Outer Planets Program

ENVIRONMENTAL REQUIREMENTS

August 1999

Outer Planets Program
ENVIRONMENTAL REQUIREMENTS

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

Outer Planets Program
ENVIRONMENTAL REQUIREMENTS

The following environmental requirements are generic across all three OP/SP missions unless explicitly stated otherwise. Other mission specific changes may emerge as development proceeds.

1. Shock and Vibration

1.1 Shipping and Transportation Shock and Vibration

Although no test will be applied to science instruments in this area, