualification environmental testing.

> **Policy**: The engineering model **shall** be flight-like and manufactured using the same assembly techniques and fabrication processes as the flight hardware including: structure, thermal design, shielding, cabling, circuit layout, power consumption, functional modes, and electrical parts with the same signal characteristics.

> **Policy**: Hardware that has been used as a qualification unit and is being considered for use as a flight unit or spare **shall** be evaluated upon completion of testing to determine the details of refurbishment and retest, if any, and an assessment of the residual risk to the project for using the hardware.

2.3.2 PROTOFLIGHT TEST APPROACH

Protoflight testing is performed on flight hardware and serves to simultaneously fulfill the requirements of design qualification and workmanship demonstration for flight acceptance. Protoflight environmental testing demonstrates design adequacy and flight hardware readiness, including appropriate performance and margin tests.

2.3.3 FLIGHT ACCEPTANCE TEST APPROACH

Flight Acceptance (FA) testing is performed on flight hardware and spares only when a previous qualification test has been performed on an identical item. If, as determined by a Heritage Review, previous qualification test levels of a heritage assembly are adequate for the mission and the heritage design and operation is not modified in a way that negates the previous qualification, then the assembly may be tested to Flight Acceptance levels and durations. Flight Acceptance testing may also be required to verify hardware quality and workmanship following minor modifications, rework, or repairs.

2.3.4 THERMAL CYCLING DESIGN CRITERIA

All assemblies are to be designed to accommodate the effects of thermal cycling.

> **Policy**: Electronic hardware **shall** be capable of surviving three times the planned mission expected number of thermal cycles, each over the allowable flight temperature (AFT) extremes, plus an estimate of the thermal cycles expected in the planned ground operations.

> **Policy**: In the absence of a specific mission thermal cycling profile, electronic hardware **shall** be capable of surviving 10,000 cycles, each of a 15 degrees C delta-T excursion.

2.3.5 ASSEMBLY LEVEL ENVIRONMENTAL TESTS

Assembly/instrument level testing is performed prior to delivery for higher level integration.

> **Policy**: Formal environmental tests **shall** be performed on all hardware intended for flight, including spares, at the level of assembly indicated in the TAM.
>
> **Policy**: Flight hardware with documentation claiming prior Qualification by Heritage or Similarity for the above tests **shall** be evaluated and approved by the Project ERE.

2.4 ENVIRONMENTAL ANALYSES

Environmental analyses are performed to verify hardware design compatibility with ground, transportation, storage, launch, and mission environments that may be impractical to verify by test or that are more cost effectively analyzed than tested (e.g., radiation dosage compatibility, venting, and atomic oxygen susceptibility), or where analysis is a better verification method.

> **Policy**: Environmental analyses **shall** be performed against environmental design criteria in Section 4 of this document.

Each level of assembly, where analyses are indicated, **shall** summarize those analyses using the Environmental Analysis Completion Statement (EACS, JPL Form 2566).

> **Policy**: Since analysis results may affect hardware design, all reports for a given hardware item **shall** be submitted to the Project Office prior to the beginning of flight hardware environmental testing.

3.0 ENVIRONMENTAL TEST POLICIES

3.1 GENERAL

This section establishes the implementation, control, and reporting policies for environmental testing of Europa Clipper flight or qualification hardware, whether performed at JPL or subcontractor facilities.

Policy: All flight and qualification hardware **shall** be environmentally tested in accordance with the requirements of this document.

Policy: Deviations from the Environmental Program requirements **shall** require approval through one of the following processes prior to start of any environmental testing:

1. A Category A waiver for project-wide deviations from JPL institutional standards, including this standard.
2. A Category B waiver for all deviations that compromise the intent of the environmental program as contained in the approved project environmental documentation. This includes deviations for non-technical reasons, such as those resulting from schedule or cost constraints.
3. The ETAS form may be used to document minor test deviations with technical justification.

3.2 TEST CONFIGURATION

Policy: All flight hardware including spares **shall** be tested in a flight-like configuration.

Policy: Electrical cabling, connectors, and other fittings normally associated with the assembly or the system **shall** be used as part of the test article.

Policy: The same configuration **shall** be used for Qualification, Protoflight, and Flight Acceptance environmental testing.

Policy: Consistency of environmental testing **shall** be evaluated for environmental tests on hardware configurations qualified in previous environmental test programs.

Policy: Configuration of the system level testing **shall** be as flight-like as possible.

3.3 ASSEMBLY OPERATION/FUNCTIONAL TEST

The hardware will operate in logic and power states that validate the integrity of all electrical circuits and interfaces, including redundant circuitry, and every effort should be made to simulate all operational modes. This includes circuits internal to the assembly and circuits that interface directly with other assemblies of the Europa Clipper system.

Policy: During environmental testing, the flight hardware **shall** be operated in functional modes demonstrating that the assembly performs to specification when exposed to the test environment.

Policy: Functional test procedures **shall** ensure all electrical circuits and interfaces are adequately exercised.

Policy: All assemblies powered during launch **shall** be powered-on and monitored during dynamics testing.

3.4 TEST SEQUENCE

For electronic assemblies, dynamic testing should precede thermal testing (in order of flight exposure). For certain composite structures, thermal cycling should precede dynamic testing for more effective workmanship verification.

EMC testing may be conducted when convenient; however, any anticipated re-work due to EMC anomalies (e.g., connector back shell rework and gasket installations) should be completed prior to dynamics and thermal testing.

> **Policy**: The sequence of environmental tests on a given flight hardware assembly **shall** be established by the responsible engineer and concurred by the Project ERE, based on the flight environment sequence or a review of the hardware design and materials, the sensitivity of the assembly to each environment, and the potential effect of each environment on other environmental characteristics.

> **Policy**: Where applicable, the Qualification or Protoflight test article for a given assembly configuration **shall** successfully pass its Qualification/PF tests prior to commencing with FA tests on an identical flight article.

3.5 ENVIRONMENTAL TEST FACILITIES

Any agency that performs environmental testing will do so in accordance with certain minimum standards, whether these facilities are at JPL, at a subcontractor's facility, or at an independent test laboratory. For testing performed for JPL flight hardware, these minimum standards are defined in Standard Environmental Testing Facilities and Practices document (Rules 35492). Test facility conformance to this Standard will be reviewed and evaluated by the JPL Environmental Test Lab (ETL). For hardware developed and delivered by other agencies, the facilities should include provisions to protect flight hardware from facility anomalies (i.e. power failures, temperature excursions, etc.) The applicable test standards for EMC tests are given in MIL-STD-462.

> **Policy**: The handling of a test article in an environmental test facility, including attachment of any test fixture, **shall** be the responsibility of the hardware Cognizant Engineer.

3.6 ENVIRONMENTAL TEST PLANS/SPECIFICATIONS

> **Policy**: Environmental Test Plans or Specifications **shall** be prepared by each supplier to define the environmental test levels and durations for assembly/subsystem, and instrument level environmental testing.

Environmental test plans should cover the following topics:

- Description of the test article
- Test objectives
- Test setup, test support equipment, and test facility
- Instrumentation and data
- Test tolerances
- Environmental simulations and test media, if applicable
- Test phases, test cases, and test profiles
- Test parameters (Test levels, margins, and durations), as applicable

- Functional and performance verifications
- Success/failure criteria
- Requirements for ETAS, Problem/Failure Reporting (PFRs)
- Flight hardware and personnel protection
- QA provisions
- Post-test activities and analysis

Policy: Revisions to the test plan or specification **shall** be submitted to the Project ERE for approval before beginning the test.

Policy: Test plans **shall** be under revision control, with redlines incorporated prior to environmental testing of any redundant units.

3.7 ENVIRONMENTAL TEST PROCEDURES

Policy: The operation of environmental test equipment and facilities during the performance of environmental tests of flight hardware **shall** be accomplished in accordance with approved test procedures.

3.8 ENVIRONMENTAL TEST AUTHORIZATION & SUMMARY

For the purpose of assuring flight hardware readiness for environmental testing and documenting test results, the Environmental Test Authorization and Completion Statement (ETAS) Process **shall** be followed.

Policy: Test Authorization portion of the ETAS form **shall** be completed by the cognizant engineer for the test article and approved by the Project ERE for each flight hardware serial number prior to commencing environmental testing.

Policy: The ETAS **shall** reference the approved test plan and procedures.

Policy: The ETAS **shall** also describe any deviations from the hardware's flight configuration.

Policy: Upon conclusion of the environmental tests, the Test Results portion of the ETAS form **shall** be completed and approved, clearly denoting the pass/fail disposition of the flight hardware.

Policy: The ETAS **shall** reference the environmental test reports and include a description of any anomalies recorded during environmental testing and reference the associated PFRs.

Appendix B contains a sample ETAS form. An electronic version of the ETAS will be made available by the Project ERE. Additionally, the project may elect to use the on-line ETAS system.

3.9 TEST FAILURE

Policy: Any hardware failure or malfunction during an environmental test or any failure or malfunction of an environmental test facility that would affect an environmental test **shall** be cause for the issuance of a PFR (Problem/Failure Report).

Policy: Flight hardware failure, malfunction, or out-of-specification performance during formal environmental testing **shall** be interpreted as a test failure.

For assembly-level environmental testing, the test may be continued if the Cognizant Engineer and Test Engineer agree that continuation is of diagnostic value and will not damage the flight hardware.

Policy: At the system-level (Instrument), the applicable test plan **shall** designate the responsible representative with the authority to determine whether or not to interrupt the test in the event of a failure or malfunction of the flight hardware.

Policy: Failures associated with environments, but accepted by the project, **shall** be handled through the Category B Waiver process.

3.10 TEST REPORTS

Policy: After each assembly, subsystem, Instrument or system environmental test is terminated (whether because the test requirements were successfully completed or because a test failure has occurred) the testing agency **shall** prepare a Test Agency Report, that includes or addresses any deviations from the approved test procedure.

Policy: For each serial number of each hardware group subjected to formal environmental testing, a report **shall** be made by the hardware provider.

Policy: The report(s) **shall** be available for Project Reviews and as inputs to the assembly Delivery and Pre-Shipment Review Boards.

3.11 RE-TEST POLICIES

Policy: Environmental retests of assemblies **shall** be required under the following circumstances:

1. To complete the protoflight or flight acceptance testing of hardware that has failed during its environmental test program.
2. To re-qualify flight hardware design where design changes, modifications or configuration changes occur after completion of environmental testing.
3. To verify the flight worthiness of refurbished units used as flight spares.
4. To verify the flight acceptability of workmanship performed as part of rework not covered by items 1 to 3.

Policy: Re-testing of assemblies to environmental requirements **shall** be coordinated with the Project ERE.

Policy: The specific re-test requirements **shall** be determined jointly between the cognizant engineer and the Project ERE (with MAM concurrence).

Policy: Flight hardware **shall** not be retested without a re-approval of the updated ETAS or test approval documentation.

4.0 ENVIRONMENTAL DESIGN AND VERIFICATION REQUIREMENTS

4.1 GENERAL

The environmental design and verification requirements contained within this section are established to assure design compatibility of proposed Europa Clipper flight hardware with the specified environments and corresponding mission modes.

4.2 HANDLING AND GROUND OPERATION ENVIRONMENTS

The handling and ground operations environmental design requirements include the environments that the flight hardware would encounter during fabrication, integration, calibration, alignment, and pre-launch operations. The ground handling environments also include transportation and storage of the flight hardware in handling fixtures or shipping containers.

4.2.1 TRANSPORTATION AND HANDLING DYNAMICS ENVIRONMENTS

Transportation and handling procedures for the flight hardware **shall** be such that transportation vibration, acceleration, and shock environments are less severe than launch phase flight acceptance environments specified herein.

4.2.2 THERMAL, PRESSURE AND RELATIVE HUMIDITY ENVIRONMENT

Flight hardware **shall** be designed to survive without degradation the thermal, pressure and relative humidity environments specified below in Table 4.2-1.

All flight hardware **shall** be designed to operate in the thermal, pressure and relative humidity environments specified below in Table 4.2-1, if they need to operate in those environments.

If hardware would be damaged by these environments, then special environmental protective devices **shall** be necessary.

Table 4.2-1 Environments for Handling, Transportation, and Storage

Control Parameter	Low Limit	High Limit
Air Temperature (Storage)	+5°C (1)	+50°C (1)
Air Temperature (Operational)	+5°C	+40°C (2)
Temperature Change Rate	-10°C/hr [TBR]	+10°C/hr [TBR]
Pressure (10,000’ max altitude)	6.9 x 10^4 N/m^2 (520 Torr)	1 x 10^5 N/m^2 (760 Torr)
Relative Humidity	30% (3)	70% (3)

NOTES:
1) Limits could be as wide as -40°C to +70°C during shipping or storage if the environment is not controlled (such as the cargo bay of an aircraft or outside in the direct sun).
2) If the hardware is operating in an environment that is within 10°C of this limit, the hardware should be monitored to ensure that its Flight Acceptance temperature is not exceeded.
3) Could be as low as 0% relative humidity during shipping or storage or as high as 100% in uncontrolled containers.

4.3 LAUNCH ENVIRONMENTS

The launch dynamics requirements are specified in Section 4.5 and the launch thermal environment is specified in Section 4.6.2 of this document.

4.3.1 VENTING

All flight hardware **shall** be designed with margin to survive without degradation a depressurization rate of -4.4kPa/s (-0.638 psi/s) during launch (Atlas V).

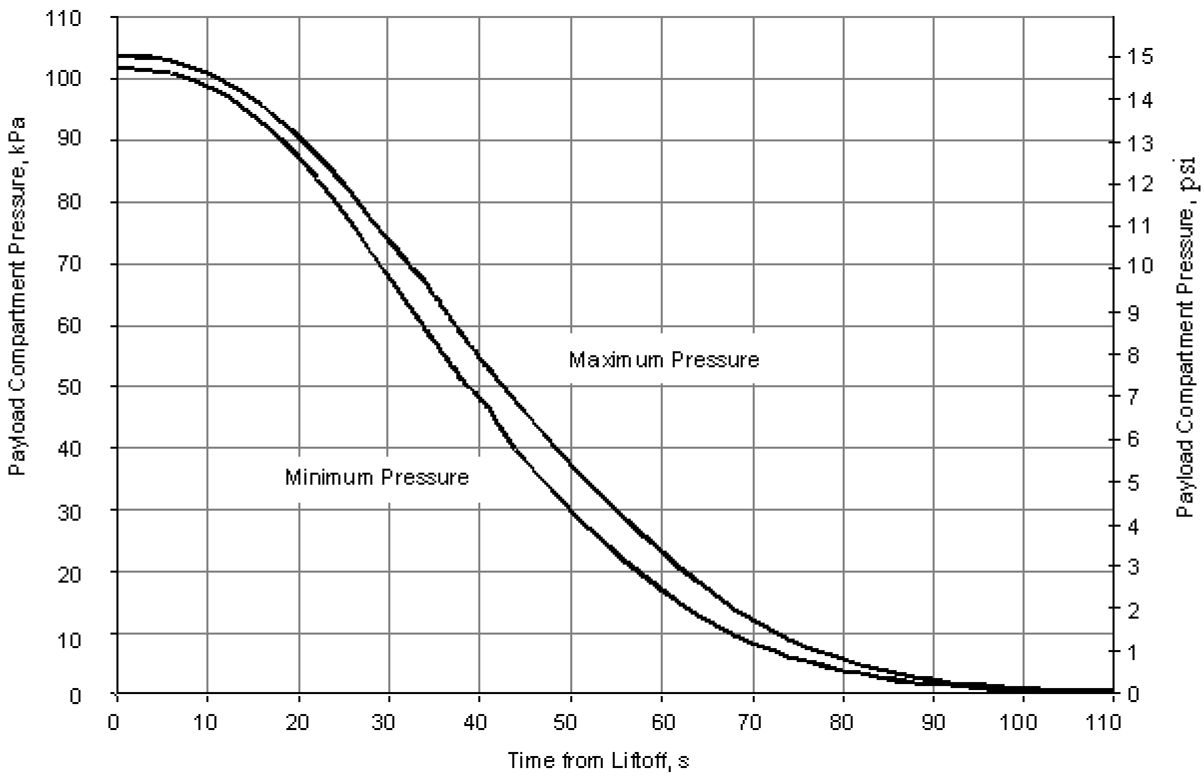


Figure 4.3-1 Typical Static Pressure Profiles inside Atlas V 5-meter fairing

A 1.5x margin for analysis **shall** be applied to this depressurization rate.

Vent paths **shall** be directed away from sensitive surfaces of the instruments.

Thermal blankets **shall** be sealed at the edges and have filtered vents to prevent particle shedding.

Venting adequacy can be established by satisfying the following empirical rule:

(V/A) < 2000 inches

where V = the total internal "void" volume of the assembly in cubic inches and A is the total area of the vent hole(s) or path(s) in square inches. If the assembly satisfies this rule, then no further venting analysis is necessary.

4.3.2 RF AND HV BREAKDOWN DURING LAUNCH AND IN FLIGHT

RF and high voltage circuitry in flight hardware is subject to multipacting/arcing damages at critical pressure.

Flight hardware that operates during launch or other partial pressure conditions **shall** be designed to prevent corona, or any other forms of high voltage breakdown at pressures between 50 and 5 x 10^{-4} Torr.

All Microwave and RF components subjected to high RF power levels (>1 watt) **shall** demonstrate adequate margins to multipaction and/or RF breakdown via either test or analysis.

Verification via test **shall** demonstrate >6 dB margin.

Verification via analysis only **shall** demonstrate >10 dB margin.

(No verification planned).

4.4 STRUCTURAL LOADS DESIGN AND VERIFICATION REQUIREMENTS

4.4.1 MASS ACCELERATION CURVE (TBR)

Quasi-static structural design loads represent the combined quasi-steady accelerations and the low frequency mechanically transmitted dynamic accelerations occurring during launch. The most conservative and earliest available design loads are from the Mass Acceleration Curve (MAC) defined in Figure 4.4-1.

This curve (Figure 4.4-1) **shall** be used as preliminary design curve for all appendage structures (including primary structures other than the spacecraft core), secondary structures, support structures for equipments, and equipment structural attachments and housings.

The MAC represents an upper bound on the dynamic portion of acceleration as a function of mass for physical masses less than 500 kg. This physical mass is the actual mass for single degree of freedom systems. For multi-degree of freedom systems, the physical mass can be approximated as the portion of mass supported by the element being analyzed. The dynamic acceleration is applied in the single direction producing the greatest load component (axial load, bending moment, reaction component, stress level, etc.) being investigated. The loads derived from the MAC should be treated as limit loads. The MAC loads are considered preliminary until validated by coupled loads analyses (CLA). Note that the environmental test requirements should be considered in conjunction with the MAC and coupled loads results.

In addition, the Europa Clipper Flight System center of gravity (c.g.) design requirements for quasi-static acceleration environments are specified in Table 4.4-1. The Flight System c.g. limit loads are for preliminary design of the core structure only. Flight System quasi-static loads on primary structure would be updated by the coupled loads analyses.

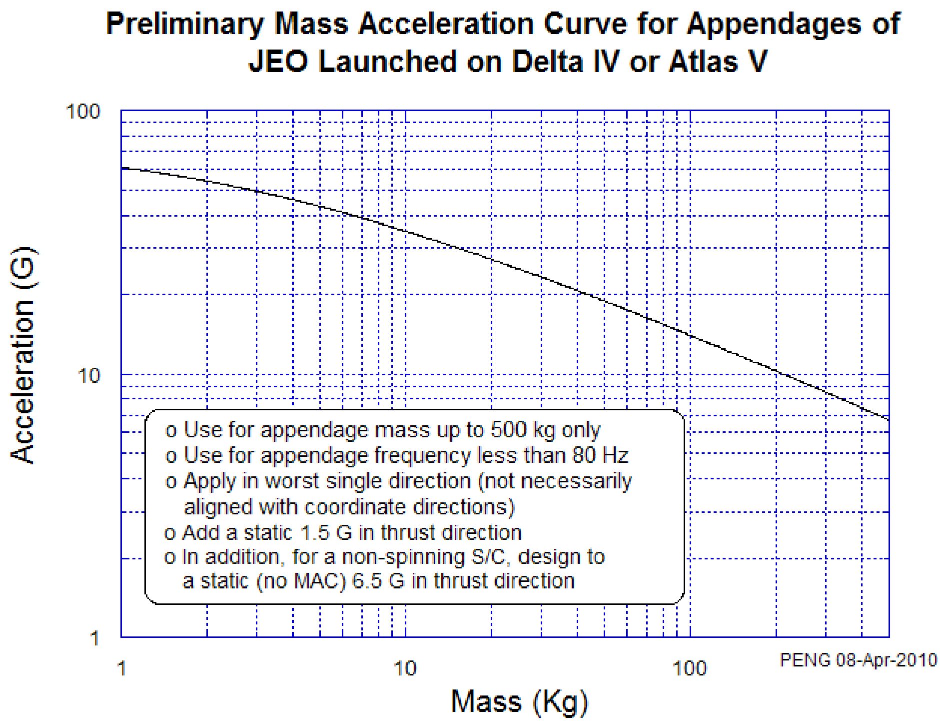


Figure 4.4-1 Preliminary Mass Acceleration Curve for the proposed Europa Clipper Mission (TBR)

Table 4.4-1. Preliminary Spacecraft C.G. Limit Load Factors for Europa Clipper Launched on Candidate Launch Vehicles (Atlas-V) (1)

Load Condition (2)	Max. Lateral Case	Max. Axial Case
Thrust Axis Lateral Axes	+4.0/-1.1 g (3) ± 2.2 g	+6.5/-2.0 g (3) ±0.8 g

Notes:
(1) Loads are applicable at spacecraft C.G. and should be multiplied by appropriate safety factors to obtain structural design loads.
(2) Lateral and thrust axes loading may act simultaneously during any flight event.
(3) Plus indicates compression loads and minus indicates tension load.

4.5 DYNAMIC ENVIRONMENT DESIGN AND VERIFICATION REQUIREMENTS

4.5.1 DYNAMIC REQUIREMENT LEVELS OF ASSEMBLY

Hardware verification requirements for the mission dynamic environments are presented in Section 4.5.2 for the Flight System and Section 4.5.3 for the instruments and assemblies.

4.5.2 EUROPA CLIPPER FLIGHT SYSTEM

4.5.2.1 Random Vibration (TBR)

The Europa Clipper Flight System **shall** be designed and tested to the random vibration requirements per Table 4.5-1.

Table 4.5-1 Flight System Random Vibration Test Levels [Preliminary] (TBR)

Frequency Hz	FA Acceleration Spectral Density	Qual/PF Acceleration Spectral Density
10 – 20	+ 3 dB/Octave	+ 3 dB/Octave
20 – 200	0.0075 g^2 / Hz	0.015 g^2 / Hz
Overall	1.19 Grms	1.68 Grms

Qual: 2 minutes in each of the three axes. PF/FA: 1 minute in each axis.

4.5.2.2 Flight System Acoustic Environment

The acoustic environment (Table 4.5-2) is the envelope of the acoustic environments for the candidate launch vehicles (Atlas V). The maximum acoustic environment for the Europa Clipper Flight System would occur during lift-off and transonic flight. The environment is represented as a reverberant acoustic field with random incidence specified in 1/3 octave bands.

Table 4.5-2 Acoustic Qual/Protoflight & Flight Acceptance Test Levels

Duration: Qual: 2 minutes; PF and FA: 1 minute

1/3 Octave Band Center Frequency	**FA Sound Pressure Level**	**Qual/PF Sound Pressure Level**	**Test Tolerances**
(Hz)	(dB ref. 20 µPa)	(dB ref. 20 µPa)	
31.5	123.5	126.5	+5, -3
40	127.5	130.5	+5, -3
50	130.0	133.0	+5, -3
63	131.5	134.5	± 3
80	132.5	135.5	± 3
100	133.0	136.0	± 3
125	133.0	136.0	± 3
160	133.0	136.0	± 3
200	133.0	136.0	± 3
250	133.0	136.0	± 3
315	133.0	136.0	± 3
400	131.0	134.0	± 3
500	129.0	132.0	± 3
630	126.5	129.5	± 3
800	124.5	127.5	± 3
1000	122.5	125.5	± 3
1250	120.7	123.7	± 3
1600	118.3	121.3	± 3
2000	118.0	121.0	± 3
2500	115.0	118.0	± 3
3150	114.5	117.5	± 3
4000	112.5	115.5	as close as possible
5000	111.5	114.5	as close as possible
6300	111.0	114.0	as close as possible
8000	111.0	114.0	as close as possible
10000	112.0	115.0	as close as possible
Overall	143.1	146.1	± 1

The Europa Clipper Flight System design **shall** perform within specification after being subjected to acoustic test levels as defined in Table 4.5-2.

4.5.2.3 Flight System Pyrotechnic Shock

The Flight System would experience a shock due to the firing of pyrotechnic or other devices during payload separation. For reference, Table 4.5-3 contains maximum predicted shock levels at the Flight System interface due to payload separation from the PAF. At the Flight System, verification would be performed by activating twice each shock-producing device that is the dominant shock source for any potentially shock susceptible hardware. All other shock producing devices shall each be activated once.

The Flight System **shall** be designed to survive without degradation and to function safely during deployment events when subjected to shock environments shown in Table 4.5-5.

Table 4.5-3 Maximum Flight Level Pyroshock Environment at the Launch Vehicle Interface [Preliminary]

Frequency, Hz	MEFL SRS (Q=10)
100	150 g
1000	5000 g
10,000	5000 g

4.5.2.4 Post Boost, Cruise and Orbit Vibrations: Induced Microphonics and Jitter Effects

Low-level dynamic environments would occur during post boost spacecraft flight. The principal sources of these environments are spacecraft/launch vehicle separation, nominal articulation and attitude control maneuvers, nominal main engine burn as well as other mechanical system operations, including reaction wheels, and sensors and instruments with moving masses. These low-level vibrations may induce microphonics or jitter effects in science instruments or spacecraft hardware. (Note: Microphonics is the inducement of noise in electrical devices and jitter is the smearing of images in optical systems caused by vibration-induced motions).

Instruments shall be designed to operate within specification during broadband base dynamic input per Table 4.5-4. Verification shall be by test in three orthogonal axes, one axis at a time.

Table 4.5-4 – Broadband Microphonic Environment For Instrument Deck (TBR)

Frequency (Hz)	Requirement
1-20	+3 dB/octave
20-300	$8x10^{-5}$ g^2/Hz
300-1000	-6 dB/octave
Overall	0.2 grms

Instruments shall also be designed to operate during sinusoidal base inputs per Table 4.5-5 below.

Table 4.5-5 – Sinusoidal Microphonic Environment For Instrument Deck (TBR)

Frequency (Hz)	Requirement
10-1000	0.1 g, 0-to-Peak

1 g = standard acceleration due to gravity = 9.81 m/s^2
Test sweep rate: 2 octave/minute (upsweep only) in each of three orthogonal directions.

Science instruments required to operate during post boost, cruise, and orbit segments of the mission **shall** be designed not to propagate low-level vibration environments (resulting in microphonics/jitter) to susceptible operating flight hardware. Instruments shall be designed to impart forces to the spacecraft no greater than those specified in Table 4.5-6 below.

Table 4.5-6 Maximum Instrument Microphonic/Jitter Emission (TBR)

Frequency (Hz)	Requirement
1-1000 Hz sinusoidal	0.1 lb, 0-to-Peak (0.45 N)
Peak transient	0.1 lb Peak (0.45 N)
Broadband	0.033 lb rms (0.15 N)

Force measured on rigid mount using appropriate instrumentation.
Instruments exhibiting higher measured forces may be subject to operational constraints.

4.5.3 ASSEMBLIES

Assemblies **shall** be tested in the launch power and mechanical configuration.

4.5.3.1 Random Vibration (TBR)

Flight hardware and spares **shall** be designed to survive without degradation when subjected to the application of the specified random vibration environment, which will be provided at a later date. Based on historical missions, typical random vibration Qual and protoflight test levels ranged from 10 to 15 Grms overall with a shaped spectrum (location dependent) ranging from 20 to 2000 Hz.

4.5.3.2 Assembly Acoustics (TBR)

Selected assemblies may be subjected to wideband acoustic noise per the sound pressure level spectral values and durations of Table 4.5-4.

Flight hardware and spares **shall** be designed to survive without degradation, when subjected to the application of the specified acoustic test environment.

4.5.3.3 Assembly Pyrotechnic Shock (TBR)

The assembly mechanical/pyroshock test levels will be provided at a later date. Based on historical missions, typical pyroshock Qual and protoflight test levels ranged from 1500 to 4000 g 0-peak with frequencies ranging from 100 to 10kHz.

Flight hardware and spares **shall** be designed to survive without degradation, when subjected to the application of the specified pyrotechnic shock environment.

Flight hardware which has critical operation during the shock-producing event **shall** be designed to function within specification during the application of the specified pyrotechnic shock environment.

Pyrotechnic shock testing **shall** be performed according to Table 2.2-1.

For more information on pyrotechnic shock testing consult NASA-STD-7003.

4.5.3.4 Quasi- Static Launch Loads (TBR)

PF Random vibration testing typically produces loads on the assemblies that achieves the maximum quasi-static launch load (margin included), as predicted by the most current model (MAC Figure 4.4-1), modal MAC, CLA).

In the event that launch loads are not achieved during vibration testing, those loads **shall** be produced by the performance of a sine transient test or static pull.

4.6 THERMAL ENVIRONMENTS AND VERIFICATION REQUIREMENTS

4.6.1 DEFINITIONS

Terms used herein for thermal design and test are defined as follows:

Operating Allowable Flight Temperature (AFT):
For specified assemblies and subsystems, the Operating AFT range includes the worst case nominal (i.e., non-emergency) hot and cold temperature limits, including allowances for prediction uncertainties. These limits encompass all nominal operating modes, performance within functional specifications, that the Thermal Control Subsystem is designed to accommodate. Temperatures are measured at the thermal control surface (e.g. mounting surface, radiator surface, etc.), as specified by Thermal Engineering.

Non-Operating Allowable Flight Temperature
For specified assemblies and subsystems, the Non-Operating AFT range includes the worst case powered-off hot and cold mission temperature limits, including allowances for prediction uncertainties. These limits encompass all nominal (i.e., non-emergency) non-operating modes that the Thermal Control Subsystem is designed to accommodate. Temperatures are measured at the thermal control surface (e.g. mounting surface, radiator surface, etc.), as specified by Thermal Engineering.

Protoflight (PF) Temperature Limits (Operating and Non-Operating)
Protoflight thermal test magnitude and duration are identical to qualification test magnitude and duration. Operating Protoflight testing implies meeting all functional specifications in the PF operating environments.

Flight Acceptance (FA) Temperature Limits (Operating and Non-Operating)
FA is the temperature range over which flight assemblies whose design has been previously qualified will be tested to verify workmanship and functionality within specification. FA testing serves to demonstrate a moderate degree of margin beyond the AFT range.

Design Temperatures

Design temperatures are the temperature limits to which assemblies are designed to meet functional and performance specifications. Design temperatures are normally equivalent to the Qualification/ Protoflight limits.

4.6.2 LAUNCH THERMAL ENVIRONMENT

The thermal control design **shall** maintain assemblies within their respective AFT limits while exposed to the launch induced thermal environments in Section 4.6.2.1 and 4.6.2.2.

4.6.2.1 Payload Fairing Wall Temperature

Atlas-V: Inner surfaces of the Atlas V 400 PLF cone and cylinder have a low-emittance finish ($\varepsilon < 0.1$). The inner surfaces of the composite 5-m PLF cone and cylinder have an emittance of 0.9. The peak heat flux radiated by the inner surfaces of the cone and cylinder of the Atlas V 400 PLF is less than 400 W/m^2 (125 $Btu/hr\text{-}ft^2$), and peak temperatures remain below 212°C (414°F) at the warmest location. The peak heat flux radiated by the inner surfaces of the cone and cylinder of the 5-m PLF is less than 914 W/m^2 (290 $Btu/hr\text{-}ft^2$), and peak temperatures remain below 93°C (200°F) at the warmest location.

4.6.2.2 Ascent Free Molecular Heating

Atlas-V Payload Fairing jettison typically occurs when the 3-sigma maximum free molecular heat flux decreases to 1,135 W/m^2 (360 $Btu/hr\text{-}ft^2$). Typical free molecular heating (FMH) profiles are highly dependent on the trajectory flown. The spacecraft thermal environment following fairing jettison includes free molecular heating, solar heating, Earth albedo heating, and Earth thermal heating, plus radiation to the upper stage and to deep space.

4.6.3 SPACE THERMAL ENVIRONMENT

The thermal control design **shall** maintain assemblies within their respective Allowable Flight Temperature ranges when subjected to the worst-case external mission environments as specified in Table 4.6-1.

4.6.3.1 Internal Heat Sources

The internal heat source for an assembly is defined as the minimum and maximum heat dissipation (thermal Watts) of the assembly for all mission-operating modes.

Allowable Flight Temperatures **shall** be maintained under all modes of internal heat-dissipation.

4.6.3.2 Vacuum

Assemblies **shall** be designed to operate within specification for a space vacuum condition of 1.0×10^{-14} Torr.

Test vacuum chambers with pressure $\leq 10^{-5}$ Torr, will satisfy the above requirement if verified through testing.

Table 4.6-1 External Heat Sources/Sinks

Mission Phases	Mean Direct Solar Flux, (W/m^2)	Reflected Solar (Albedo)	Planetary IR Emission (W/m^2)	Heat Sink (Deep Space) Temperature (K)
Near Earth	1323 (aphelion) 1414 (perihelion) 1367.5 (mean)	0.30±0.01 (mean)	234±7 (mean)	2.7
Near Venus	3235 at 0.65AU 2579 (aphelion) 2650 (perihelion) 2614 (mean)	0.8 ±0.02	153	2.7
Cruise (End of Cruise)	50.5	n/a	n/a	2.7
Jupiter Orbiting	46 (aphelion) 56 (perihelion) 51 (mean)	0.343 ± 0.032	13.6	2.7
Jupiter Eclipse	0 (Up to 5 hours)			

4.6.4 FLIGHT SYSTEM THERMAL VACUUM TEST

The Flight System-level thermal vacuum test **shall** include thermal balance and functional testing phases.

4.6.5 ASSEMBLY/ SUBSYSTEM THERMAL DESIGN AND VERIFICATION REQUIREMENTS

Newly designed flight hardware **shall** be tested to Protoflight/Qualification limits.

Flight hardware assemblies **shall** be designed to perform within specification (including start-up capability), while in vacuum, over their respective thermal test limits.

Flight hardware assemblies **shall** be designed to survive without degradation after exposure, while in vacuum, to the non-operating thermal test limits.

A recommended test profile is shown in Figure 4.6-1; however, alternate test profiles may be used, as long as all the required test parameters are met.

Assemblies, which are powered-on during launch, **shall** be operated during chamber evacuation to monitor corona effects.

Each plateau **shall** be maintained for a minimum of 2 hours, once temperature stabilization is achieved.

Total operating and non-operating durations **shall** be as designated in Table 4.6-2.

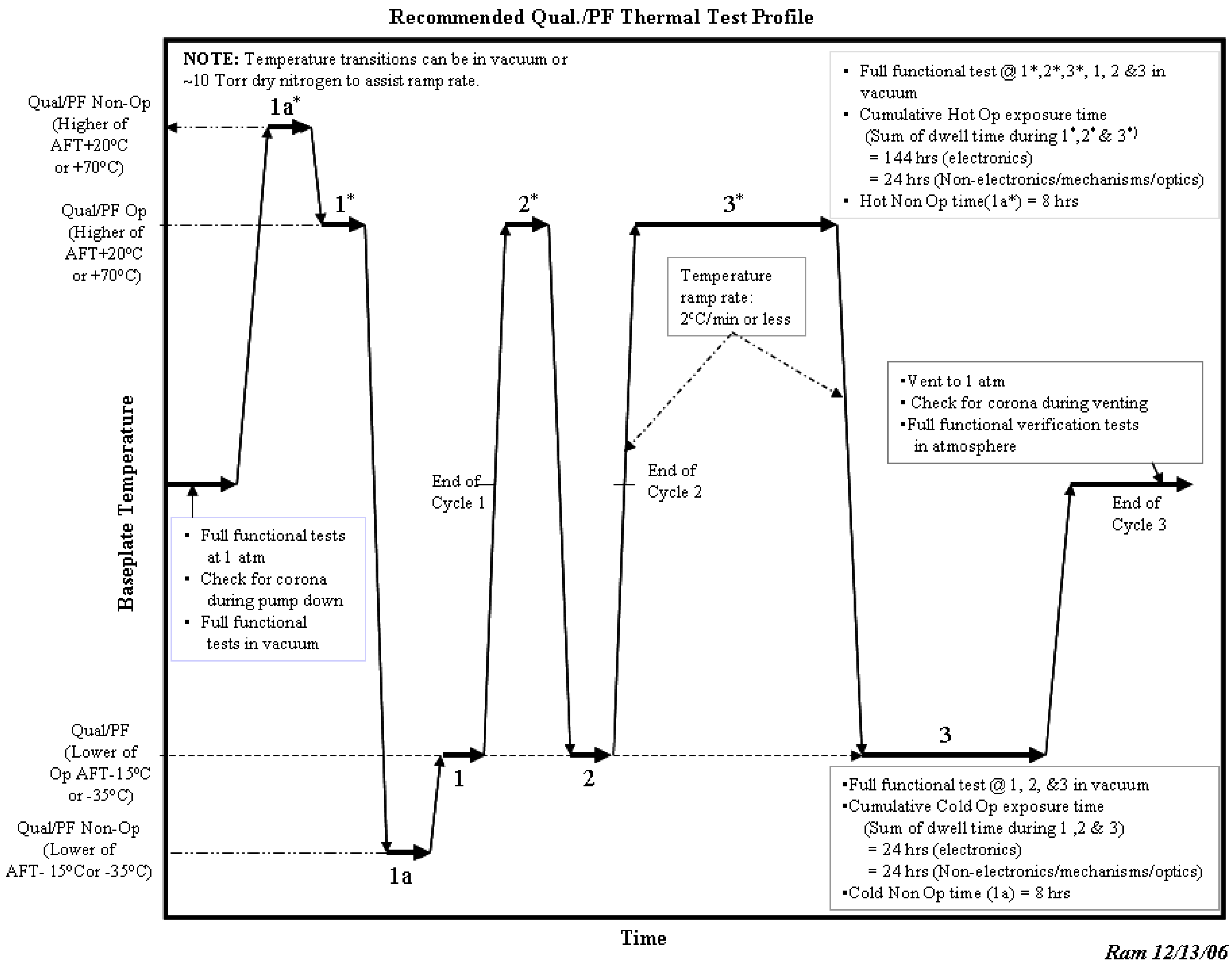


Figure 4.6-1 Example of Recommended Thermal Testing Profile – Assembly Test

Notes:

1. Pump-down to 10^{-5} Torr. Corona check during pump-down, if applicable
2. Initial performance test following pump-down
3. Abbreviated performance test
4. Full performance test
5. Hot/cold start-ups
6. Accumulate remaining operational hours, as required (Table 4.6-4)
7. Return to ambient pressure; final performance test
8. Heater tests and /or cold non-op start-up, if required

Functional testing **shall** be performed a minimum of three times at the hot operational test limits and a minimum of three times at the cold operational test limits. (Ideally, a functional test should be run at each temperature plateau for a total of 6 times, minimum.)

Table 4.6-2 Operational/Non-operational Thermal Vacuum Durations

	Operating, hours Hot/Cold	Non-Operating, hours Hot/Cold
PF/QUAL: Electronics (spacecraft and instrument)	72/24	6/6
FA:Electronics (spacecraft and instrument)	60/8	6/6
PF/QUAL:Non-Electronics (antennas, mechanisms, etc.)	Hot and cold dwell times as needed to run tests of all required functions	6/6
FA: Non-Electronics (antennas, mechanisms, etc.)	Hot and cold dwell times as needed to run tests of all required functions	6/6

Assemblies **shall** demonstrate a minimum of three proper start-ups at the hot and cold operational test limits and also at the cold non-operational test limit (if required*).

Exception: One-time deployable mechanisms, or launch latches and restraints, with the approval of the Project ERE and the environmental discipline specialists, and documented in the project-approved Environmental Requirements Document, may be operated only one time at the hot plateau and one time at the cold plateau of the thermal cycle.

***Note:** Start-ups from the cold non-op test limit are required if the mission thermal control scheme requires powering on equipment at the cold non-operational Allowable Flight Temperature.

Special thermal design features, such as heater and louver operations, should be demonstrated, if applicable. Additionally, any flight temperature sensing devices should be calibrated in this test.

4.7 ELECTROMAGNETIC COMPATIBILITY (EMC)

The EMC design and verification program is intended to produce a Europa Clipper Flight System (1) that would be electromagnetically compatible with itself and its external environment during all mission phases; and (2) that permit instrument operations without operational constraints. This includes the launch environment (launch vehicle and launch site) and all mission operating conditions.

4.7.1 LAUNCH VEHICLE/SITE EMC

4.7.1.1 Atlas V Launch Vehicle Transponder and RF Characteristics

Atlas V Launch Vehicle (LV) intentional transmissions are limited to the S-band telemetry transmitters (for operation with the Tracking/Data Relay Satellite System and GPS Metric Tracking System), S-band video, and the C-band beacon transponder. LV transmitter and receiver characteristics for the Atlas V 500 series LVs appear in Tables 4.7-1 through 4.7-3.

Table 4.7-1. Atlas V 500 Series C-Band Transponder and RF Characteristics

TRANSMITTER		
p/n 58-03240-1		
Frequency	5765	MHz
Frequency Stability	±3	MHz
Bandwidth	6	MHz
Pulse Modulation		
Pulse Frequency	2600	pps (max ops)
	1000	pps (nominal ops)
Pulsewidth	0.5 (±0.1)	microseconds
Fixed Delay Setting	2.5 (±0.1)	microseconds
Output Power (peak)	700	watts (max)
RECEIVER		
p/n 58-03240-1		
Frequency	5690	MHz
Stability	±3	MHz
3 dB Bandwidth	11 (±3)	MHz
Sensitivity	-67	dBm minimum

ANTENNA SYSTEM	Clock Angle Pattern Cut (0 to 360°) in 10° (theta) bands.		
p/n 58-03220-3		(includes 3 dB power split)	
Type	Theta	Omni, with PLF	Omni, no PLF
Slot	(deg)	Gain dBi Max.	Gain dBi Max.
RHC Polarized	80 to 90	-3.17	-7.57
	70 to 80	-3.17	-1.75
Locations	60 to 70	-2.27	-0.07
Centaur Station,	50 to 60	-1.08	+0.28
97.8 inches	40 to 50	-0.75	0
Centaur Clock Angle,	30 to 40	-0.06	-0.01
177° and 357°	20 to 30	+0.35	+0.04
	10 to 20	+2.03	+1.69
PLF Station,	0 to 10	+2.76	+1.91
2535.4 inches	-10 to 0	+2.91	+1.81
PLF Clock Angle,	-20 to -10	+2.20	+1.02
128° and 308°	-30 to -20	+1.05	-0.36
	-40 to -30	-0.09	-0.75
Vehicle Min. RF Loss	-50 to -40	-0.53	-1.33
6.8 dB, with PLF	-60 to -50	-1.35	-1.33
2.3 dB, no PLF	-70 to -60	-2.48	-1.98
	-80 to -70	-2.77	-2.84
	-90 to -80	-3.16	-4.13

Table 4.7-2. Atlas V 500 Series S-Band Transponder and RF Characteristics

TRANSMITTER		
p/n 55-03053-3		
Frequency	2211	MHz
Frequency Stability	4.4	kHz
Bandwidth	±4	MHz
Modulation		BPSK/QPSK
Telemetry Rate (NRZ-M)	1024 or 256	kbps I - Channel
Forward Error Correction	Convolutional	Rate 1/2, k=7
	3200 or 200	kbps Q - Channel
Output Power:		
Single Port	26.0	watt minimum
	45.0	watt maximum
Dual Port	11.6	watt minimum
	25.4	watt maximum

ANTENNA SYSTEM	Clock Angle Pattern Cut (0 to 360°) in 10° (theta) bands.			
p/n 58-03220-3		(includes 3 dB power split)		(no 3 dB power split)
Type Slot	Theta (deg)	Omni, with PLF(1) Gain dBi Max.	Omni, no PLF Gain dBi Max.	Single Antenna, no PLF Gain dBi Max.
RHC Polarized	80 to 90	-0.99	-6.03	-3.31
	70 to 80	+0.01	-2.93	-0.57
Locations	60 to 70	+1.65	-0..20	+1.82
Centaur Station,	50 to 60	+1.65	+1.87	+3.87
97.8 inches	40 to 50	+1.44	+2.50	+4.99
Centaur Clock Angle,	30 to 40	+2.40	+2.50	+5.21
177° and 357°	20 to 30	+3.54	+2.26	+5.17
	10 to 20	+3.54	+1.86	+4.87
Booster Station,	0 to 10	+3.86	+1.65	+4.66
2041.6 inches	-10 to 0	+3.86	+1.44	+4.40
Booster Clock Angle,	-20 to -10	+3.60	+1.25	+4.16
180° and 357.6°	-30 to -20	+2.92	+0.75	+3.63
	-40 to -30	+2.01	+0.17	+2.69
	-50 to -40	+0.89	-0.57	+1.86
Vehicle Min. RF Loss	-60 to -50	-0.04	-1.68	+0.80
8.7 dB, with PLF	-70 to -60	-0.54	-1.97	+0.30
1.1 dB, no PLF	-80 to -70	-0.87	-2.30	-0.28
	-90 to -80	-2.53	-2.30	-0.84

NOTE:
(1) This antenna pattern is from the telemetry antennas located on the Booster Interstage Adapter (BISA) and used prior to payload fairing jettison.

Table 4.7-3. Atlas V 500 Series Flight Termination System (FTS) Receiver and RF Characteristics

RECEIVER p/n 58-03230-1		
Frequency	421.0	MHz
Stability	±0.0005	% of 410.3 MHz
Bandwidth	0.180	MHz
Sensitivity	-107.0	dBm minimum

ANTENNA SYSTEM	Clock Angle Pattern Cut (0 to 360°) in 10° (theta) bands.		
p/n 58-03220-3		(includes 3 dB power split)	
Type Slot	Theta (deg)	Omni, with PLF Gain dBi Max.	Omni, no PLF Gain dBi Max.
Linear Vertical Polarized	80 to 90	-5.62	-2.34
	70 to 80	-4.67	-2.62
Locations	60 to 70	-2.20	-2.78
Centaur Station,	50 to 60	-3.04	-1.32
106.9 inches	40 to 50	-3.25	-2.50
Centaur Clock Angle,	30 to 40	-3.90	-2.57
177° and 357°	20 to 30	-4.85	-2.54
	10 to 20	-4.31	-2.20
PLF Station,	0 to 10	-4.53	-2.20
2526.4 inches	-10 to 0	-4.02	-2.10
PLF Clock Angle,	-20 to -10	-4.98	-2.23
128° and 308°	-30 to -20	-3.71	-2.27
	-40 to -30	-2.75	-2.33
Vehicle Min. RF Loss	-50 to -40	-3.26	-2.75
2.2 dB, with PLF	-60 to -50	-2.92	-1.96
3.0 dB, no PLF	-70 to -60	-3.16	-1.37
	-80 to -70	-3.75	-1.39
	-90 to -80	-3.90	-2.52

4.7.1.2 Launch Vehicle Unintentional RF Emissions (Atlas V)

Figure 4.7-1 depicts the unintentional Radio Frequency (RF) emissions generated by the LV. LV unintentional emissions shall not exceed an E-field level of 114 dBμV/m in the frequency range from 14 kHz to 18 GHz.

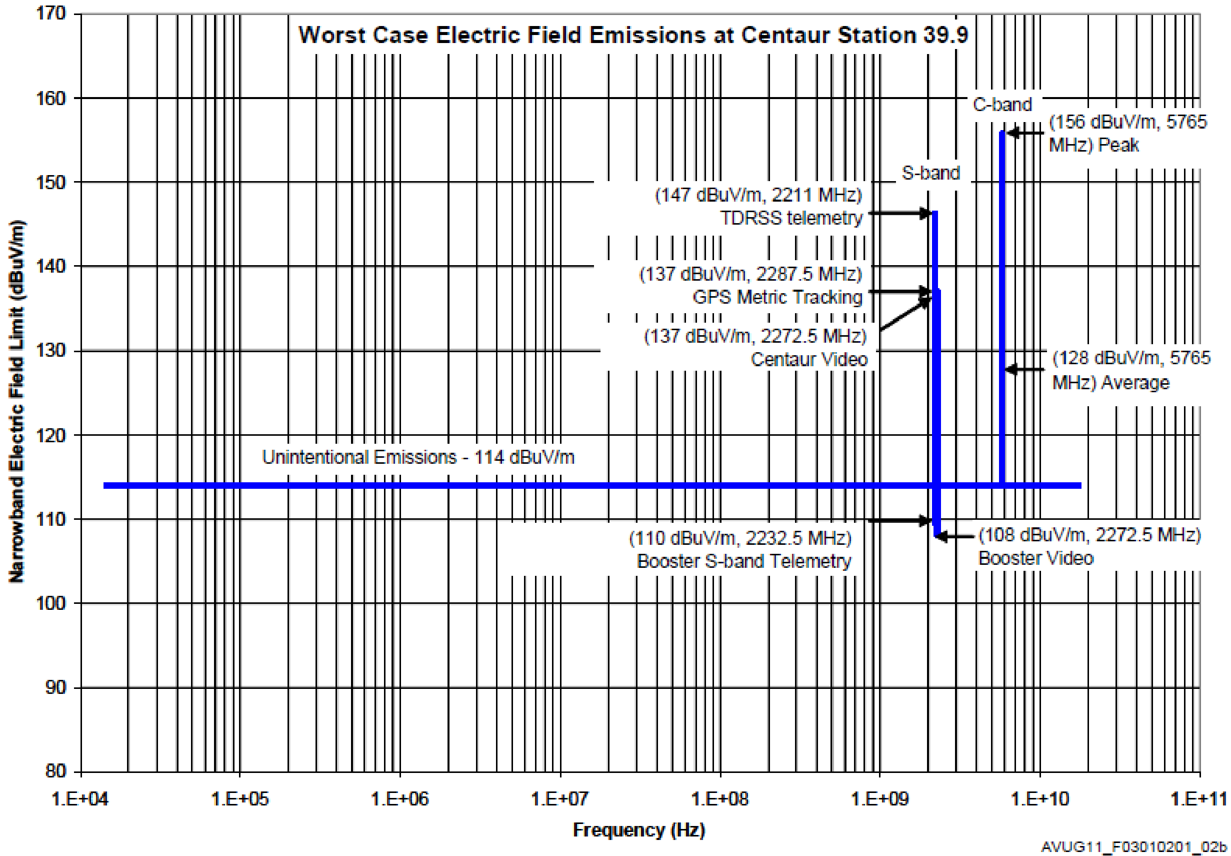


Figure 4.7-1. Atlas V 500 Series Launch Vehicle Field Radiation Observed at Top of C22

4.7.1.3 Launch Range Electromagnetic Environment (Atlas V)

An EMC analysis will be performed to ensure EMC of the SC/LV with the Eastern and Western Range environments, including updates as available. On customer request, the LV will coordinate with the Range to address SC issues with Range-controlled EM emitters during transport from the payload processing facility to the launch site and at the launch complex itself.

Tables 4.7-4 and 4.7-5 depict the EM emitters in the vicinity of CCAFS. The launch range EM environment is primarily based on information in TOR-2005 (1663)-3790 “Cape Canaveral Spaceport Radio Frequency Environment,” November 2005; Rev G (UFOUO) E-field intensities during transport from Astrotech and at SLC-41 are also shown. Data can be provided for other locations upon request. The launch site RF environment is dynamic and subject to change. These data represent the known (peak*) RF environment as of the date of the March 2010 Atlas V Launch Services User’s Guide. The launch site and transport RF environment data will be updated in the mission Interface Control Documents (ICDs) on an as-needed basis.

*Peak levels are defined in the TOR as the root-mean-square value of the continuous-wave sinusoid for that portion of the duty cycle when the emitter is active.

Table 4.7-4. Worst-Case (Peak) RF Environment during Transport from Astrotech Spaceflight Operations to SLC-41

Emitter Name	**Frequency (MHz)[1]**	**Theoretical Intensity (Peak) [1] [3] (V/m)**		***Duty Cycle*[1] [2]**	**Typical Mitigation[1]**	
CSAS Orbit	406.5/416.5/421.0	*0.33*		*1.0*	None	
Radar ARSR-4	1244.06, 1326.92	**1.54**		**0.0432**	[Topography]	
GPS Grnd Antenna	1784.74	*2.47*		*1.0*	None	
NASA STDN	2025 to 2110	*6.39*		*1.0*	None	
Miscellaneous #1	2710	*6.58*		*0.0012*	None	
Miscellaneous #2	2702.6-2897.5	*1.19*		*0.0008*	None	
Miscellaneous #3	2750 & 2840	*6.13*		*0.0008*	None	
WSR-88D (NEXRAD)	2865	*14.57*		*0.006*	None	
SRB Retrieval Ship (S-Band)	3049.4	*4.49*		*0.00072*	None	
SRB Retrieval Ship (S-Band)[6]	3049.4	*276.12*		*0.00072*	None	
Miscellaneous #4	3050	*2.20*		*0.00072*	None	
Channel 9 Weather	5550	*17.38*		*0.010*	None	
Channel 2 Weather	5570	**6.47**		**0.0032**	[Topography]	
WSR-74C	5625	*12.62*		*0.0064*	None	
TDR 43-250 (Dec. 08)	5625	*22.19*		*0.0030*	None	
TDWR	5640	**14.36**		**0.010**	[Topography]	
Radar 0.14 (0.134)	5690	**83.97**		**0.0016**	Procedure Mask	
Radar 1.16	5690	*60.31*		*0.00064*	PRD Action Required	
Radar 19.39	5710	*83.09*		*0.005*	PRD Action Required	
Radar 19.14	5690	*182.78*		*0.0016*	PRD Action Required	
Radar 19.17	5690	*104.53*		*0.0008*	PRD Action Required	
Radar 28.14	5690	**15.82**		**0.0016**	[Topography]	
NDR (MCR) C-Band Pulse Doppler	5525	**204.31**		**0.004**	PRD Action Required 5 Degree elevation	
SRB Retrieval Ship (X-Band)	9413.6	*1.08*		*0.00072*	None	
SRB Retrieval Ship (X-Band)[6]	9413.6	*66.64*		*0.00072*	None	
Miscellaneous #5	9410	*3.37*		*0.00072*	None	
ET Barge Tug	9410	*69.57*		*0.00072*	None	
Miscellaneous #6	9410	*645.22*	*(70)*	*0.00072*	Masking	Measured
Miscellaneous #7	9410	*2.40*		*0.00072*	None	
Miscellaneous #8[7]	9455	*5.78*		*0.0024*	None	
Cruise Ships	9410	*2.84*		**0.0012**	None	
NASA X-Band CW Hangar (Liberty)	10490, 10499	*5.19*		*1.0*	None	
NASA X-Band CW (LCU)	10490, 10499	*1.73*		*1.0*	None	
NASA Avian Detector	9410	*6.46*		*0.0005*	None	
Radar Test Bed	5690	*30.03*		*0.0016*	None[5]	

Notes:

(1) Majority data taken from Aerospace TOR-2005(1663)-3790, "Cape Canaveral Spaceport Radio Frequency Environment," November 2005, Rev. G (UFOUO)

(2) Avg. V/m = PkV/m*sqrt (Duty Cycle).

(3) Non-shaded sources are without specific mechanical or software mitigation measures; bold sources have masking/mechanical or topography and italicized sources indicate no masking or topography controls.

(4) Measured E-fields indicated by ( ) – measurements performed during the WGS SC-1 transport.

(5) Radar Test Bed is pointing up when not in use.

(6) Results based on SRB Retrieval Ship being used as ET Barge tug vessel.

(7) Radar is not yet installed.

Table 4.7-5: Worst-Case (Peak) RF Environment at SLC-41

Emitter Name	Frequency (MHz)[1]	Theoretical Intensity (Peak)[1] [3] (V/m)		*Duty Cycle*[1] [2]	Typical Mitigation [1]	
CSAS Orbit	406.5/416.5/421.0	*0.23*		*1.0*	None	
Radar ARSR-4	1244.06, 1326.92	**1.26**		**0.0432**	[Topography][5]	
GPS Grnd Antenna	1784.74	*2.25*		*1.0*	None	
NASA STDN	2025 to 2110	*0.93*		*1.0*	None	
Miscellaneous #1	2710	*4.46*		*.0012*	None	
Miscellaneous #2	2702.6-2897.5	*1.06*		*0.0008*	None	
Miscellaneous #3	2750 & 2840	*5.19*	*(2.18)*	*0.0008*	None	Measured
WSR-88D (NEXRAD)	2865	**12.69**	**(0.10)**	**0.006**	[Topography][5]	Measured
SRB Retrieval Ship (S-Band)	3049.4	*3.58*		*0.00072*	None	
SRB Retrieval Ship (S-Band)[8]	3049.4	*16.91*		*0.00072*	None	
Miscellaneous #4	3050	*1.59*		*0.00072*	None	
Channel 9 Weather	5550	*9.930*		*0.010*	None	
Channel 2 Weather	5570	**4.66**		**0.0032**	[Topography][5]	
WSR-74C	5625	*10.58*	*(0.07)*	*0.0064*	None	Measured
TDR 43-250 (Dec. 08)	5625	*10.39*		*0.0030*	None	
TDWR	5640	**9.97**		**0.010**	[Topography][5]	
Radar 0.14 (0.134)	5690	**71.7**[4]		**0.0016**	Procedure Mask	
Radar 1.16	5690	**52.6**[4]		**0.00064**	Procedure Mask	
Radar 19.39	5710	**29.8**[4]		**0.005**	Procedure Mask	
Radar 19.14	5690	**106.4**[4]		**0.0016**	Procedure Mask	
Radar 19.17	5690	**55.1**[4]		**0.0008**	Procedure Mask	
Radar 28.14	5690	**15.5**		**0.0016**	Topography[5]	
NDR (MCR) C-Band Pulse Doppler	5525	**173.0**[4]		**0.004**	5 Degree Elevation	
SRB Retrieval Ship (X-Band)	9413.6	*0.86*		*0.00072*	None	
SRB Retrieval Ship (X-Band)[8]	9413.6	*4.08*		*0.00072*	None	
Miscellaneous #5 (X-Band)	9410	*2.43*		*0.00072*	None	
Miscellaneous #6	9410	*41.93*	*(0.13)*	*0.00072*	Masking	Measured
Miscellaneous #7	9410	*1.94*		*0.00072*	None	
ET Barge Tug	9410	*4.17*		*0.0012*	None	
Miscellaneous #8[9]	9455	*3.52*		*0.0024*	None	
Cruise Ships	9410	*2.19*		*0.0012*	None	
NASA X-Band CW Hanger (Liberty)	10490, 10499	*4.15*		*1.0*	None	
NASA X-Band CW (LCU)	10490, 10499	*1.73*		*1.0*	None	
NASA Avian Detector	9410	*2.41*		*0.0005*	None	
Radar Test Bed	5690	*25.52*		*0.0016*	None[7]	

Notes:

(1) Majority data taken from Aerospace TOR-2005(1663)-3790, "Cape Canaveral Spaceport Radio Frequency Environment," November 2005, Rev. G (UFOUO)

(2) Avg. V/m = PkV/m*sqrt (Duty Cycle).

(3) Non-shaded sources are without specific mechanical or software mitigation measures; bold sources have masking/mechanical or topography and italicized sources indicate no masking or topography controls.

(4) In-flight tracking levels for Tracking Radars (0.14, 1.16, 19.39, 19.14, 19.17 and NASA C-Band) are typically 20 V/m.

(5) E-field levels are above the VIF/MLP – E-fields will be seen after launch.

(6) Measured E-fields indicated by ( ) – in VIF at Level 6 – Test Report, BOEING-KSC-N120-53434-05 dated 9 February 2005.

(7) Radar Test Bed is pointing up when not in use.

(8) Results based on closest approach during ET Barge transit.

(9) Radar is not yet installed.

4.7.1.4 Spacecraft-Generated EMC Environment Limitation (Atlas V)

During ground and launch operation time frames through SC separation, any SC Electromagnetic Interference (EMI) radiated emissions (including antenna radiation) should not exceed values depicted in Figure 4.7-2. LV/SC external interfaces (EMI-conducted emissions) must be examined individually. SC shall provide available unintentional radiated emissions data to the LV in the frequency ranges from 410 to 430 MHz, 1500 to 1650 MHz, and from 5660 to 5720 MHz.

Each SC will be treated on a mission-unique basis. Assurance of the LV/SC EMC with respect to payload emissions will be a shared responsibility between ULA and the SC provider.

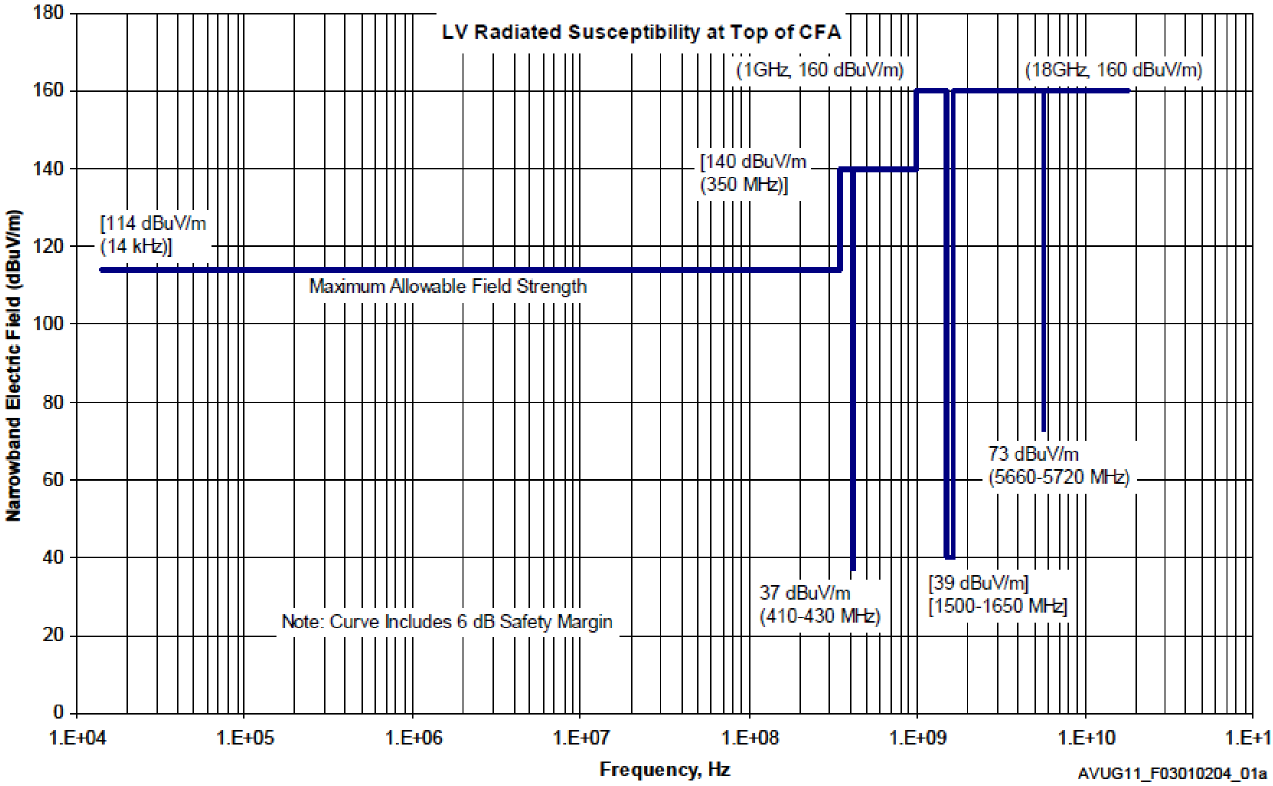


Figure 4.7-2: Spacecraft Electric Field Radiation Impingement on Launch Vehicle

4.7.2 ELECTROMAGNETIC COMPATIBILITY REQUIREMENTS, EUROPA CLIPPER SUBSYSTEMS & ASSEMBLIES

Assembly EMC test requirements (Table 4.7-6) include the following tests based on, but modified/tailored in this requirements document, the EMC test designation procedures and limits of MIL-STD-461/462.

Table 4.7-6 Europa Clipper Subsystem/Assembly EMI/EMC Test Requirements

Test Method	Test Type	Qualification method
CE01/CE03	Conducted Emissions; Power 30 Hz to 50 kHz	Test
CE06	Conducted Emissions; Antenna Terminals 10 kHz to 18 GHz	Test (1)
CE07	Conducted Emissions; Power Leads, Spikes, Time Domain	Test
CE	In-rush Current and Related Power Line Transients	Test (2)
RE02	Radiated Emissions; Electric Field, 14 kHz to 10 GHz	Test (3)
RS03	Radiated Susceptibility; Electric Field, 14 kHz to 11GHz	Test (4)
CS01/CS02	Conducted Susceptibility; Power Leads, 30 Hz to 50MHz	Test
CS04	Rejection of Undesired Signals (Receivers only)	Test (1)
CS06	Conducted Susceptibility; Spikes, Power Leads	Test
CS	Conducted Susceptibility, Power System Fault Test	Test
CS	Conducted Susceptibility, Powerline Surge Test	Test
RE	DC Magnetic Fields	Test
ESD	ESD Grounding and Touchdown ESD	Test/Inspect
Bonding, Isolation and Grounding	Bonding	Test/Inspect
	Isolation	Test
	Ground Referencing	Inspection
Shielding	Faraday Chambers - Enclosures	Inspection
Cabling	Wiring/Cable Shielding	Inspection
Pyro-circuits	Pyro-circuit Cable Shielding	Test/Inspect
1. Applies to unit antenna terminals if antenna is absent. 2. Applies only to power input terminals without powerline turn-on soft-switching. 3. Includes emission notches at receive frequencies; may extend to 40 GHz for some equipment 4. Includes poles at frequencies of known RF sources, onboard, launch-site, etc		

4.7.2.1 Electrical Grounding of Input Power and Electronic Circuitry

The subsystem design **will** comply with grounding requirements established by specific Europa Clipper spacecraft requirements for ground referencing of electrical and electronic circuitry.

In this document, it will be assumed that a single point ground system would be imposed on all hardware. For the Europa Clipper project, this means that all hardware would have a single zero volt ground reference and return wires such that all hardware would be referenced to chassis in one and only one location, and no deliberate power or signal (data/command/telemetry) current could flow in chassis.

There will be a separate requirement that the input power (approximately 28 V (TBC)) would be floating and supplied by a resistive reference to ground: +14 and –14 V with respect to chassis, and the main power would be referenced to chassis with a 5,000 ohm resistance from + to chassis and **–** to chassis. These EMC requirements are based on that power architecture.

4.7.2.2 Isolation of Input Power Leads and Signal Interfaces

Power input leads **shall** be isolated from chassis by a resistance R such that 20 megohm < R < 100 megohm.

All non-power (signal, data, command, telemetry) interfaces to other subsystems **will** be designed per spacecraft rules to provide electrical isolation between boxes so that no net dc current can flow via those interface wires between subsystems.

The electrically isolated interface circuits **will** provide dc isolation R such that 1 megohm < R < 100 megohm in most instances, or by use of standard interfaces that have been approved by the System Design organization, and will otherwise be compliant with isolation chassis ground at those interfaces.

For heritage subsystems and assemblies, one megohm or more of isolation would be acceptable for both powered and non-powered interfaces.

4.7.2.3 Electrical Bonding of Structure, Housing, Cabling/Connectors/Shields, and Other Conductive Elements

A bond for electrical purposes is the conductive joining of two metallic assemblies.

To ensure electrical continuity of the chassis and other metallic non-electrical/electronic hardware throughout the Flight System, bonding **shall** meet the impedances indicated in Table 4.7-7.

Table 4.7-7 Mechanical Bonding Equipotential Plane Requirements (TBR)

Electronic boxes to Structure (System Reference Plane)	<2.5 mΩ
Large area metal-to-metal structural surfaces	<2.5 mΩ
Non-electronic boxes to Structure	<25 mΩ
Across hinges (antenna deployed booms & solar array)	<25 mΩ
Harness shield to Structure	<25 mΩ
Thermal blankets ground to Structure	<100 mΩ
Mechanical equipment to Structure	<100 mΩ
Thermal blanket to multiple grounding tab to tab	<100 mΩ
Thermal shields (thrusters) to Structure	<100 mΩ
Bonding to composite components	<100 Ω

Thermal blanket layers to chassis **shall** measure less than 100 milliohms via a ground wire less than 15 cm long.

4.7.2.4 CE01/03 Conducted Emissions, Power, 30 Hz to 50 MHz

Differential mode conducted emissions on assembly input power leads **shall** not exceed the levels depicted in Figure 4.7-3.

Differential mode conducted emissions **shall be** measured on the power and return lines simultaneously, as shown in Figure 4.7-4 for Differential Mode Configuration.

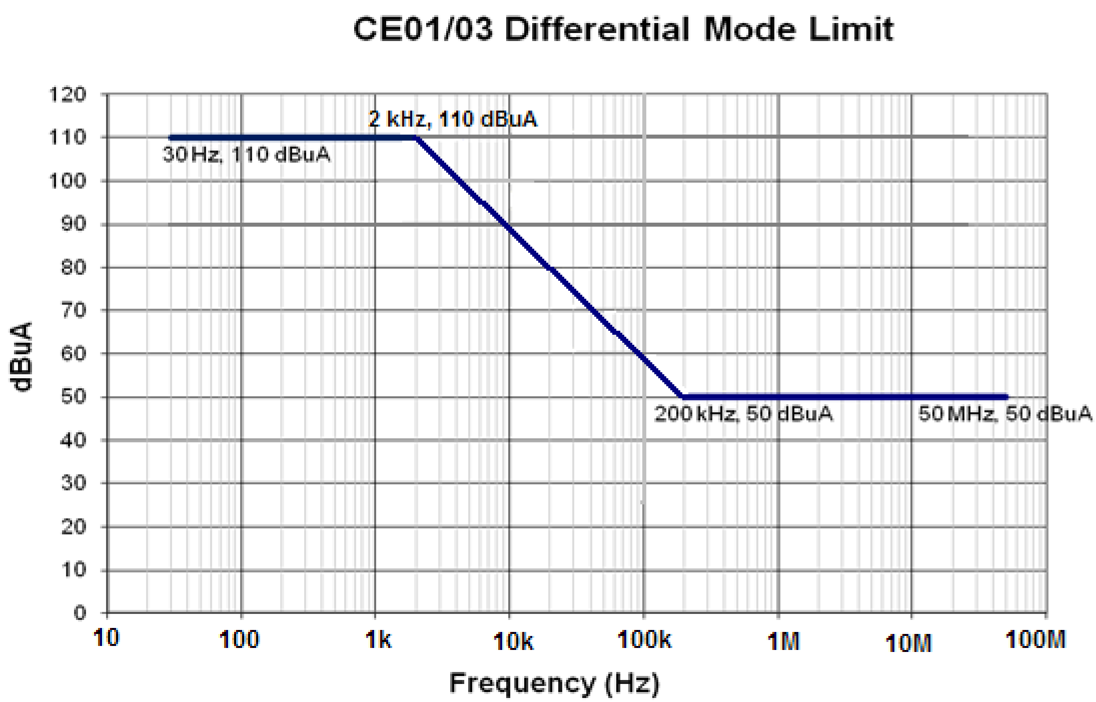


Figure 4.7-3. CE01/03 Conducted Emissions, Differential Mode, Power Bus Current Ripple [Preliminary]

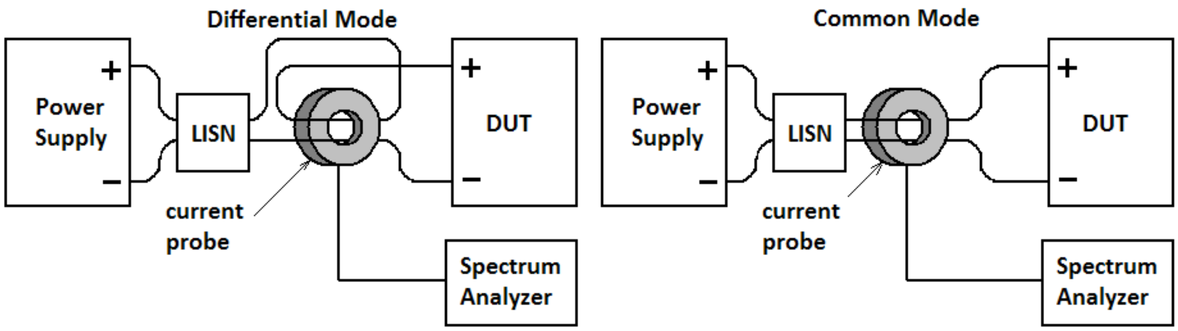


Figure 4.7-4. CE01/03 Conducted Emissions, Mode Configurations

Common mode conducted emissions on assembly input power leads **shall** not exceed the levels depicted in Figure 4.7-5.

Common mode conducted emissions **shall** be measured on the power and return lines simultaneously, as shown in Figure 4.7-4, Common Mode Configuration.

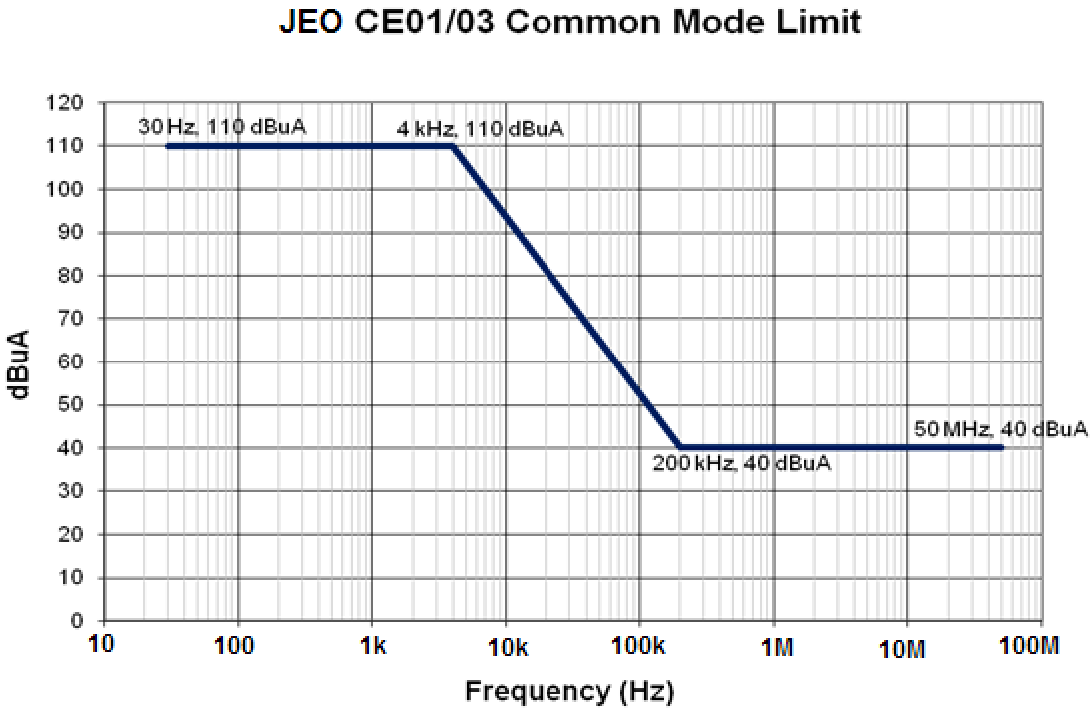


Figure 4.7-5 CE01/03 Conducted Emissions Common Mode, Power Bus Current Ripple [Preliminary

4.7.2.5 CE06 Conducted Emissions, Antenna Terminals (transmitters) 10 kHz to 18 GHz

The requirements of MIL-STD-461C/462 method CE06 **shall** be applied to all subsystems and components containing RF transmitters and receivers and verified by the hardware supplier.

Harmonics, except the second and third, and all other spurious emissions **shall** have peak powers at least 80 dB (or levels negotiated between the hardware supplier and Project EMC) down from the power of the fundamental.

The second and third harmonics **shall** be suppressed by at least 60 dB (or levels negotiated between the hardware supplier and Project EMC) down from the fundamental.

All other spurious emissions **shall** be suppressed by at least 60 dB (or levels negotiated between the hardware supplier and Project EMC) down from the fundamental).

Verification would be principally by tests but may be by analysis if design features such as waveguides or filtering are present.

4.7.2.6 CE07 Conducted Emissions, Power Transients, Time Domain

Assemblies **shall** not produce differential transient voltage spikes on the spacecraft 28-volt power bus under any operating mode or transition condition in excess of the limits specified in Figure 4.7-6.

The 14 volt limit for pulses shorter than 10 us, for example, means that transient pulses may vary as much as +14 V from 28 V nominal (42 V peak) to -14 V from nominal (14 V peak) differential.

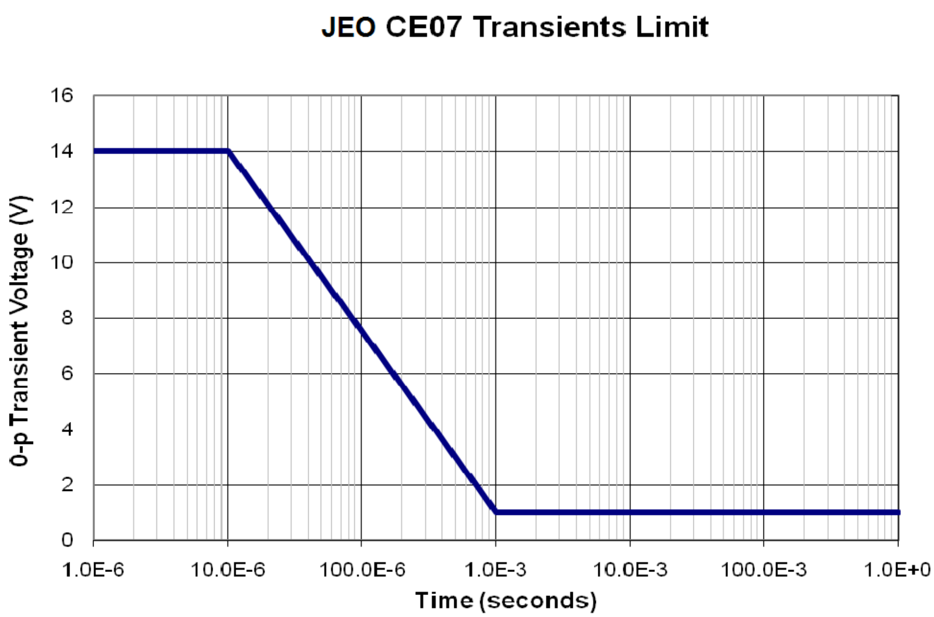


Figure 4.7-6. CE07 Conducted Emissions, Time Domain Voltage [Preliminary]

4.7.2.7 Conducted Emissions, In-Rush Current and Reverse Current

Assuming the spacecraft has solid state, and controlled voltage turn-on ramp rates as well as current limiting all supplied by the power distribution subsystem, the subsystem power supplies **shall** be designed to accommodate the specified system power quality and turn-on voltage/current parameters.

4.7.2.8 CS01/02 Conducted Susceptibility, Power, 30 Hz to 50 MHz

Assemblies connected to the power bus **shall** operate nominally under the following bus conditions of sine wave voltage ripple of amplitude shown in Figure 4.7-7 added differentially to any DC voltage.

A 2 A p-p current ripple or 100% of operating current either + or – (not to go negative), whichever is less, **shall** not be exceeded during test.

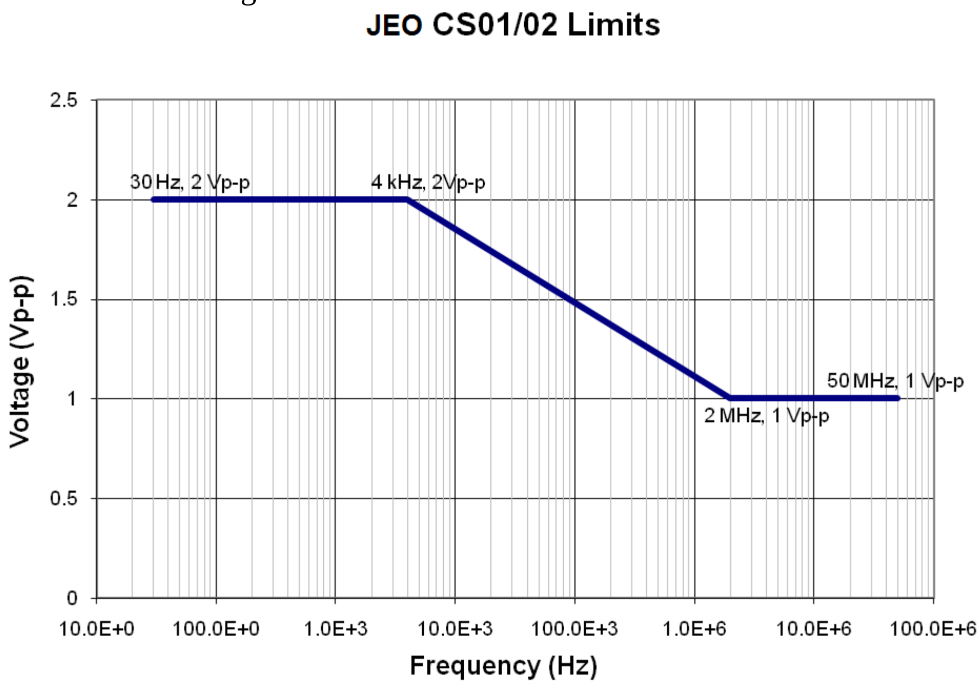


Figure 4.7-7. CS01/02 Conducted Susceptibility, Power Line Ripple [Preliminary]

4.7.2.9 CS04 Rejection of Undesired Signals, 30 Hz to 10 GHz

The requirements of MIL-STD-461C (Class A2, Part 3, Paragraph 9) and MIL-STD-462 method CS04 **shall** be applied to all subsystems and assemblies containing RF receivers and be verified by the flight hardware supplier.

Tailoring of requirements **shall** be accomplished by negotiations between the Project ERE and the hardware vendor.

Europa Clipper receiver subsystems and assemblies **shall** operate within performance parameters (without indications of interference, degradation of performance or malfunction) when tested per the requirements of MIL-STD-461C/462 method CS04.

The subsystem **shall** not exhibit any undesired response when subjected to the test signal shown in Figure 4.7-8.

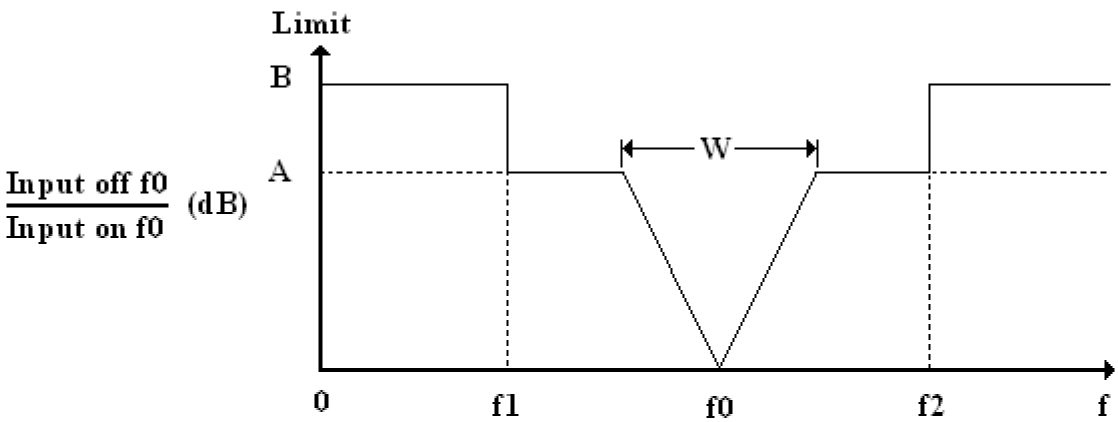


Figure 4.7-8. CS04 Conducted Susceptibility Receiver Terminals Limit (TBR)

Notes:

1. fo = receiver tuned frequency or band center for amplifiers.
2. f1 = lowest tunable frequency of receiver band in use or the lowest frequency of amplifier passband.
3. f2 = highest tunable frequency of receiver band in use or the highest frequency of amplifier passband.
4. W = bandwidth between the 80 dB points of the receiver selectivity curve as defined in the test sample's technical requirements or the control plan.

Limit:

The limit at A is 80 dB above the input level required to produce the standard reference output (this limit will not be used for amplifiers).
The limit at B is set as follows:

Receivers: 0 dBm applied directly to the receiver input terminals.
Amplifiers: The limit is as specified in the test sample's technical requirements or control plan.
As a default, 0 dBm is used for limit B.

4.7.2.10 CS06 Conducted Susceptibility, Power Line Transients (TBR)

Assemblies **shall** operate within specification when the input 28 V power leads are subjected to the transients illustrated in Figure 4.7-9 and as specified in Table 4.7-4.

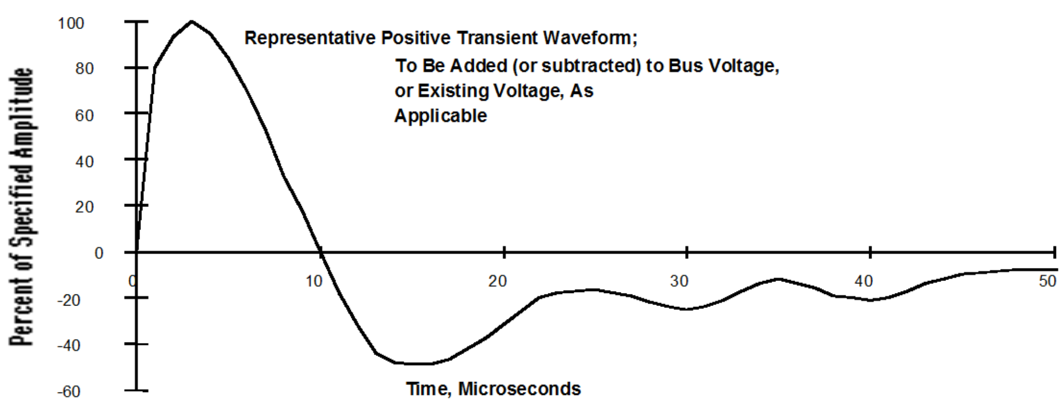


Figure 4.7-9. CS06 Conducted Susceptibility Power Line Transient (TBR)

Table 4.7-8 CS06 Conducted Susceptibility Power Line Transient Limits (TBR)

Transient Polarity	DC Line Voltage	Pulse Width	Repetition Rate	Duration
Positive Transient	+100% of max bus voltage	10μsec	100 Hz or Less	5 Minutes
Negative Transient	-100% of max bus voltage	10μsec	100 Hz or Less	5 Minutes

The transient **shall** be 100% of the nominal bus voltage, 0-p, making the maximum differential voltage 56 volts with a positive transient (on a 28 volt bus), and making the minimum differential voltage approaching but not equal to zero volts during the negative transient.

The transient current **shall** not exceed 6 Amps + or -, or the magnitude of the nominal steady state current, either + or -, whichever is less; the current shall never go negative.

For the common mode, Figure 4.7-10 **shall** be satisfied with a transient amplitude of 50% of the nominal bus voltage (±14 V for 28 V bus), so that both + and return are raised and lowered with respect to chassis by that amount. This is applicable only if the balanced bus is implemented.

The maximum allowable current injected **shall** not be more than 6 Amperes.

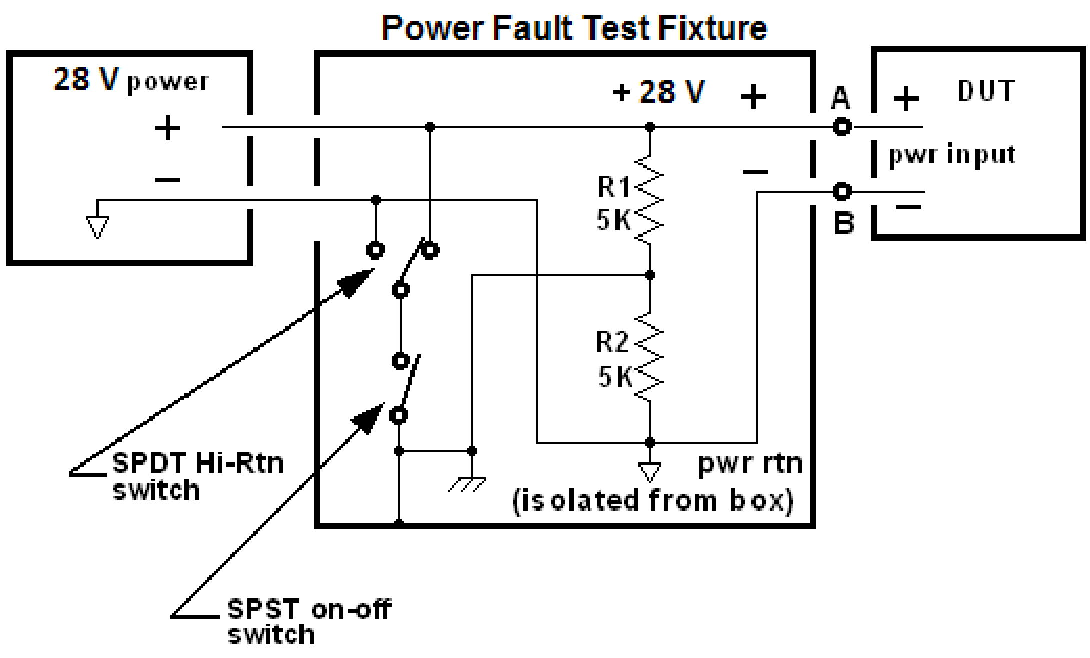


Figure 4.7-10 Power Systems Fault Test Configuration [Preliminary]
(Add 0.1 uF capacitor, return to chassis in parallel with R2 – TBD per Europa Clipper design)

4.7.2.11 Power Subsystems Fault Test

The Europa Clipper subsystems/assemblies connected to the power bus **shall** operate without degradation of performance during the power systems fault test (bus jump/bounce test).

The power input voltage measured terminal-to-terminal will remain a constant 28 volts (test case nominal) but the voltage from terminal-to-chassis ground will fluctuate with switching action of the hi-Rtn switch.

4.7.2.12 RE01 Radiated Emissions, Magnetic Field, 20 Hz to 50 kHz

Assemblies **shall** not radiate magnetic fields in excess of those shown in Figure 4.7-11.

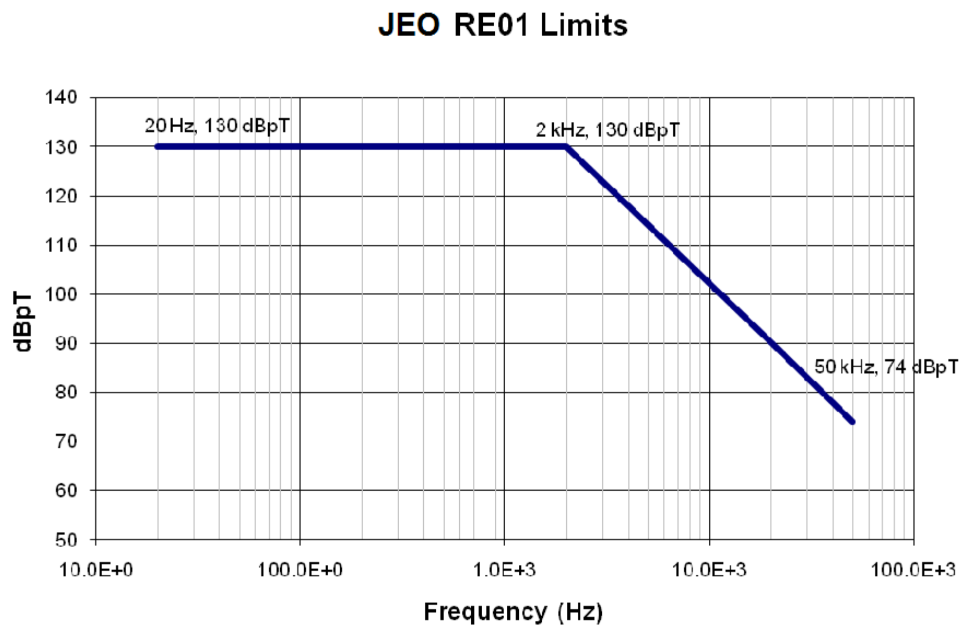


Figure 4.7-11. RE01 Radiated Emissions Magnetic Field [Preliminary] (TBR)

4.7.2.13 RE02 Radiated Emissions, Electric Field, 14 kHz to 18 GHz (TBR)

Assemblies **shall** not radiate electric fields in excess of those described in Table 4.7-9.

Table 4.7-9 RE02 Radiated Emissions, E-Field Limits [Preliminary] (TBR)

Frequency Range	Electric Field Limit	Potential Victim
14 kHz to 18 GHz	60 dBµV/m	Maximum Allowable Radiated Emissions Limits
TBD	TBD	for particle and plasma instrument;
TBD	TBD	Europa Clipper S-Band Transponder
TBD	TBD	Atlas Command Destruct
TBD	TBD	Atlas C Band
TBD	(notch TBD)	for X-Band receiver
TBD	(notch TBD)	for Ka-Band receiver

4.7.2.14 RS03, Radiated Susceptibility, Electric Field, 14 kHz to 40 GHz (TBR)

Assemblies **shall** perform within specification when subjected to the electric (E) fields defined in Table 4.7-10 under the stated conditions and modulation.

Above 1 MHz, the applied field **shall** be modulated with a 1 kHz AM square wave, 100% depth as default unless otherwise specified.

Table 4.7-10 RS03 Radiated Susceptibility E-Field Limits [Preliminary] (TBR)

Frequency Range	Electric Field Level	Emitter Source
14 kHz to 40 GHz(1)	20 V/m	General
(TBC) 2.2 GHz to 2.3 GHz (3)	40 V/m	(Atlas also TBD)
(TBC) 5765 MHz (3)	80 V/m	(Atlas also TBD)
(TBC) 2.2 GHz to 2.5 GHz (3)	45 V/m	Atlas V
(TBC) 5.6 GHz to 5.8 GHz (3)	158 V/m	Atlas V (max peak)
~8.4 GHz +/- TBD MHz	(field TBD)	for X-band transmitter
~32. 2 GHz +/- TBD MHz	(field TBD)	for Ka-band transmitter

Notes:
1. Test to 18 GHz and analyze for susceptibility likelihood between 18 and 40 GHz.
2. Protective Band applies to EMC tests involving radiometer subsystem only. During instrument and Flight System level EMC testing, the notch may be reduced to 0 V/m to further protect the Radiometer.
3. Limit applies only to subsystems/assemblies that will be on during Launch. However, assemblies/subsystems must still demonstrate survivability and no damage from exposure to these fields even if the assembly is not powered on during Launch. Launch Vehicle emitter source amplitude is at the LV separation plane.

4.7.3 MAGNETIC COMPATIBILITY REQUIREMENTS

All equipment **shall** be designed to survive without degradation and function within specification in the presence of the magnetic field levels present during all mission phases.

All hardware **shall** be designed to tolerate a 50 gauss field without damage or change of required performance.

The magnetic cleanliness of each subsystem **shall** be less than 10 nT under all operating conditions, when measured at one meter from its center.

Use of soft magnetic materials **shall** be avoided.

Use of magnetized materials **shall** be avoided.

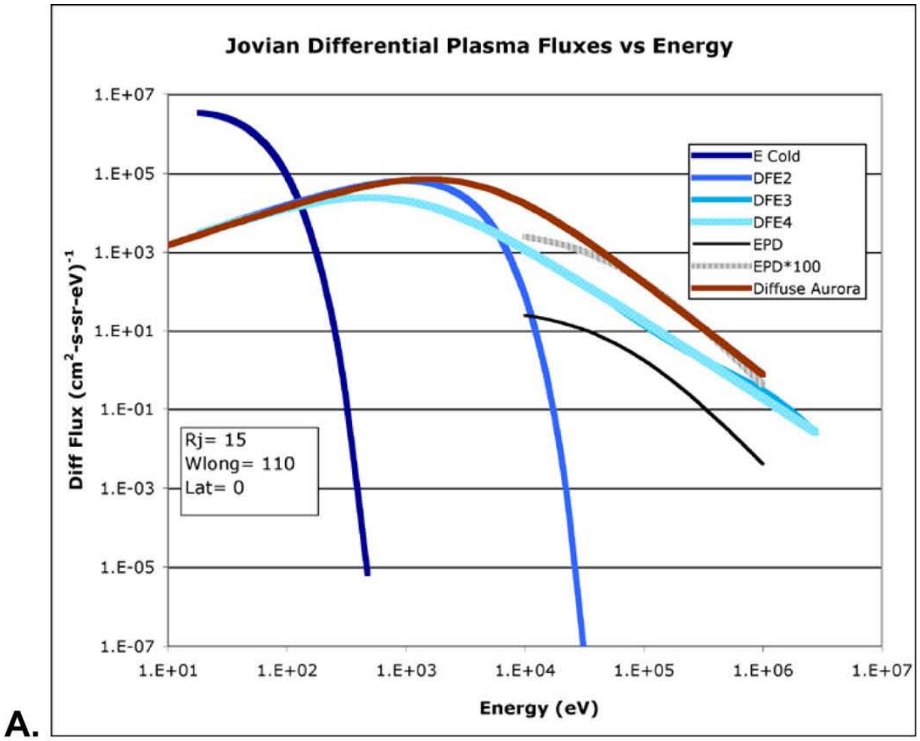
The changing magnetic field produced by each subsystem **shall** not exceed 0.5 nT in the frequency range of dc to 64 Hz.

Europa Clipper Project will produce a Magnetics Cleanliness Program Plan with specific measures to characterize and limit magnetic fields to preserve science data quality for magnetic field and plasma investigations.

4.7.4 SPACECRAFT CHARGING AND ESD REQUIREMENTS (TBR)

The magnetosphere is the primary controlling factor for local plasma environments. The magnetosphere of Jupiter is dominated by three factors: the magnetic field tilt (11°) relative to its spin axis, its rapid rotation, and the jovian moon Io at 5.9 . Io generates a vast torus of gas and ions. The more rapid rotation of Jupiter's magnetic field forces the cold plasma associated with this torus to accelerate and expand by centrifugal force into a giant disc. The magnetic field tilt and rotation rate cause the plasma disc to wave up and down so that at a given location plasma parameters vary radically during a 10 h period. Jupiter's environment can be roughly divided into three populations: the cold plasma associated with the Io torus and the plasma disc (< 1 keV), the intermediate "warm" plasma (1 keV – 100 keV), and the trapped radiation environment (>100 keV). The trapped radiation environment is discussed in detailed in Section 4.9. This section is concerned primarily with characteristics of the cold and warm plasma environments near Jupiter.

The energy characteristics of the important plasma components in the equatorial plane at 15Rj are plotted in Figure 4.7-12a,b below.



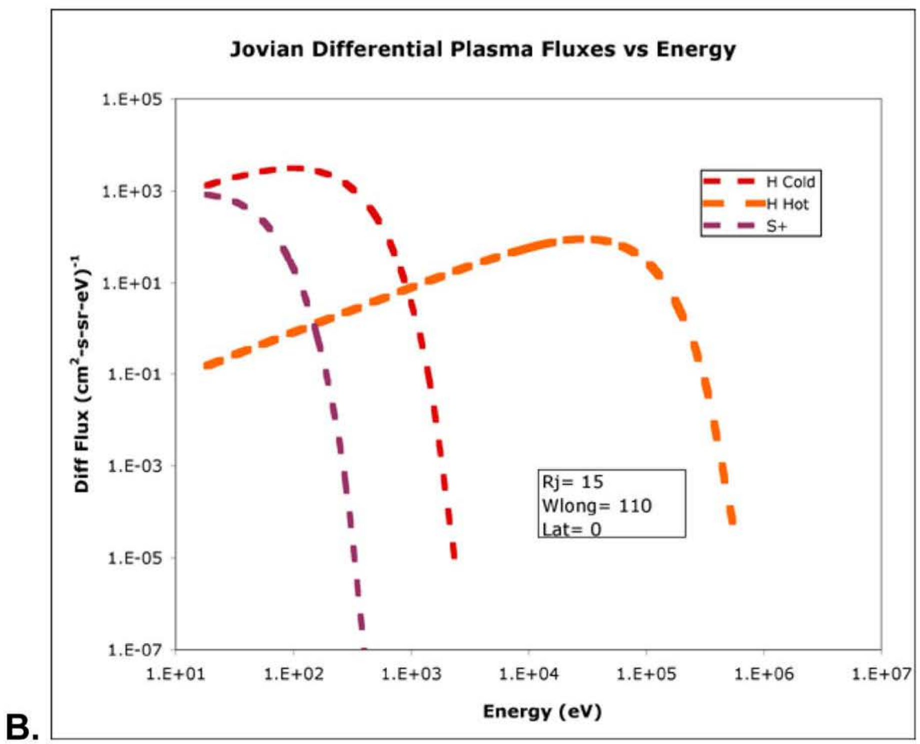


Figure 4.7-12. Plasma differential fluxes at 15 Rj, 110° W, and 0° illustrating the various plasma components and their relative flux values in the jovian plasma sheet.

Where the legend labels are defined as follows:

DFe1 = differential flux for cold electrons

DFe2 = differential flux for warm electrons
DFe3 = differential flux for high energy electrons (E> 100 keV)
DFe4 = differential flux for Kappa electrons (defaults to warm electrons if no fit)
DFS+ = differential flux for the cold S+ ions (representative of the other ionic species in the model)

The distributions of the plasma species can be represented by Kappa functions:

$$f_\kappa(E) = N_\kappa (m_\kappa / 2\pi E_0)^{3/2} \kappa^{-3/2} \frac{\Gamma(\kappa+1)}{\Gamma(\kappa-1/2)} \frac{1}{(1+E/\kappa E_0)^{\kappa+1}}$$

Where:

$E = 1/2mv^2$
N_κ = Kappa number density (cm^{-3}) of species (e- and H+)
m_κ = *Kappa mass (g) of species (e- and H+)*
κ = *Kappa value*
E_0 = *Kappa temperature or characteristic energy*

At Rj = 15, parameters for the warm electron plasma are: $N_\kappa = 2\ cm^{-3}$, E_0 = 1500 eV and $\kappa = 2.4$

4.7.4.1 Surface Charging and ESD (TBR)

In order to tolerate the effects of spacecraft surface charging in energetic space plasmas, each conductive layer of thermal blankets and all exterior exposed conductive surfaces of the Flight System **shall** be conductive and grounded (bonded to chassis) or otherwise ground referenced (see Section 4.7.3.1).

Implication of plasma environment for worst-case surface potentials on shadowed surfaces is up to -5 kV.

Requirement: Conductive materials with surfaces exposed to space (visible on the surface shall be grounded to structure with a resistance so that: $R < 1 \times 10^9 / A$ ohms, where R is the resistance, ohms, from the conductive material to ground A is the area exposed to space, in cm^2 This requirement has relevance to the MLI bonding approach and is inclusive of the material that forms up the sun shade.
Requirement: Surface coatings over metal or conductive composites shall have a resistivity-thickness product so that: $Rv * t < 3 \times 10^{11}$ ohm-cm^2, where resistivity Rv is volume resistivity in ohm-cm, and thickness t is in cm.
Requirement: Surface coatings over dielectric shall have a surface resistivity and grounding so that: $Rv * h^2/t \leq 4 \times 10^{11}$ ohm-cm^2, where Resistivity Rv is volume resistivity in ohm-cm, and h is the greatest distance on a surface to a ground point in cm, and t is the material thickness in cm.

NASA-HDBK-4002A contains design guidelines for this environment and are only to be used as references and do not constitute any design requirements.

4.7.4.2 Internal Charging and Electrostatic Discharge (ESD) (TBR)

It is assumed that there would be one or more enclosures of thick metal that would be used to protect most spacecraft hardware contained inside it from the effects of space radiation.

The basic ESD requirement for hardware contained within the enclosure is that the electron flux s**hall** be below 0.1 pA/cm^2 average for any 20 hour period [Preliminary].

Hardware located outside the enclosure **shall** have a similar equivalent thickness of material or circuit protection to protect against internal charging.

Cabling located outside the enclosure **shall** have a multiple copper foil wrap of at least 6.5 mil copper foil equivalent thickness [TBD], with an external wrap of conductive black Kapton tape, tightly wrapped so that there is no trapped air gap in any of the wrapped layers.

The copper wrap and conductive black Kapton tape **shall** be grounded/bonded at both ends of the cable so as to make an excellent EMC shield as well as the ESD covering.

All conductive layers **shall** have good grounding/electrical continuity from wrap to wrap, and **shall** have excellent bonding at the cable connectors.

All cable connectors **shall** have bonding equivalent to 2.5 milliohms per joint to their mating connectors at subsystem interfaces.

The length of floating wires shall not exceed 15 cm, if inside of the vault or equivalent shield. Otherwise floating wires are prohibited.

This applies to all cable connectors and not just for ESD purposes outside the enclosure or subsystem enclosures.

All interface circuits connected to cabling that is routed outside the enclosure **shall** be immune to the effects of a MIL-STD-883G, Method 3015.7, Electrostatic Discharge Sensitivity Classification, Class 2 [TBC] requirement ESD pulse.

NASA HDBK 4002A contains design guidelines for this environment and are only to be used as references and do not constitute any design requirements.

4.7.4.3 V x B Effects on Charging (TBR)

The co-rotating plasma near Europa reaches a velocity of approx. 120 km/s, while the local magnetic field is approximately 400 nT (4 mGauss). These conditions lead to ~0.05V/m due to vxB effects.

4.7.5 SPACECRAFT LIGHTNING PROTECTION (TBR)

Any interface circuit connected to the T-0 umbilical **shall** be designed to survive lighting-induced voltage transients of 10 microseconds at 200 volts peak calibrated against a 5-Ohm resistor.

4.8 EUROPA CLIPPER METEOROID ENVIRONMENT (TBR)

The Flight System **shall** have a greater than 95% probability of performing within specification after exposure to the meteoroid environment for the mission duration. Probability of the Flight System maneuverability performing within specification prior to the final Earth fly-by for a VEEGA trajectory will be 99.999+% (TBR) for an RPS vehicle.

The meteoroid environment will be updated to the true Europa Clipper mission parameters at a later date. Based on historical missions, a typical meteoroid spectrum is shown in Table 4.8-1. The estimated mass/velocity micrometeoroid distribution for launch through JOI (for Juno) is shown in Table 4.8-2.

Table 4.8-1 A typical Meteoroid Fluence vs. Mass and Speed from Launch through End of Mission (TBR)

PARTICLE MASS (g)	Integral Omnidirectional Fluence (Particles/m^2) Mass Greater or Equal to M
1.0E-12	4.38E + 4
1.0E-11	2.36E + 4
1.0E-10	1.35E + 4
1.0E-09	5.23E + 3
1.0E-08	1.49E + 3
1.0E-07	293
1.0E-06	45.8
1.0E-05	7.31
1.0E-04	1.15
0.001	9.93E - 2
0.01	5.61E -3
0.1	2.67E - 4
1.0	1.24E - 5
Mean Relative Velocity, km/s	15 to 23, depending on mass and trajectory
Mean Density, g/cm^3	2.5

Table 4.8-2 Juno Interplanetary (Earth to JOI) Omni-directional Meteoroid Fluence (m^{-2}) vs. Velocity and Mass Threshold. (TBR)

Velocity [lower edge of bin] (m/s)	Velocity [bin average] (m/s)	Mass > 1E-12 g	Mass > 1E-11 g	Mass > 1E-10 g	Mass > 1E-9 g	Mass > 1E-8 g	Mass > 1E-7 g	Mass > 1E-6 g	Mass > 1E-5 g	Mass > 1E-4 g	Mass > 1E-3 g	Mass > 1E-2 g	Mass > 1E-1 g	Mass > 1 g	Mass > 1E+1 g	Mass > 1E+2 g
0	500	1.42E-01	6.64E-02	2.98E-02	1.38E-02	5.54E-03	1.40E-03	2.23E-04	2.57E-05	2.74E-06	2.09E-07	1.15E-08	5.40E-10	2.50E-11	1.17E-12	5.43E-14
1000	1500	2.83E+00	1.33E+00	5.95E-01	2.76E-01	1.11E-01	2.82E-02	4.65E-03	6.47E-04	8.85E-05	7.34E-06	4.11E-07	1.95E-08	9.07E-10	4.23E-11	1.97E-12
2000	2500	1.32E+01	6.18E+00	2.78E+00	1.29E+00	5.17E-01	1.32E-01	2.21E-02	3.31E-03	4.86E-04	4.11E-05	2.31E-06	1.10E-07	5.11E-09	2.39E-10	1.11E-11
3000	3500	3.66E+01	1.72E+01	7.72E+00	3.59E+00	1.44E+00	3.75E-01	7.00E-02	1.46E-02	2.72E-03	2.42E-04	1.38E-05	6.56E-07	3.06E-08	1.43E-09	6.69E-11
4000	4500	8.24E+01	3.87E+01	1.74E+01	8.08E+00	3.26E+00	8.56E-01	1.73E-01	4.34E-02	8.76E-03	7.91E-04	4.52E-05	2.16E-06	1.01E-07	4.71E-09	2.20E-10
5000	5500	1.55E+02	7.25E+01	3.27E+01	1.51E+01	6.10E+00	1.60E+00	3.33E-01	8.97E-02	1.86E-02	1.69E-03	9.66E-05	4.62E-06	2.16E-07	1.01E-08	4.71E-10
6000	6500	2.41E+02	1.13E+02	5.09E+01	2.34E+01	9.41E+00	2.41E+00	5.09E-01	1.43E-01	3.01E-02	2.74E-03	1.57E-04	7.50E-06	3.50E-07	1.64E-08	7.65E-10
7000	7500	3.42E+02	1.60E+02	7.23E+01	3.29E+01	1.32E+01	3.27E+00	6.79E-01	1.89E-01	3.97E-02	3.61E-03	2.07E-04	9.87E-06	4.61E-07	2.15E-08	1.01E-09
8000	8500	4.39E+02	2.05E+02	9.33E+01	4.21E+01	1.68E+01	4.05E+00	8.20E-01	2.22E-01	4.64E-02	4.21E-03	2.41E-04	1.15E-05	5.38E-07	2.51E-08	1.18E-09
9000	9500	5.65E+02	2.64E+02	1.21E+02	5.42E+01	2.14E+01	5.08E+00	9.77E-01	2.44E-01	4.95E-02	4.47E-03	2.56E-04	1.22E-05	5.70E-07	2.66E-08	1.25E-09
10000	10500	6.67E+02	3.13E+02	1.43E+02	6.40E+01	2.52E+01	5.87E+00	1.10E+00	2.60E-01	5.17E-02	4.65E-03	2.66E-04	1.27E-05	5.92E-07	2.77E-08	1.29E-09
11000	11500	7.19E+02	3.38E+02	1.55E+02	6.90E+01	2.70E+01	6.18E+00	1.13E+00	2.58E-01	5.04E-02	4.52E-03	2.58E-04	1.23E-05	5.75E-07	2.69E-08	1.26E-09
12000	12500	7.69E+02	3.62E+02	1.67E+02	7.40E+01	2.87E+01	6.50E+00	1.16E+00	2.56E-01	4.93E-02	4.41E-03	2.52E-04	1.20E-05	5.61E-07	2.62E-08	1.22E-09
13000	13500	7.54E+02	3.56E+02	1.66E+02	7.26E+01	2.79E+01	6.20E+00	1.10E+00	2.44E-01	4.70E-02	4.21E-03	2.40E-04	1.15E-05	5.35E-07	2.50E-08	1.17E-09
14000	14500	7.53E+02	3.56E+02	1.67E+02	7.27E+01	2.77E+01	6.05E+00	1.06E+00	2.32E-01	4.46E-02	3.99E-03	2.28E-04	1.09E-05	5.07E-07	2.37E-08	1.11E-09
15000	15500	8.03E+02	3.80E+02	1.79E+02	7.76E+01	2.95E+01	6.40E+00	1.10E+00	2.29E-01	4.30E-02	3.83E-03	2.18E-04	1.04E-05	4.86E-07	2.27E-08	1.06E-09
16000	16500	8.26E+02	3.91E+02	1.84E+02	7.96E+01	3.02E+01	6.46E+00	1.09E+00	2.19E-01	4.05E-02	3.60E-03	2.05E-04	9.77E-06	4.56E-07	2.13E-08	9.95E-10
17000	17500	7.74E+02	3.65E+02	1.71E+02	7.35E+01	2.79E+01	5.65E+00	9.04E-01	1.74E-01	3.14E-02	2.78E-03	1.58E-04	7.53E-06	3.52E-07	1.64E-08	7.67E-10
18000	18500	7.76E+02	3.64E+02	1.71E+02	7.27E+01	2.76E+01	5.28E+00	7.97E-01	1.43E-01	2.49E-02	2.19E-03	1.24E-04	5.93E-06	2.77E-07	1.29E-08	6.04E-10
19000	19500	7.58E+02	3.55E+02	1.67E+02	7.03E+01	2.65E+01	4.80E+00	6.86E-01	1.18E-01	2.00E-02	1.75E-03	9.93E-05	4.73E-06	2.21E-07	1.03E-08	4.81E-10
20000	20500	6.95E+02	3.27E+02	1.55E+02	6.47E+01	2.42E+01	4.30E+00	5.97E-01	9.68E-02	1.59E-02	1.38E-03	7.81E-05	3.72E-06	1.74E-07	8.10E-09	3.78E-10
21000	21500	6.25E+02	2.96E+02	1.41E+02	5.89E+01	2.18E+01	3.90E+00	5.40E-01	8.30E-02	1.31E-02	1.12E-03	6.35E-05	3.02E-06	1.41E-07	6.57E-09	3.07E-10
22000	22500	5.42E+02	2.58E+02	1.25E+02	5.17E+01	1.88E+01	3.36E+00	4.58E-01	6.57E-02	9.73E-03	8.25E-04	4.65E-05	2.21E-06	1.03E-07	4.80E-09	2.24E-10
23000	23500	4.61E+02	2.22E+02	1.09E+02	4.48E+01	1.59E+01	2.85E+00	3.84E-01	5.17E-02	7.21E-03	6.02E-04	3.38E-05	1.60E-06	7.46E-08	3.48E-09	1.62E-10
24000	24500	4.11E+02	2.00E+02	9.96E+01	4.07E+01	1.42E+01	2.57E+00	3.45E-01	4.24E-02	5.28E-03	4.27E-04	2.37E-05	1.12E-06	5.22E-08	2.43E-09	1.14E-10
25000	25500	3.56E+02	1.75E+02	8.91E+01	3.61E+01	1.23E+01	2.21E+00	2.95E-01	3.51E-02	4.18E-03	3.33E-04	1.85E-05	8.74E-07	4.06E-08	1.89E-09	8.82E-11
26000	26500	3.14E+02	1.56E+02	8.10E+01	3.25E+01	1.07E+01	1.93E+00	2.56E-01	2.87E-02	3.11E-03	2.40E-04	1.32E-05	6.22E-07	2.88E-08	1.34E-09	6.26E-11
27000	27500	2.90E+02	1.46E+02	7.67E+01	3.06E+01	9.94E+00	1.82E+00	2.43E-01	2.58E-02	2.55E-03	1.89E-04	1.03E-05	4.82E-07	2.23E-08	1.04E-09	4.83E-11
28000	28500	2.31E+02	1.19E+02	6.47E+01	2.52E+01	7.74E+00	1.34E+00	1.73E-01	1.75E-02	1.61E-03	1.16E-04	6.25E-06	2.92E-07	1.35E-08	6.27E-10	2.92E-11
29000	29500	2.08E+02	1.08E+02	5.99E+01	2.32E+01	6.93E+00	1.20E+00	1.55E-01	1.51E-02	1.24E-03	8.42E-05	4.47E-06	2.07E-07	9.54E-09	4.42E-10	2.06E-11
30000	30500	1.91E+02	1.01E+02	5.62E+01	2.17E+01	6.38E+00	1.12E+00	1.46E-01	1.39E-02	1.07E-03	7.00E-05	3.67E-06	1.69E-07	7.77E-09	3.60E-10	1.67E-11
31000	31500	1.62E+02	8.61E+01	4.90E+01	1.87E+01	5.33E+00	9.06E-01	1.16E-01	1.05E-02	7.21E-04	4.36E-05	2.23E-06	1.02E-07	4.63E-09	2.14E-10	9.91E-12
32000	32500	1.45E+02	7.71E+01	4.41E+01	1.68E+01	4.74E+00	7.97E-01	1.01E-01	9.00E-03	5.84E-04	3.38E-05	1.69E-06	7.68E-08	3.49E-09	1.60E-10	7.43E-12
33000	33500	1.18E+02	6.39E+01	3.73E+01	1.39E+01	3.80E+00	5.90E-01	7.04E-02	6.02E-03	3.58E-04	1.92E-05	9.37E-07	4.19E-08	1.89E-09	8.65E-11	4.00E-12
34000	34500	9.53E+01	5.21E+01	3.10E+01	1.14E+01	2.96E+00	4.03E-01	4.29E-02	3.53E-03	2.07E-04	1.11E-05	5.38E-07	2.40E-08	1.08E-09	4.95E-11	2.29E-12
35000	35500	8.42E+01	4.59E+01	2.73E+01	9.96E+00	2.60E+00	3.40E-01	3.45E-02	2.73E-03	1.48E-04	7.28E-06	3.41E-07	1.50E-08	6.66E-10	3.03E-11	1.40E-12
36000	36500	7.41E+01	4.02E+01	2.37E+01	8.68E+00	2.29E+00	3.01E-01	3.02E-02	2.32E-03	1.12E-04	4.75E-06	2.05E-07	8.61E-09	3.74E-10	1.68E-11	7.65E-13
37000	37500	6.38E+01	3.43E+01	2.01E+01	7.38E+00	1.98E+00	2.57E-01	2.55E-02	1.92E-03	8.68E-05	3.30E-06	1.33E-07	5.34E-09	2.26E-10	9.95E-12	4.50E-13
38000	38500	5.25E+01	2.81E+01	1.64E+01	6.01E+00	1.62E+00	2.03E-01	1.90E-02	1.39E-03	6.01E-05	2.12E-06	8.03E-08	3.11E-09	1.28E-10	5.54E-12	2.48E-13
39000	39500	4.33E+01	2.29E+01	1.31E+01	4.83E+00	1.34E+00	1.64E-01	1.46E-02	1.03E-03	4.27E-05	1.39E-06	4.87E-08	1.79E-09	7.04E-11	2.97E-12	1.30E-13
40000	40500	3.45E+01	1.77E+01	9.81E+00	3.66E+00	1.07E+00	1.28E-01	1.05E-02	7.09E-04	2.84E-05	8.76E-07	2.91E-08	1.02E-09	3.88E-11	1.59E-12	6.87E-14
41000	41500	2.74E+01	1.34E+01	7.01E+00	2.68E+00	8.65E-01	1.04E-01	8.20E-03	5.37E-04	2.10E-05	6.18E-07	1.95E-08	6.50E-10	2.36E-11	9.34E-13	3.94E-14
42000	42500	2.19E+01	1.01E+01	4.82E+00	1.91E+00	7.01E-01	8.41E-02	6.23E-03	3.88E-04	1.47E-05	4.11E-07	1.21E-08	3.77E-10	1.28E-11	4.77E-13	1.92E-14
43000	43500	1.86E+01	8.29E+00	3.72E+00	1.52E+00	6.02E-01	7.25E-02	5.19E-03	3.14E-04	1.17E-05	3.14E-07	8.74E-09	2.55E-10	7.99E-12	2.75E-13	1.04E-14
44000	44500	1.64E+01	7.25E+00	3.23E+00	1.32E+00	5.29E-01	6.18E-02	4.12E-03	2.35E-04	8.58E-06	2.24E-07	5.97E-09	1.65E-10	4.79E-12	1.51E-13	5.24E-15
45000	45500	1.43E+01	6.37E+00	2.83E+00	1.15E+00	4.62E-01	5.12E-02	2.98E-03	1.49E-04	5.24E-06	1.35E-07	3.54E-09	9.48E-11	2.65E-12	7.93E-14	2.58E-15
46000	46500	1.30E+01	5.76E+00	2.56E+00	1.04E+00	4.16E-01	4.52E-02	2.46E-03	1.15E-04	3.92E-06	9.98E-08	2.57E-09	6.68E-11	1.79E-12	5.00E-14	1.49E-15
47000	47500	1.21E+01	5.36E+00	2.38E+00	9.67E-01	3.88E-01	4.28E-02	2.45E-03	1.20E-04	4.18E-06	1.06E-07	2.68E-09	6.84E-11	1.77E-12	4.68E-14	1.28E-15
48000	48500	1.08E+01	4.79E+00	2.13E+00	8.60E-01	3.46E-01	3.82E-02	1.74E-03	6.76E-05	2.17E-06	5.47E-08	1.38E-09	3.52E-11	9.04E-13	2.36E-14	6.37E-16
49000	49500	9.84E+00	4.37E+00	1.94E+00	7.82E-01	3.14E-01	3.19E-02	1.36E-03	4.13E-05	1.18E-06	2.96E-08	7.47E-10	1.89E-11	4.80E-13	1.23E-14	3.22E-16
50000	50500	9.17E+00	4.07E+00	1.81E+00	7.29E-01	2.93E-01	2.97E-02	1.27E-03	3.84E-05	1.09E-06	2.75E-08	6.92E-10	1.74E-11	4.39E-13	1.11E-14	2.83E-16
51000	51500	8.54E+00	3.79E+00	1.69E+00	6.78E-01	2.72E-01	2.74E-02	1.12E-03	3.09E-05	8.27E-07	2.08E-08	5.22E-10	1.31E-11	3.30E-13	8.32E-15	2.10E-16
52000	52500	8.01E+00	3.56E+00	1.58E+00	6.35E-01	2.55E-01	2.56E-02	1.02E-03	2.62E-05	6.66E-07	1.67E-08	4.20E-10	1.06E-11	2.65E-13	6.67E-15	1.68E-16
53000	53500	7.57E+00	3.37E+00	1.50E+00	6.01E-01	2.42E-01	2.41E-02	9.63E-04	2.43E-05	6.13E-07	1.54E-08	3.87E-10	9.71E-12	2.44E-13	6.13E-15	1.54E-16
54000	54500	7.21E+00	3.20E+00	1.42E+00	5.72E-01	2.30E-01	2.30E-02	9.16E-04	2.30E-05	5.79E-07	1.45E-08	3.65E-10	9.18E-12	2.31E-13	5.79E-15	1.46E-16
55000	55500	6.92E+00	3.08E+00	1.37E+00	5.49E-01	2.21E-01	2.21E-02	8.78E-04	2.21E-05	5.54E-07	1.39E-08	3.50E-10	8.78E-12	2.21E-13	5.55E-15	1.39E-16
56000	56500	6.68E+00	2.97E+00	1.32E+00	5.30E-01	2.13E-01	2.13E-02	8.48E-04	2.13E-05	5.35E-07	1.34E-08	3.38E-10	8.48E-12	2.13E-13	5.35E-15	1.35E-16
57000	57500	6.45E+00	2.87E+00	1.28E+00	5.12E-01	2.06E-01	2.06E-02	8.19E-04	2.06E-05	5.17E-07	1.30E-08	3.26E-10	8.19E-12	2.06E-13	5.17E-15	1.30E-16
58000	58500	6.25E+00	2.78E+00	1.24E+00	4.96E-01	1.99E-01	1.99E-02	7.94E-04	1.99E-05	5.01E-07	1.26E-08	3.16E-10	7.94E-12	1.99E-13	5.01E-15	1.26E-16
59000	59500	6.06E+00	2.69E+00	1.20E+00	4.81E-01	1.93E-01	1.93E-02	7.69E-04	1.93E-05	4.85E-07	1.22E-08	3.06E-10	7.69E-12	1.93E-13	4.86E-15	1.22E-16
60000	60500	5.87E+00	2.61E+00	1.16E+00	4.66E-01	1.87E-01	1.87E-02	7.44E-04	1.87E-05	4.70E-07	1.18E-08	2.96E-10	7.44E-12	1.87E-13	4.70E-15	1.18E-16
61000	61500	5.66E+00	2.52E+00	1.12E+00	4.49E-01	1.81E-01	1.81E-02	7.19E-04	1.81E-05	4.53E-07	1.14E-08	2.86E-10	7.19E-12	1.81E-13	4.54E-15	1.14E-16
62000	62500	5.37E+00	2.38E+00	1.06E+00	4.26E-01	1.71E-01	1.71E-02	6.81E-04	1.71E-05	4.30E-07	1.08E-08	2.71E-10	6.81E-12	1.71E-13	4.30E-15	1.08E-16
63000	63500	4.99E+00	2.22E+00	9.86E-01	3.96E-01	1.59E-01	1.59E-02	6.33E-04	1.59E-05	4.00E-07	1.00E-08	2.52E-10	6.33E-12	1.59E-13	4.00E-15	1.01E-16
64000	64500	4.52E+00	2.01E+00	8.93E-01	3.59E-01	1.44E-01	1.44E-02	5.74E-04	1.44E-05	3.62E-07	9.10E-09	2.29E-10	5.74E-12	1.44E-13	3.62E-15	9.11E-17
65000	65500	3.97E+00	1.76E+00	7.84E-01	3.15E-01	1.27E-01	1.27E-02	5.04E-04	1.27E-05	3.18E-07	7.98E-09	2.01E-10	5.04E-12	1.27E-13	3.18E-15	7.99E-17
66000	66500	3.46E+00	1.54E+00	6.83E-01	2.74E-01	1.10E-01	1.10E-02	4.39E-04	1.10E-05	2.77E-07	6.95E-09	1.75E-10	4.39E-12	1.10E-13	2.77E-15	6.96E-17
67000	67500	3.05E+00	1.36E+00	6.03E-01	2.42E-01	9.73E-02	9.72E-03	3.87E-04	9.73E-06	2.44E-07	6.14E-09	1.54E-10	3.87E-12	9.73E-14	2.44E-15	6.14E-17
68000	68500	2.52E+00	1.12E+00	4.97E-01	2.00E-01	8.02E-02	8.02E-03	3.19E-04	8.02E-06	2.01E-07	5.06E-09	1.27E-10	3.19E-12	8.02E-14	2.02E-15	5.06E-17
69000	69500	2.16E+00	9.61E-01	4.27E-01	1.72E-01	6.90E-02	6.89E-03	2.75E-04	6.90E-06	1.73E-07	4.35E-09	1.09E-10	2.75E-12	6.90E-14	1.73E-15	4.36E-17
70000	70500	1.73E+00	7.69E-01	3.42E-01	1.37E-01	5.52E-02	5.51E-03	2.20E-04	5.51E-06	1.39E-07	3.48E-09	8.74E-11	2.20E-12	5.51E-14	1.39E-15	3.48E-17
71000	71500	1.25E+00	5.55E-01	2.47E-01	9.92E-02	3.99E-02	3.98E-03	1.59E-04	3.99E-06	1.00E-07	2.51E-09	6.32E-11	1.59E-12	3.99E-14	1.00E-15	2.52E-17
72000	72500	8.90E-01	3.95E-01	1.76E-01	7.06E-02	2.84E-02	2.84E-03	1.13E-04	2.84E-06	7.12E-08	1.79E-09	4.50E-11	1.13E-12	2.84E-14	7.13E-16	1.79E-17
73000	73500	7.18E-01	3.19E-01	1.42E-01	5.70E-02	2.29E-02	2.29E-03	9.11E-05	2.29E-06	5.75E-08	1.44E-09	3.63E-11	9.11E-13	2.29E-14	5.75E-16	1.45E-17
74000	74500	4.01E-01	1.78E-01	7.92E-02	3.18E-02	1.28E-02	1.28E-03	5.09E-05	1.28E-06	3.21E-08	8.06E-10	2.03E-11	5.09E-13	1.28E-14	3.21E-16	8.07E-18
75000	75500	3.30E-01	1.47E-01	6.51E-02	2.62E-02	1.05E-02	1.05E-03	4.18E-05	1.05E-06	2.64E-08	6.63E-10	1.67E-11	4.18E-13	1.05E-14	2.64E-16	6.64E-18
76000	76500	2.52E-01	1.12E-01	4.97E-02	2.00E-02	8.03E-03	8.03E-04	3.20E-05	8.03E-07	2.02E-08	5.07E-10	1.27E-11	3.20E-13	8.03E-15	2.02E-16	5.07E-18
77000	77500	1.14E-01	5.06E-02	2.25E-02	9.05E-03	3.64E-03	3.63E-04	1.45E-05	3.63E-07	9.13E-09	2.29E-10	5.76E-12	1.45E-13	3.63E-15	9.13E-17	2.29E-18
78000	78500	1.07E-01	4.75E-02	2.11E-02	8.47E-03	3.41E-03	3.40E-04	1.36E-05	3.40E-07	8.55E-09	2.15E-10	5.40E-12	1.36E-13	3.41E-15	8.56E-17	2.15E-18
79000	79500	3.60E-02	1.60E-02	7.11E-03	2.86E-03	1.15E-03	1.15E-04	4.57E-06	1.15E-07	2.88E-09	7.24E-11	1.82E-12	4.57E-14	1.15E-15	2.88E-17	7.25E-19
80000	80000	1.79E-02	7.97E-03	3.54E-03	1.42E-03	5.72E-04	5.72E-05	2.28E-06	5.72E-08	1.44E-09	3.61E-11	9.07E-13	2.28E-14	5.72E-16	1.44E-17	3.61E-19
Total		1.49E+04	7.15E+03	3.45E+03	1.46E+03	5.36E+02	1.09E+02	1.78E+01	3.60E+00	6.67E-01	5.93E-02	3.37E-03	1.61E-04	7.51E-06	3.51E-07	1.64E-08

4.9 HIGH ENERGY RADIATION ENVIRONMENTS (TBR)

Unless otherwise stated, all tables and graphs within this section represent environments external to the Flight System, and do not contain a design factor (i.e., RDF=1). The Radiation Design Factor (RDF) is defined as:

$$RDF = \frac{\text{Radiation-tolerance level of a part or component in a given application}}{\text{Radiation environment present at the location of the part or component}}$$

4.9.1 IONIZING RADIATION

The ionizing radiation exposure of Europa Clipper flight hardware will come primarily from the Jovian radiation belt environment, and secondarily from solar protons, solar and galactic cosmic rays, and jovian heavy ions. The contribution from Jovian radiation belts is expected to dominate for all hardware.

Flight System components and devices shall be selected such that they operate within performance specification during and after the exposure to the radiation environment documented herein at a radiation design factor (RDF) of 2 times the level present at the location of the device.

Devices that require spot shielding shall be assessed at an RDF of 3 times the TID level present at the location of the device. (TBR)

4.9.1.1 Europa Clipper Integral Fluences of Electrons and Protons

Trajectory 13-F7 is used for a representative trajectory for a mission radiation environment. Trajectory 13-F7 contains 59 orbits of the planet Jupiter including Orbit insertion/Ganymede 0.

NOTE: need to add contribution of proton environment beyond 12 Rj (GIRE model cut-off for trapped proton environment).

Table 4.9-1 lists the preliminary Jupiter trapped particle fluences derived using the model GIRE2K (JPL IOM 5130-11-053 “Galileo Interim Radiation Electron Model Update—2011”, To Distribution, From H. Garrett, M. Kokorowski, I. Jun, and R. W. Evans, 29 November 2011) for trajectory13-F7. Figure 4.9-1 shows these fluences. Fluences are integral in particles/cm^2 for Energy equal to and greater than Energy listed.

Table 4.9-1. Integral Fluences Through End of Mission (59 Orbits) (TBR)
RDF=1

Energy (MeV)	GIRE2 Electrons Integral Fluence (cm^{-2})	13-F7 Protons Integral Fluence (cm^{-2})
0.1	2.87E+15	2.64E+16
0.2	1.45E+15	4.66E+15
0.3	9.69E+14	1.71E+15
0.5	5.77E+14	4.92E+14
1	2.70E+14	9.40E+13
2	1.14E+14	1.89E+13
3	6.49E+13	7.63E+12
5	3.02E+13	2.49E+12
10	8.80E+12	5.59E+11
20	1.83E+12	1.05E+11
30	6.77E+11	2.72E+10
50	1.92E+11	2.66E+09
100	3.51E+10	6.23E+07
200	6.46E+09	1.87E+06
300	2.39E+09	4.03E+05
500	6.75E+08	9.29E+04
1000	1.07E+08	1.66E+04

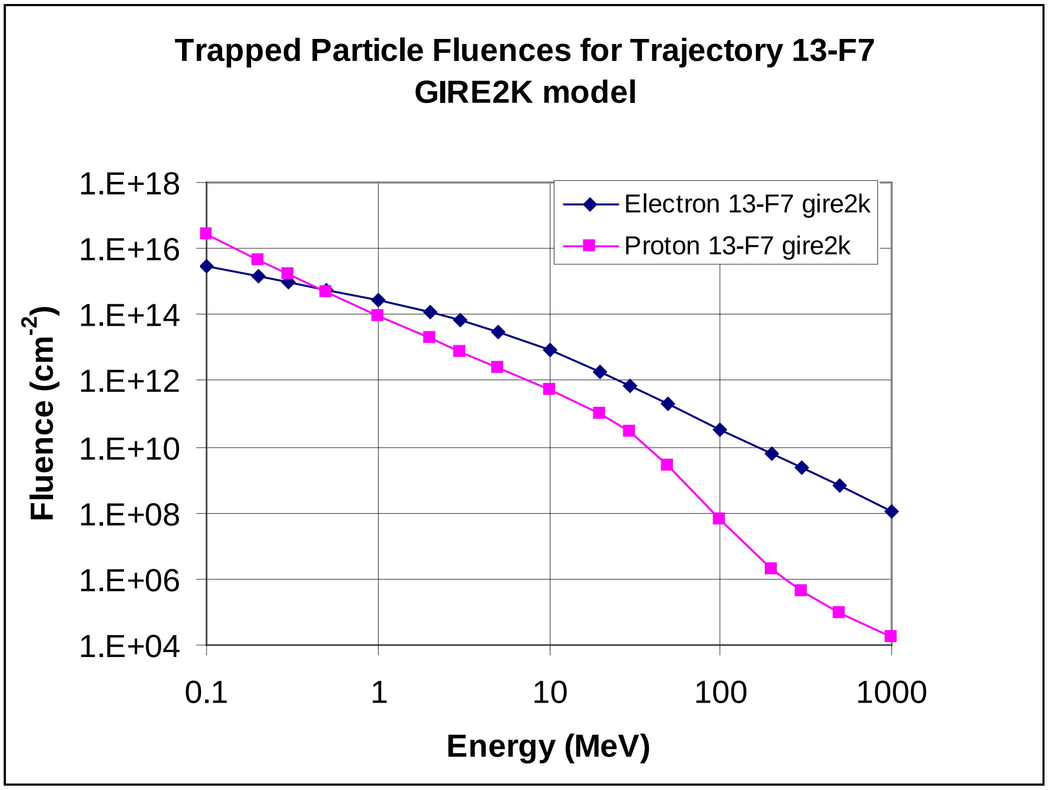


Figure 4.9 -1. GIRE2 Fluences for Trajectory 13-F7

4.9.1.2 Europa Clipper Total Ionizing Dose

Table 4.9. -2 lists the dose using NOVICE (Thomas Jordan 1993, NOVICE, A Radiation Transport Shielding Code, Experimental and Mathematical Physics Consultants, Jan. 2006 Version) for the GIRE2k fluences.

Table 4.9-2 shows the total dose inside a spherical Aluminum shell for various shielding thicknesses. Figure 4.9-2 shows the total dose for GIRE2k. Dose is in rads Silicon, Shielding thickness is in mils. The table also gives Shielding thicknesses in grams/cm^2 and millimeters.

Table 4.9-2 Total Dose for trajectory using GIRE2 and NOVICE (TBR) RDF=1

Spherical Shell Shielding Thickness (Aluminum)			
g/cm^2	mm	mils	GIRE2k
6.86E-03	2.54E-02	1.00E+00	2.61E+08
6.86E-02	2.54E-01	1.00E+01	2.60E+07
1.37E-01	5.08E-01	2.00E+01	1.37E+07
2.06E-01	7.62E-01	3.00E+01	9.32E+06
2.74E-01	1.02E+00	4.00E+01	7.06E+06
3.43E-01	1.27E+00	5.00E+01	5.65E+06
4.12E-01	1.52E+00	6.00E+01	4.69E+06
4.80E-01	1.78E+00	7.00E+01	3.99E+06
5.49E-01	2.03E+00	8.00E+01	3.46E+06
6.17E-01	2.29E+00	9.00E+01	3.05E+06
6.86E-01	2.54E+00	1.00E+02	2.70E+06
8.23E-01	3.05E+00	1.20E+02	2.19E+06
9.60E-01	3.56E+00	1.40E+02	1.82E+06
1.10E+00	4.06E+00	1.60E+02	1.55E+06
1.17E+00	4.32E+00	1.70E+02	1.43E+06
1.23E+00	4.57E+00	1.80E+02	1.33E+06
1.37E+00	5.08E+00	2.00E+02	1.17E+06
1.51E+00	5.59E+00	2.20E+02	1.03E+06
1.65E+00	6.10E+00	2.40E+02	9.17E+05
1.78E+00	6.60E+00	2.60E+02	8.20E+05
1.92E+00	7.11E+00	2.80E+02	7.37E+05
2.06E+00	7.62E+00	3.00E+02	6.67E+05
2.20E+00	8.13E+00	3.20E+02	6.06E+05
2.74E+00	1.02E+01	4.00E+02	4.30E+05
3.43E+00	1.27E+01	5.00E+02	2.98E+05
4.12E+00	1.52E+01	6.00E+02	2.17E+05
4.80E+00	1.78E+01	7.00E+02	1.62E+05
5.49E+00	2.03E+01	8.00E+02	1.25E+05
6.17E+00	2.29E+01	9.00E+02	9.93E+04
6.86E+00	2.54E+01	1.00E+03	8.10E+04

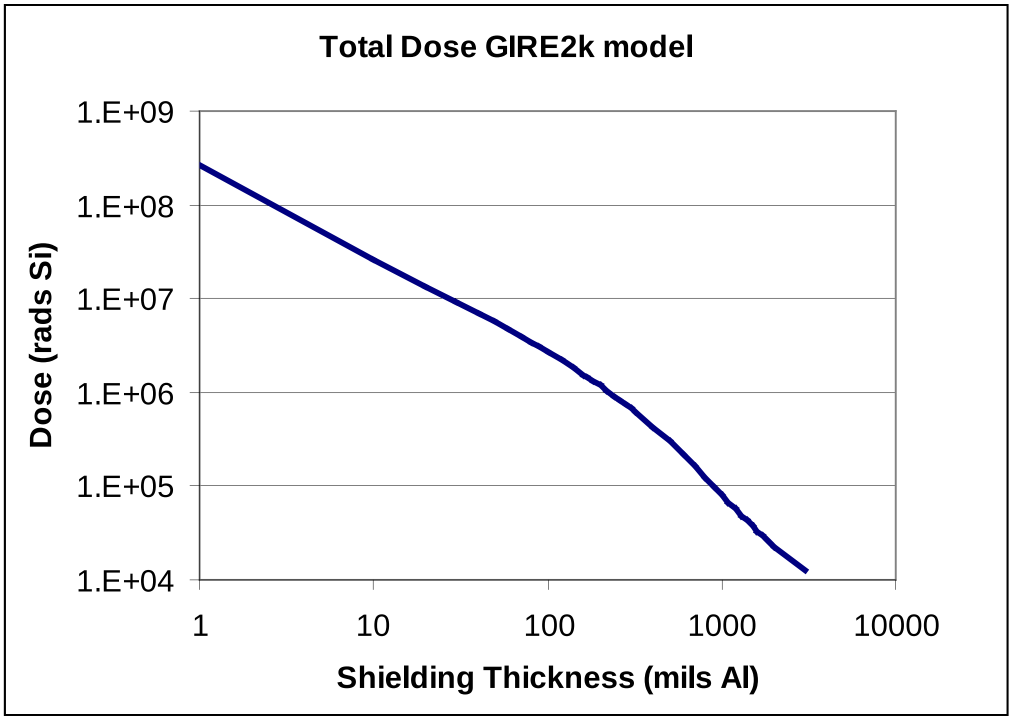


Figure 4.9-2 Spherical Shell Dose/Depth Curve for Trajectory 13-F7

Average dose rate profiles through various levels of shielding during a Europa flyby is shown in Figure 4.9-3. Electronics within well-shielded areas will see typical maximum dose rates of ~100 mrad/sec.

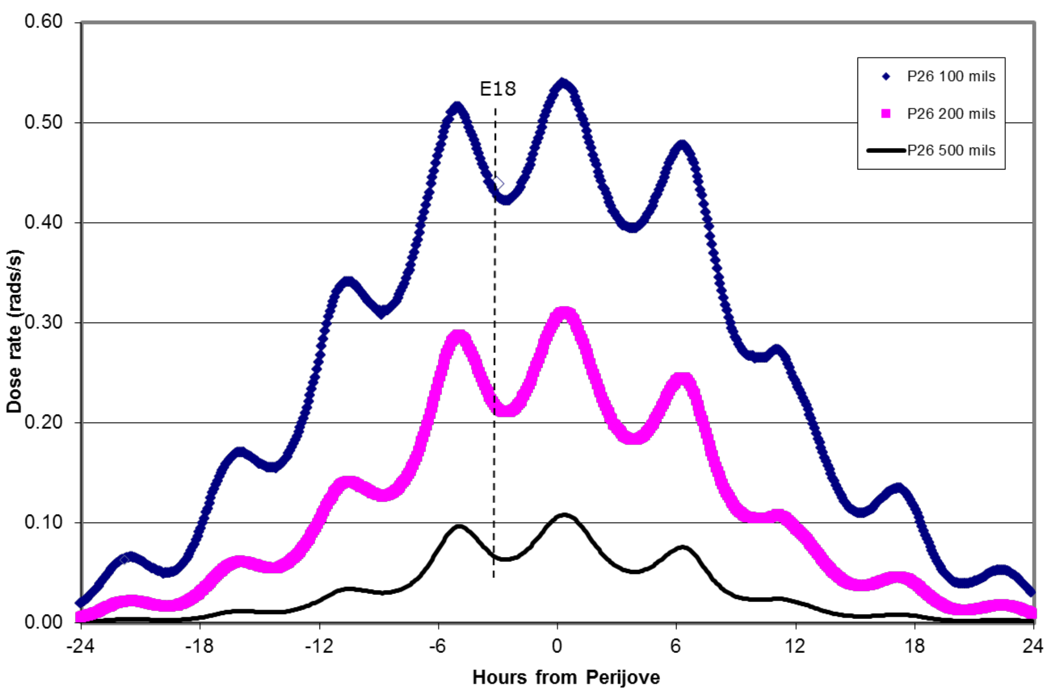


Figure 4.9-2. Dose Rate Profile for Europa Flyby E18 in Trajectory 13-F7

4.9.1.3 Galactic Cosmic Rays (GCR)

The flux of galactic cosmic rays (GCR) contributes approximately 0.02 Rad-Si /day to the mission dose, independent of shielding. The jovian magnetic field provides some shielding from GCRs, particularly in the perijove portions of the tour. For the Europa Clipper mission, GCR contribution to TID will be neglected.

4.9.2 DISPLACEMENT DAMAGE DOSE

The radiation degradation of certain electronic devices (solar cells and opto-couplers, among others), cannot be adequately characterized in terms of TID; the Displacement Damage Dose (DDD) is a more useful characterization.

An assembly's electronic devices shall be selected such that the assembly operates within performance specification during and after the exposure to the radiation environment documented herein at a radiation design factor (RDF) of 2 times the DDD level present at the location of the device. Displacement Damage Dose in Silicon at the center of an aluminum spherical shell shield (RDF=1) is provided in Figure 4.9-3 and Table 4.9-3. Europa Clipper mission DDD is based on solar protons and trapped Jovian protons and electrons through 59 Science Orbits. Bremsstrahlung radiation will not contribute any noticeable DDD.

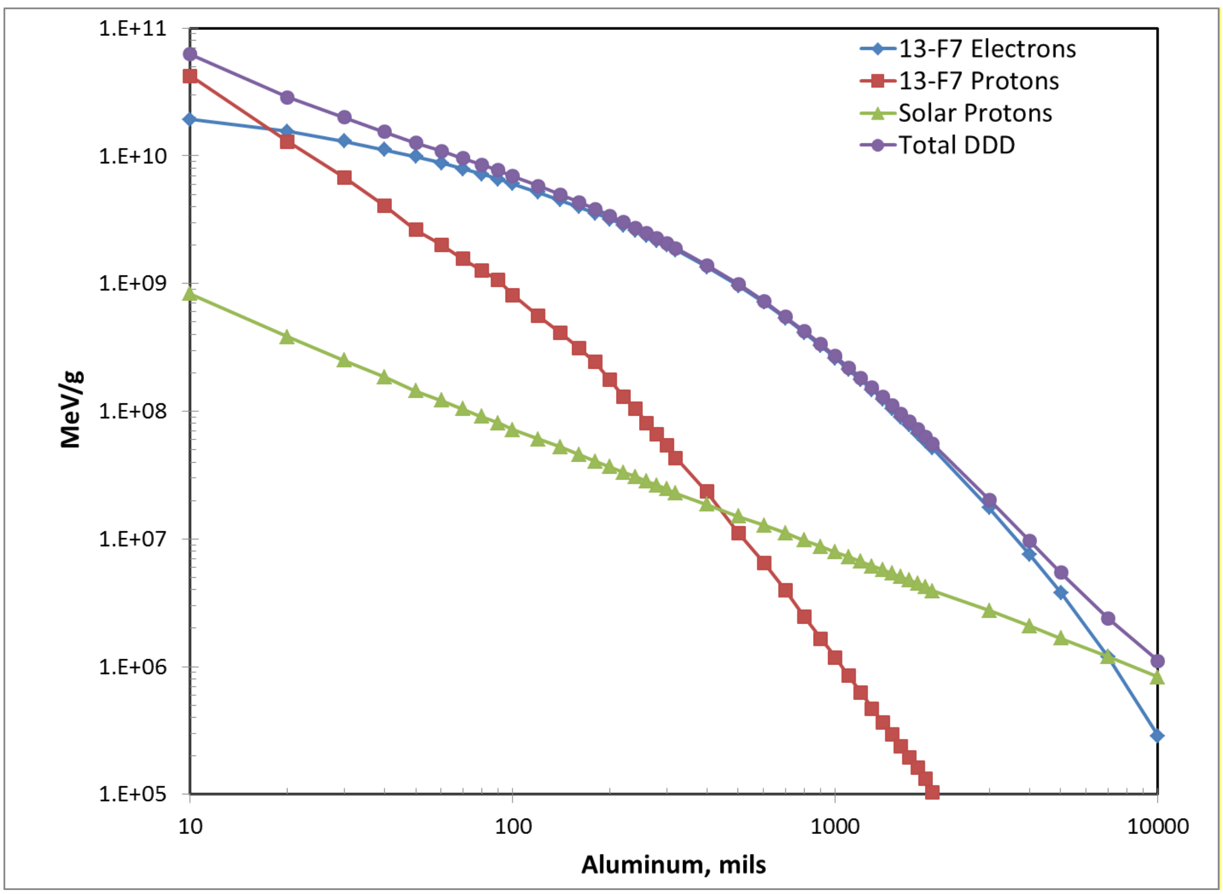


Figure 4.9-3 Europa Clipper Mission Displacement Damage Dose (DDD). (RDF = 1)

Table 4.9-3 Europa Clipper Mission Displacement Damage Dose (DDD)9 [RDM (RDF) = 1]

Spherical Shell Aluminum Shield Thickness		13-F7 Electrons DDD (RDF=1)	13-F7 Protons DDD (RDF=1)	Solar Protons DDD (RDF=1)	Total Mission DDD (RDF =1)
(mm)	(mils)	(MeV/g,Si)	(MeV/g,Si)	(MeV/g,Si)	(MeV/g,Si)
2.54E-03	1.00E-01	2.50E+10	4.78E+14	2.74E+11	4.78E+14
2.54E-02	1.00E+00	2.46E+10	3.49E+12	1.40E+10	3.53E+12
2.54E-01	1.00E+01	1.93E+10	4.22E+10	8.31E+08	6.23E+10
5.08E-01	2.00E+01	1.55E+10	1.29E+10	3.83E+08	2.88E+10
7.62E-01	3.00E+01	1.30E+10	6.79E+09	2.50E+08	2.00E+10
1.02E+00	4.00E+01	1.12E+10	4.08E+09	1.86E+08	1.55E+10
1.27E+00	5.00E+01	9.85E+09	2.63E+09	1.44E+08	1.26E+10
1.53E+00	6.00E+01	8.78E+09	2.01E+09	1.22E+08	1.09E+10
1.78E+00	7.00E+01	7.90E+09	1.56E+09	1.04E+08	9.56E+09
2.03E+00	8.00E+01	7.18E+09	1.27E+09	9.08E+07	8.54E+09
2.29E+00	9.00E+01	6.56E+09	1.06E+09	8.08E+07	7.70E+09
2.54E+00	1.00E+02	6.03E+09	8.13E+08	7.16E+07	6.91E+09
3.05E+00	1.20E+02	5.19E+09	5.59E+08	6.06E+07	5.81E+09
3.56E+00	1.40E+02	4.52E+09	4.12E+08	5.25E+07	4.98E+09
4.07E+00	1.60E+02	3.99E+09	3.13E+08	4.58E+07	4.35E+09
4.57E+00	1.80E+02	3.55E+09	2.43E+08	4.06E+07	3.83E+09
5.08E+00	2.00E+02	3.19E+09	1.76E+08	3.66E+07	3.40E+09
5.59E+00	2.20E+02	2.87E+09	1.30E+08	3.31E+07	3.03E+09
6.10E+00	2.40E+02	2.61E+09	1.04E+08	3.07E+07	2.74E+09
6.61E+00	2.60E+02	2.38E+09	8.10E+07	2.83E+07	2.49E+09
7.12E+00	2.80E+02	2.17E+09	6.58E+07	2.63E+07	2.26E+09
7.62E+00	3.00E+02	1.99E+09	5.42E+07	2.46E+07	2.07E+09
8.13E+00	3.20E+02	1.83E+09	4.31E+07	2.28E+07	1.90E+09
1.02E+01	4.00E+02	1.35E+09	2.35E+07	1.86E+07	1.39E+09
1.27E+01	5.00E+02	9.64E+08	1.11E+07	1.50E+07	9.90E+08
1.53E+01	6.00E+02	7.10E+08	6.49E+06	1.28E+07	7.29E+08
1.78E+01	7.00E+02	5.35E+08	3.99E+06	1.11E+07	5.50E+08
2.03E+01	8.00E+02	4.12E+08	2.46E+06	9.75E+06	4.24E+08
2.29E+01	9.00E+02	3.25E+08	1.66E+06	8.72E+06	3.35E+08
2.54E+01	1.00E+03	2.61E+08	1.18E+06	7.90E+06	2.70E+08
2.80E+01	1.10E+03	2.12E+08	8.49E+05	7.22E+06	2.20E+08
3.05E+01	1.20E+03	1.76E+08	6.27E+05	6.64E+06	1.83E+08
3.30E+01	1.30E+03	1.47E+08	4.69E+05	6.13E+06	1.54E+08
3.56E+01	1.40E+03	1.24E+08	3.67E+05	5.73E+06	1.30E+08
3.81E+01	1.50E+03	1.05E+08	2.95E+05	5.38E+06	1.11E+08
4.07E+01	1.60E+03	9.01E+07	2.37E+05	5.05E+06	9.54E+07
4.32E+01	1.70E+03	7.76E+07	1.94E+05	4.74E+06	8.25E+07

Spherical Shell Aluminum Shield Thickness		13-F7 Electrons DDD (RDF=1)	13-F7 Protons DDD (RDF=1)	Solar Protons DDD (RDF=1)	Total Mission DDD (RDF =1)
(mm)	(mils)	(MeV/g,Si)	(MeV/g,Si)	(MeV/g,Si)	(MeV/g,Si)
4.57E+01	1.80E+03	6.74E+07	1.61E+05	4.49E+06	7.21E+07
4.83E+01	1.90E+03	5.88E+07	1.33E+05	4.23E+06	6.32E+07
5.08E+01	2.00E+03	5.16E+07	1.04E+05	3.92E+06	5.56E+07
7.62E+01	3.00E+03	1.75E+07	3.10E+04	2.75E+06	2.03E+07
1.02E+02	4.00E+03	7.60E+06	1.21E+04	2.09E+06	9.70E+06
1.27E+02	5.00E+03	3.79E+06	5.52E+03	1.67E+06	5.47E+06
1.78E+02	7.00E+03	1.20E+06	2.35E+03	1.20E+06	2.40E+06
2.54E+02	1.00E+04	2.87E+05	8.80E+02	8.26E+05	1.11E+06

4.9.3 SINGLE EVENT EFFECTS (TBR)

Electronics may be susceptible to Single Event Effects, or SEE, which include reversible, non-destructive actions (Single Event Upsets, or SEUs) such as memory bit-flips; or potentially destructive actions such as device latch-up. SEEs are caused by high-energy ions. The term “heavy ion”, as used below, refers to any ion having atomic number Z > 1; i.e. anything larger than a proton. If the part’s SEE threshold LET (linear energy transfer) is less than 15 MeV-cm^2/mg, then high-energy protons can also cause SEE. These types of high-energy particles are found in galactic cosmic rays and solar particle events.

In electronic sensors, SEE can manifest itself as spurious signals, i.e. radiation-induced background noise.

An assembly’s electronic devices shall be chosen such that the assembly operates within performance specification during and after exposure to the high-energy radiation environments specified in the following subsections. The subsystem/assembly and system-level requirements regarding performance with respect to SEE during operation are as follows:

1) Temporary loss of function or loss of data shall be permitted provided that the loss does not compromise subsystem/system health, full performance can be recovered rapidly, and there is no time in the mission that the loss is mission critical.

2) Normal operation and function shall be restored via internal/spacecraft correction methods without external intervention in the event of a SEU.

3) Fault traceability shall be provided in the telemetry stream to the greatest extent practical for all anomalies involving SEEs.

An RDF = 1 shall be applied to the environments specified in the following sub-sections.

4.9.3.1 Peak Flux of Jovian Electrons and Protons(TBR)

The peak average Jovian electron and proton fluxes are provided in Table 4.9-4. Since the radiation model provides a time-averaged value of the flux at a given position, the maximum flux seen along the orbit is the peak average flux, rather than the peak instantaneous flux. Flux averaging is based on the statistical mean of energetic particle measurements made at the Jovian magnetic equator.

An estimate of the statistical variation of energetic charged particle flux, and potential worst-case environments can be deduced from Figure 4.9-4. The figure provides super-imposed plots of the Galileo Energetic Particle Detector (EPD) DC3 channel (E>11 MeV) count rate versus radial distance for individual Galileo orbits (each indicated by different symbols/colors).

Table 4.9-4. Peak Average Flux of Jovian Electrons and Protons (TBR) RDF = 1

Energy (MeV)	Peak Average Electron Flux ($cm^{-2}s^{-1}$)	Peak Average Proton Flux ($cm^{-2}s^{-1}$)
0.1	5.49E+08	3.19E+11
0.2	2.35E+08	2.68E+10
0.3	1.24E+08	6.31E+09
0.5	9.27E+07	1.03E+09
1	8.93E+07	9.43E+07
2	8.16E+07	1.22E+07
3	7.99E+07	4.65E+06
5	7.77E+07	3.12E+06
10	7.17E+07	2.73E+06
20	4.82E+07	1.92E+06
30	2.34E+07	1.12E+06
50	4.48E+06	3.25E+05
100	2.29E+05	3.57E+04
200	7.28E+04	3.69E+03
300	4.27E+04	9.66E+02
500	2.17E+04	1.89E+02
1000	8.70E+03	4.22E+01
2000	1.00E+00	1.00E+00

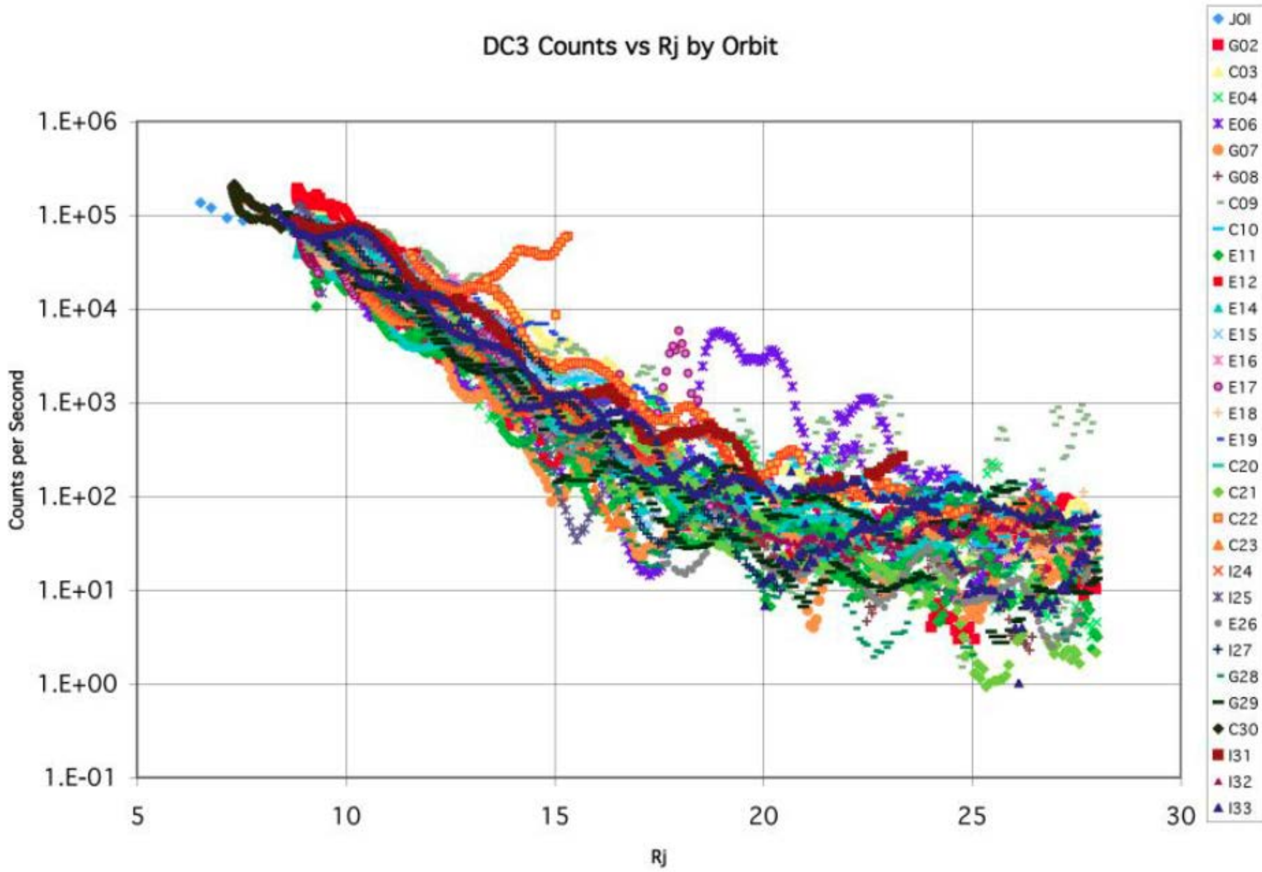


Figure 4.9-4 Raw EPD DC3 counts per second (10 minute averages) for the Galileo mission

Note the magnitude of the statistical fluctuation decreases at smaller Rj, with less than a factor of 10 variation near 9.4 Rj (Europa orbit). Current recommended worst-case flux is 10x (TBR) the value estimate from GIRE-2.

4.9.3.2 Solar Proton Peak Flux

The solar proton peak flux environment, which is to be used for proton-induced SEE in parts susceptible to proton-induced SEE, is given by the CREME96 model for the worst-case (5 minute average) solar event protons. For information purposes, the flux behind 25 mils of aluminum shielding is provided in Figure 4.9.3-5. Peak fluxes for other shielding thicknesses should be determined using CREME96 models located at: https://creme96.nrl.navy.mil/.

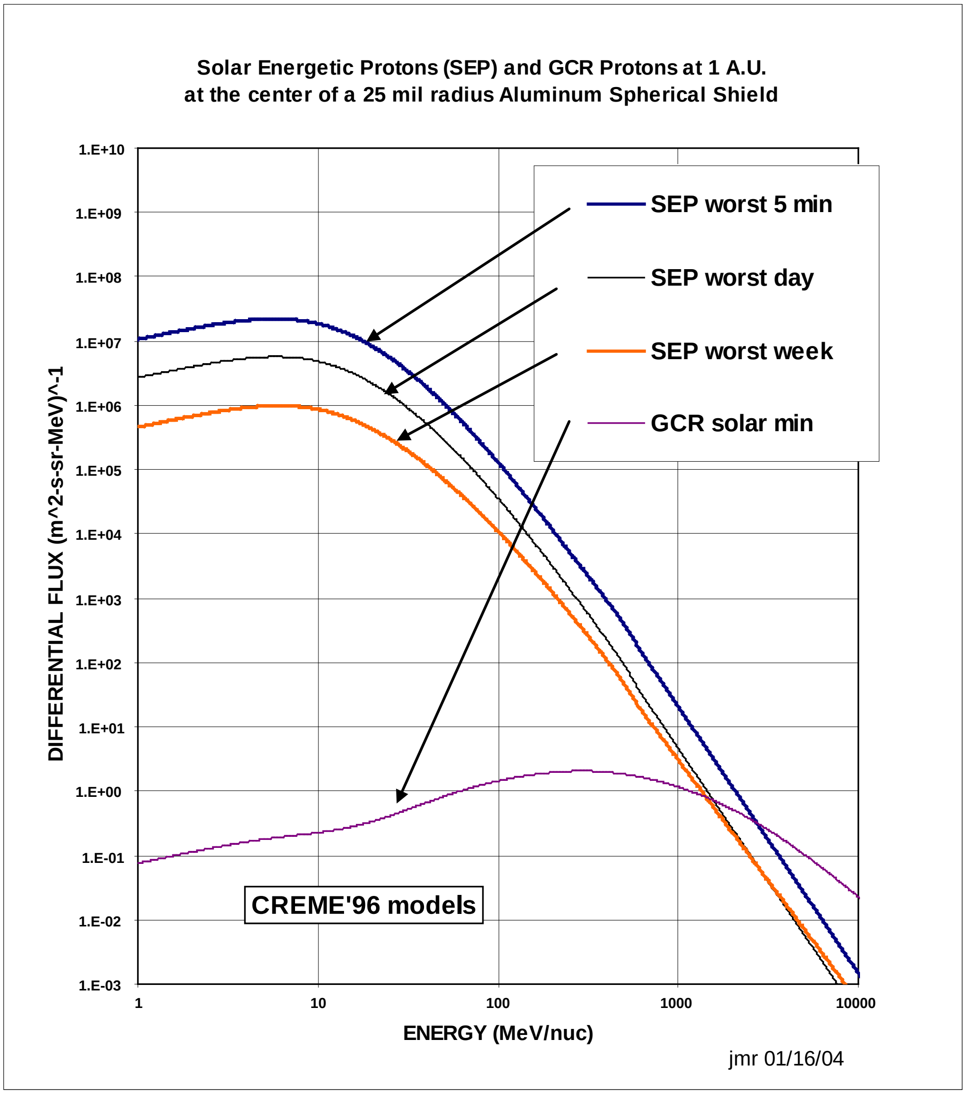


Figure 4.9-5. Solar Energetic Proton and GCR Proton fluxes (TBR)

4.9.3.3 Solar Heavy Ion Peak Flux (TBR)

The solar particle event heavy ion peak flux environment is given by the CREME96 model for the worst case (5 minute average) heavy ions. For information purposes, the flux behind 25 mils of aluminum shielding is provided in Figure 4.9-6. Peak fluxes for other shielding thicknesses should be determined using CREME96 models located at: https://creme96.nrl.navy.mil/

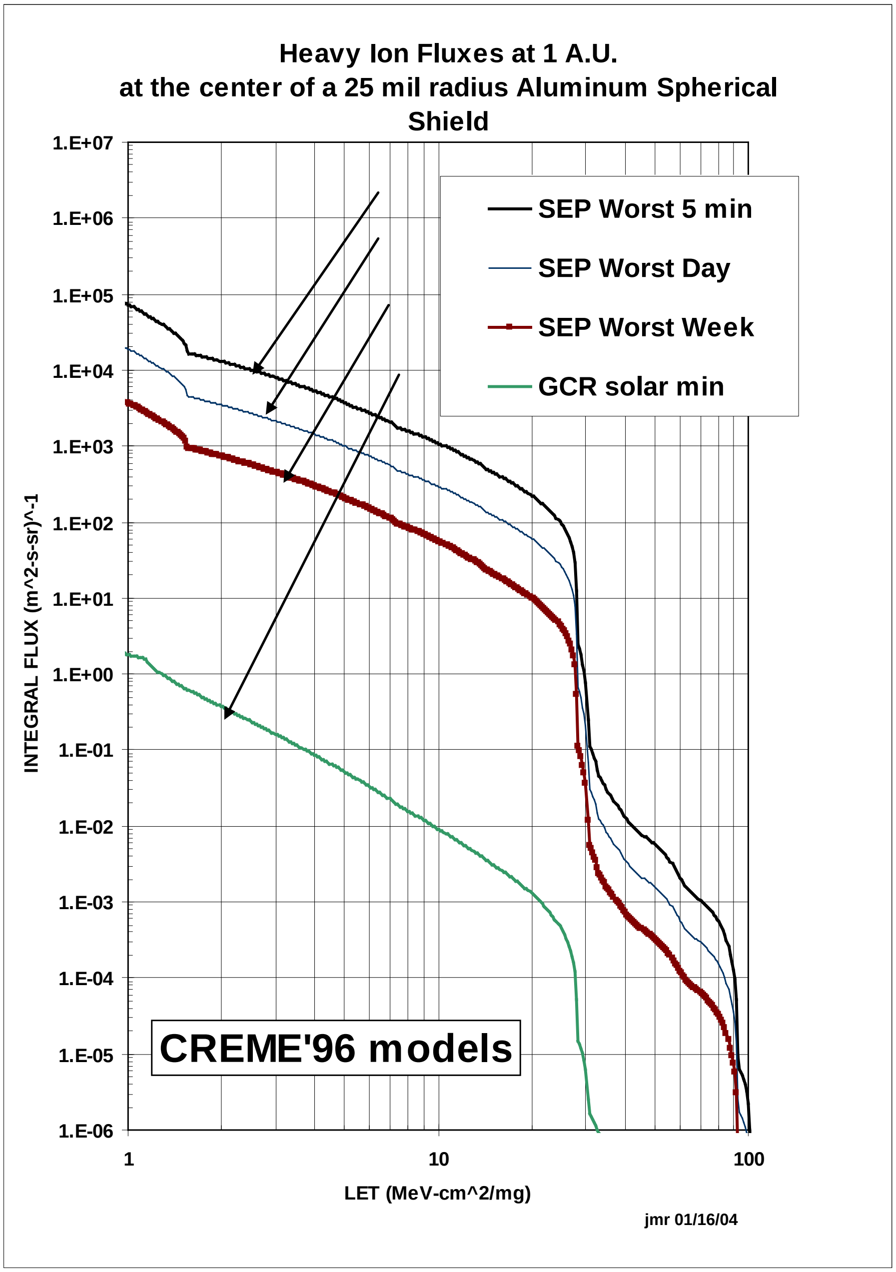


Figure 4.9-6. Solar and GCR Heavy Ion fluxes (TBR)

4.9.3.4 Galactic Cosmic Ray Proton Flux (TBR)

The GCR proton environment, which is to be used for proton-induced SEE in parts susceptible to proton-induced SEE, is given by the CREME96 model for GCR protons. For information purposes, the flux behind 25 mils of aluminum shielding is provided in Figure 4.9-5.

4.9.3.5 Galactic Cosmic Ray Heavy Ion Flux (TBR)

The GCR heavy ion environment is given by the CREME96 model for heavy ions at solar minimum. For information purposes, the flux behind 25 mils of aluminum shielding is provided in Figure 4.9-5.

4.9.4 MULTI-MISSION RADIOISOTOPE THERMOELECTRIC GENERATOR (MMRTG) (TBR)

4.9.4.1 TID Due to MMRTGs (TBR)

The TID contour plot shown in Figure 4.9-7 is constructed to show the TID levels contributed by a single, 8-module MMRTG as a function of radial (horizontal axis) and axial (vertical axis) distance from the center of the MMRTG (having initial source term strength of 8000 neutron/s/g-of-Pu238). Note: These charts are to be updated for larger distances from the MMRTG to reflect the Europa Clipper mechanical configuration.

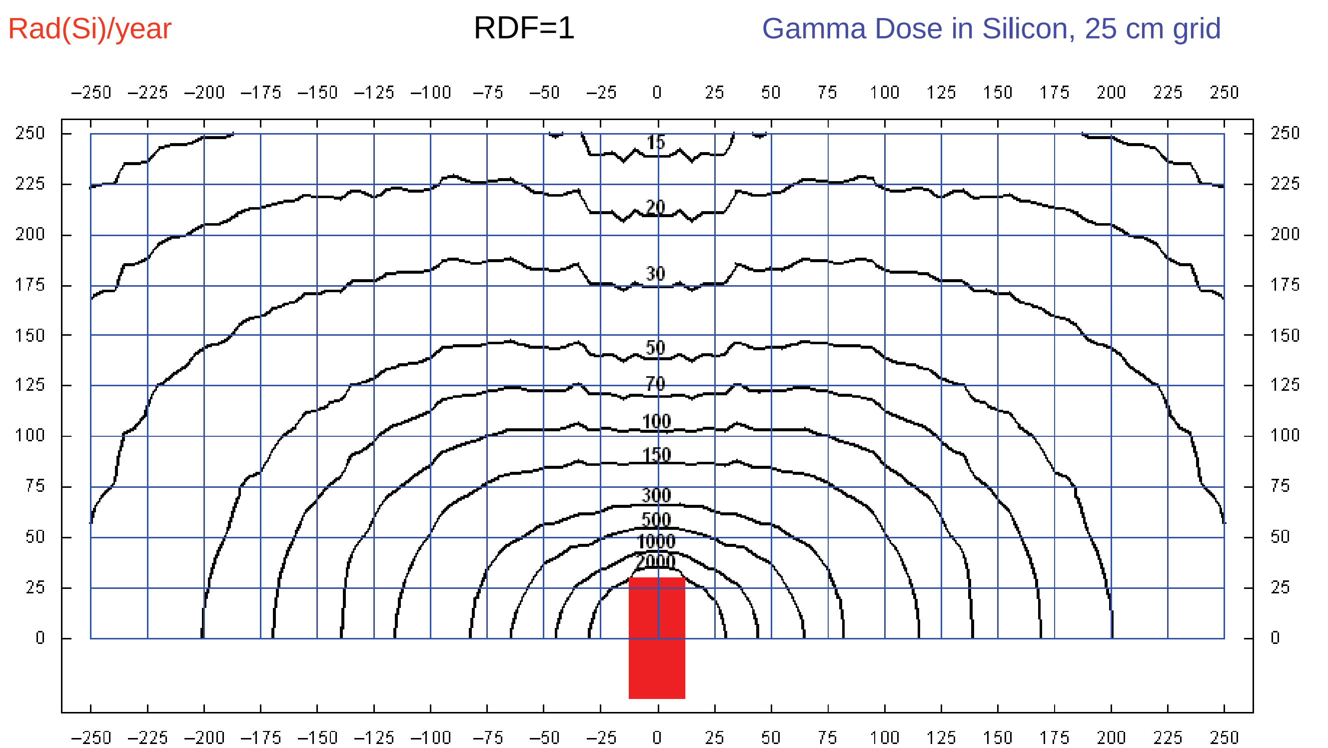


Figure 4.9-7 Contour Plot of One Year TID Levels of a Single, 8-module MMRTG (TBR)

4.9.4.2 DDD Due to MMRTGs (TBR)

Figure 4.9-8 shows the DDD levels as a function of radial (horizontal axis) and axial (vertical axis) distance from the center of the MMRTG.

1 Year Fluence

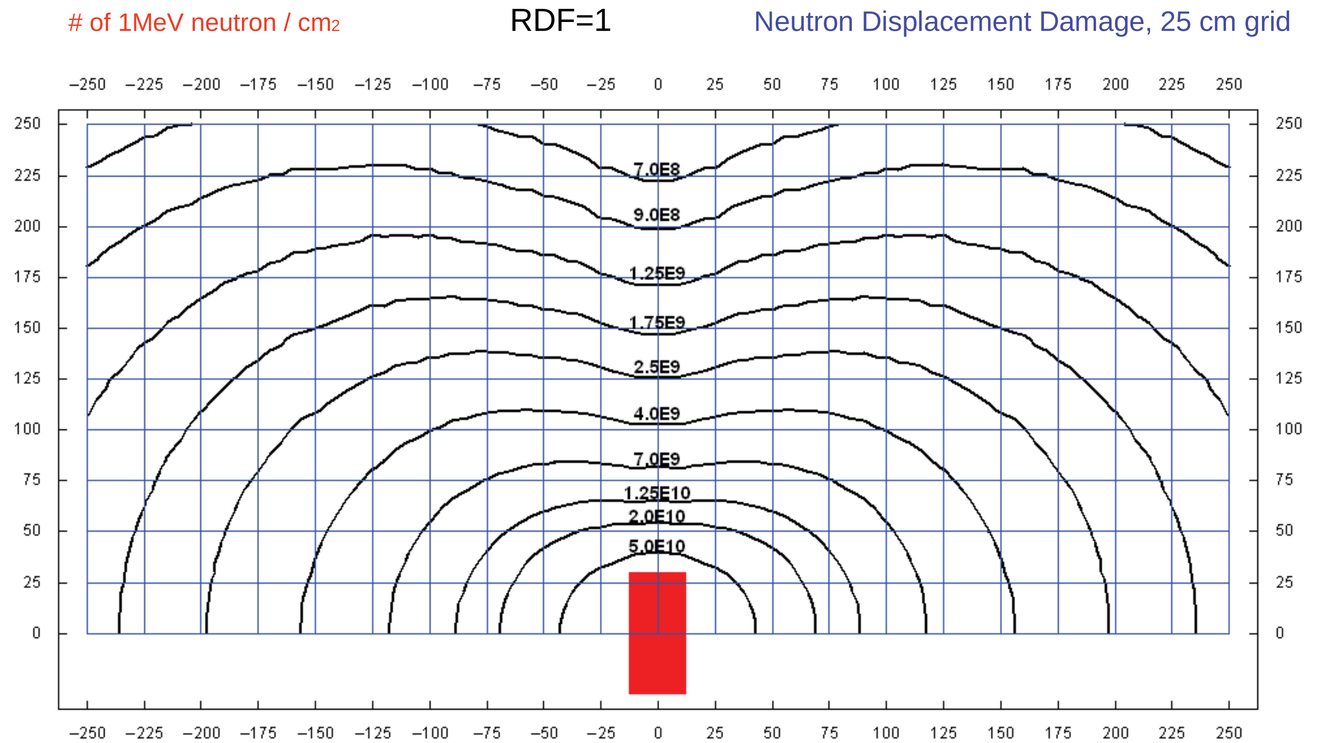


Figure 4.9-8 Contour Plot of One Year Displacement Damage Dose (in Equivalent 1 MeV neutrons/cm2 Fluence from a Single, 8-module MMRTG) (TBR)

4.10 ATOMIC OXYGEN

The baseline Europa Clipper mission fluence of atomic oxygen (AO) is to be provided at a later date. Materials exposed to space with a vector in the ram direction **shall** survive the mission exposure to AO with acceptable property characteristics.

4.11 SOLAR SPECTRAL IRRADIANCE

The solar electromagnetic environment mean flux for each mission phase is as stated in Table 4.6-1, with a solar irradiance spectrum shown in Table 4.11-1.

Materials directly exposed to the sun **shall** survive the mission exposure to the electromagnetic environment with acceptable property characteristics.

Table 4.11-1 Solar Spectral Irradiance 0.0850 – 7.0 Microns

λ (μm)	P (%)	λ (μm)	P (%)	λ (μm)	P (%)
0.0850	3.8×10^{-4}	0.36	5.317	0.67	43.745
0.0900	3.9×10^{-4}	0.365	5.723	0.68	44.816
0.0950	4.0×10^{-4}	0.37	6.151	0.69	45.856
0.1000	4.1×10^{-4}	0.375	6.583	0.70	46.880
0.1050	4.2×10^{-4}	0.38	7.003	0.71	47.882
0.1100	4.2×10^{-4}	0.385	7.413	0.72	48.865
0.1150	4.3×10^{-4}	0.39	7.819	0.73	49.827
0.1200	4.4×10^{-4}	0.395	8.242	0.74	50.769
0.1250	4.7×10^{-4}	0.40	8.725	0.75	51.691
0.1320	4.9×10^{-4}	0.405	9.293	0.80	56.019
0.1350	5.2×10^{-4}	0.41	9.920	0.85	59.890
0.1400	5.4×10^{-4}	0.415	10.572	0.90	63.358
0.1450	5.6×10^{-4}	0.42	11.222	0.95	66.544
0.1500	5.8×10^{-4}	0.425	11.858	1.0	69.465
0.1550	6.3×10^{-4}	0.43	12.474	1.1	74.409
0.1600	6.9×10^{-4}	0.435	13.084	1.2	78.386
0.1650	8.2×10^{-4}	0.44	13.726	1.3	81.638
0.1700	1.01×10^{-3}	0.445	14.415	1.4	84.343
0.1750	1.31×10^{-3}	0.45	15.141	1.5	86.645
0.1800	1.70×10^{-3}	0.455	15.892	1.6	88.607
0.1850	2.33×10^{-3}	0.46	16.653	1.7	90.256
0.1900	3.16×10^{-3}	0.465	17.414	1.8	91.590
0.1950	5.2×10^{-3}	0.47	18.168	1.9	92.643
0.2000	8.1×10^{-3}	0.475	18.921	2.0	93.489
0.2050	1.34×10^{-2}	0.48	19.682	2.1	94.202
0.2100	2.05×10^{-2}	0.485	20.430	2.2	94.827
0.2150	3.53×10^{-2}	0.49	21.156	2.3	95.370
0.22	0.0502	0.495	21.878	2.4	95.858
0.225	0.0729	0.50	22.599	2.5	96.294
0.23	0.0972	0.505	23.313	2.6	96.671
0.235	0.1205	0.51	24.015	2.7	97.007
0.24	0.1430	0.515	24.702	2.8	97.310
0.245	0.1681	0.52	25.379	2.9	97.584
0.25	0.1944	0.525	26.060	3.0	97.828
0.255	0.2267	0.53	26.743	3.1	98.038
0.26	0.270	0.535	29.419	3.2	98.218
0.265	0.328	0.54	28.084	3.3	98.372
0.27	0.405	0.545	28.738	3.4	98.505
0.275	0.486	0.55	29.381	3.5	98.620
0.28	0.465	0.555	30.017	3.6	98.725
0.285	0.644	0.56	30.648	3.7	98.819
0.29	0.811	0.565	31.276	3.8	98.906
0.295	1.008	0.57	31.908	3.9	98.985
0.30	1.211	0.575	32.542	4.0	99.058
0.305	1.417	0.58	33.176	4.1	99.125
0.31	1.656	0.585	33.809	4.2	99.186
0.315	1.924	0.59	34.440	4.3	99.241
0.32	2.219	0.595	35.065	4.4	99.291
0.325	2.552	0.60	35.683	4.5	99.337
0.33	2.928	0.61	36.902	4.6	99.379
0.335	3.324	0.62	38.098	4.7	99.416
0.34	3.722	0.63	39.270	4.8	99.450
0.345	4.118	0.64	40.421	4.9	99.482
0.35	4.517	0.65	41.550	5.0	99.511
0.355	4.919	0.66	42.658	6.0	99.718
				7.0	99.819

λ (μm) is wavelength; and P is the percentage of the solar constant associated with wavelengths shorter than λ.

APPENDIX A: ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AFT	Allowable Flight Temperature
AM	Amplitude Modulation
AO	Atomic Oxygen
ATLO	Assembly, Test, and Launch Operations
CE	Conducted Emissions
C.G.	Center of Gravity
CLA	Coupled Loads Analysis
CS	Conducted Susceptibility
dB	Decibel
DC	Direct Current
DDD	Displacement Damage Dose
DUT	Device Under Test
EM	Engineering Model
EMC	Electromagnetic Compatibility
ERD	Environmental Requirements Document
ERE	Environmental Requirements Engineer
ESD	Electrostatic Discharge
FA	Flight Acceptance
FMH	Free Molecular Heating
GCR	Galactic Cosmic Ray
GHz	Giga-Hertz
GN2	Gaseous Nitrogen
Grms	Gravity Root Mean Squared
Hi-Rtn	High-Return
Hrs	Hour(s) [
HV	High Voltage
Hz	Hertz
IESD	Internal Electrostatic Discharge
JPL	Jet Propulsion Laboratory
K	Kelvin
kHz	kilo-Hertz
LISN	Line Impedance Simulation Network
LVDS	Low Voltage Differential Signaling
MAC	Mass Acceleration Curve
MeV	Million electron Volts
MEFL	Maximum Expected Flight Level
min	Minute
MinEFL	Minimum Expected Flight Level
MHz	Mega-Hertz
MIL-STD	Military Standard
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
mΩ	Milli-Ohm
MΩ	Meg-Ohm
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
Non-Op	Non-Operating
nT	nano-Testla
Op	Operating
PAF	Payload Adapter Fairing
PF	Protoflight
PLF	Payload Fairing

PSI	Pounds per Square Inch
PWA	Printed Wiring Assembly
Qual	Qualification (Model)
RDF	Radiation Design Factor
RE	Radiated Emissions
RF	Radio Frequency
RHU	Radioisotope Heater Units
Rj	Jupiter Radius
RMS	Root Mean Square
RS	Radiated Susceptibility
SEE	Single Event Effects
SEP	Solar Energetic Particle (or Proton)
SEU	Single Event Upset
SPL	Sound Pressure Level
SRS	Shock Response Spectrum
TBC	To Be Completed or Confirmed
TBD	To Be Determined
TBR	To Be Reviewed/Revised
TID	Total Ionizing Dose
W/m2	Watt per Square Meter

APPENDIX B: ETAS FORM (ENVIRONMENTAL TEST AUTHORIZATION SUMMARY)

[http://jplforms.jpl.nasa.gov/active_forms_E.html (Form 2683)]

ETAS LOG#* ______

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

AUTHORIZATION SECTION

PROJECT:*	SUBSYSTEM/ASSEMBLY (TEST ARTICLE):*	SERIAL #:*
CONFIGURATION NAME:		
SUPPLIER:*	PART # & REV:* (NOTE: if applicable, list lower tier h/w on continuation sheet)	YEAR MFG:
H/W TYPE:* ☐EM ☐QUAL ☐FLIGHT ☐FLT SPARE ☐ OTHER ______	WIRING HARNESS (IF APPLICABLE): ☐ FLIGHT ☐ EM ☐ GSE ☐ OTHER	

ENVIRONMENTAL TEST(S) PLANNED:* CHECK ALL APPLICABLE, INDICATE TEST LEVEL: Q= Qual. , PF= Protoflight , FA= Flight Acceptance

RANDOM VIB. ☐Q ☐PF ☐FA	PYROSHOCK ☐Q ☐PF ☐FA	ACOUSTIC ☐Q ☐PF ☐FA	SINE VIB. ☐Q ☐PF ☐FA
QUASI-STATIC ☐Q ☐PF ☐FA	TEMP. ATM. ☐Q ☐PF ☐FA	THERMAL VAC. ☐Q ☐PF ☐FA	

☐ EMC: ☐Cond.Susc. ☐Cond. Emis. ☐Rad. Emis. ☐Rad. Susc. ☐Isolation ☐ESD ☐Magnetics ☐ Other ______

☐ OTHER ENV TEST: ______

ARE ANY OF THE TESTS BEING AUTHORIZED RETEST(S)?* ☐ YES ☐ NO If YES, explain: ______

FOR THE FOLLOWING QUESTIONS, PLEASE PROVIDE EXPLANATION FOR ANY "NO" ANSWERS (USE SPACE PROVIDED ON PAGE 2 AS NECESSARY)

1. DO ALL TESTS/LEVELS/DURATIONS COMPLY WITH PROJECT ENVIRONMENTAL REQUIREMENTS?* PROJ. DOC. NO. AND REV (ERD OR OTHER): ______ Comments:	☐ YES ☐ NO
2. IS THE TEST ARTICLE IDENTICAL TO THE FLIGHT CONFIGURATION?* Comments: .	☐ YES ☐ NO
3. HAS THE TEST ARTICLE PASSED ALL PRE-ENVIRONMENTAL FUNCTIONAL TESTS?* Comments: .	☐ YES ☐ NO ☐ NA
4. HAVE ALL DESIGN ANALYSES BEEN COMPLETED AND REQUIRED CHANGES INCORPORATED?* Comments:	☐ YES ☐ NO
5. ARE ALL PFRs AGAINST THIS HARDWARE CLOSED?* List Open PFRs:	☐YES or None Generated ☐ NO
6. HAVE ALL WAIVERS AND ECRs BEEN APPROVED AND REQUIRED CHANGES INCORPORATED?* List Open Items:	☐YES or None Generated ☐ NO
7. ARE ALL INSPECTION REPORTS CLOSED AND REQUIRED CHANGES INCORPORATED?* List Open Items:	☐YES or None Generated ☐ NO
8. HAS THE TEST ARTICLE PASSED ITS PRE-ENVIRONMENTAL INSPECTION?* AIDS and/or IR# ______ Comments:	☐ YES ☐ NO
9. HAS THE FUNCTIONAL TEST PROCEDURE BEEN APPROVED?* Comments:	☐YES ☐ NO
10. IS THE REQUIRED GSE (INCLUDING TEST AND HANDLING FIXTURES) AVAILABLE AND FUNCTIONING PROPERLY? Comments:	☐YES ☐ NO
11. HAVE THE OPERATIONAL SAFETY SURVEYS FOR EACH TEST BEEN SCHEDULED? Comments:	☐YES ☐ NO
12. IS A PLANETARY PROTECTION DRY HEAT MICROBIAL REDUCTION REQUIRED FOR THIS TEST ARTICLE?* If YES, indicate date completed (or planned):	☐YES ☐ NO
13. IS A CONTAMINATION CONTROL BAKEOUT REQUIRED FOR THIS TEST ARTICLE?* If YES, indicate date completed (or planned):	☐YES ☐ NO

THE FOLLOWING QUESTIONS APPLY FOR SYSTEM TESTS ONLY

14. HAVE ALL HRCR ACTION ITEMS BEEN CLOSED AND APPROVED? If NO, please provide list of exceptions and explanations:	☐YES ☐ NO
15. HAVE ALL WAIVERS BEEN REVIEWED FOR SYSTEM TEST IMPACT? Explain any system test impacts (Use additional sheets as necessary):	☐YES ☐ NO

Please continue to page 2.

ETAS LOG#*______

JPL

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

AUTHORIZATION SECTION (Cont'd)

PROJECT:*	SUBSYSTEM/ASSEMBLY (TEST ARTICLE):*	SERIAL #:*

AUTHORIZED PROVISIONS AND EXPLANATIONS

AS A MINIMUM INCLUDE: 1) TEST PLANS/TEST PROCEDURES/OTHER TEST DOCUMENTATION, 2) TEST AGENCIES AND LOCATIONS, 3) TEST LEVELS AND DURATIONS. *

TESTS AUTHORIZED BY

COGNIZANT ENGINEER* (CTM for non-JPL h/w)	PDM/TECHNICAL MGR./INSTR MGR*	ENVIRONMENTAL REQTS. ENG*
Print Name	Print Name	Print Name
Signature Date	Signature Date	Signature Date

ETAS LOG#*______

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

TEST RESULTS SECTION

PROJECT:*	SUBSYSTEM/ASSEMBLY (TEST ARTICLE):*	SERIAL #:*

ENTER TEST SUMMARY DATA FOR EACH TEST AUTHORIZED ON PAGE 1.

TEST ENVIRONMENT* LEVELS & DURATION	TEST START/END DATES*	TEST AGENCY & LOCATION*	TEST REPORTS, PFRS, WAIVERS, TEST WITNESS & OTHER COMMENTS*	PASS/ FAIL*

Please continue to page 4.

ETAS LOG#* ______

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

TEST RESULTS SECTION (Cont'd)

PROJECT:*	SUBSYSTEM/ASSEMBLY (TEST ARTICLE):*	SERIAL #:*

FOR THE FOLLOWING QUESTIONS, PLEASE USE SPACE PROVIDED BELOW, AS NECESSARY, FOR FURTHER EXPLANATION

1. WERE ALL PLANNED TESTS/LEVELS/DURATIONS ACHIEVED?* (IF NO, ATTACH EXCEPTIONS LIST)	☐ YES ☐ NO
2. WERE THERE ANY ANOMALIES OBSERVED DURING OR FOLLOWING ENVIRONMENTAL TESTS?* (IF YES PROVIDE EXPLANATIONS AND PFR #S)	☐ YES ☐ NO
3. HAS THE TEST ARTICLE PASSED ITS POST-ENVIRONMENTAL DAMAGE INSPECTIONS?* INSPECTION AIDS OR IR #: ______	☐ YES ☐ NO ☐ N/A
4. HAS THE TEST ARTICLE PASSED ITS POST-ENVIRONMENTAL FUNCTIONAL TESTS?* REPORT #: ______	☐ YES ☐ NO ☐ N/A
5. WERE ANY WAIVERS GENERATED AS A RESULT OF THE TEST(S)?* WAIVER #S*: ______	☐ YES ☐ NO

TEST SUMMARY AND EXPLANATIONS (attach test data as necessary)

TEST RESULTS DISPOSITION: *

☐ Pass ☐ Pass with Waiver ☐ Fail

COGNIZANT ENGINEER* (CTM for non-JPL h/w) Print Name	PDM/TECHNICAL MGR./INSTR MGR* Print Name	ENVIRONMENTAL REQTS. ENG* Print Name
Signature Date	Signature Date	Signature Date

NASA has not decided whether to proceed with the proposed Europa Clipper mission. Any such decision would be made after completion of the National Environmental Policy Act (NEPA) process for the proposed mission.

ETAS LOG#*______

JPL	ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)	
TEST RESULTS CONTINUATION SHEET (use as necessary)		
PROJECT:*	SUBSYSTEM/ASSEMBLY (TEST ARTICLE):*	SERIAL #:*

APPENDIX C: EACS (ENVIRONMENTAL ANALYSIS COMPLETION STATEMENT)

[http://jplforms.jpl.nasa.gov/active_forms_E.html (Form 2566)]

PROJECT	**ASSEMBL/SUBASSEMBLY TITLE**
ENVIRONMENT SPECIFICATION: (ERD paragraph # or attach as necessary).	
ANALYSIS APPROACH :	
ANALYSIS CONCLUSIONS:	
Hardware compliance with design environment? _______yes _________no (explain)	
LIST OF PERTINENT DOCUMENTS (IOM'S, REPORTS): ATTACH AS APPROPRIATE	
____________________________________ ____________________________________ ____________________________________ ____________________________________	
PREPARED BY: ____________________________________ ____________________________________ ____________ **Cognizant Engineer** **date** **phone #**	
APPROVED BY: ____________________________________ ____________________________________ **Technical Manager / Instrument Mgr. or P.I.** **Environmental Requirements Engineer (ERE)**	
After Technical Manager approval, send statement and supporting documentation to the Project ERE.	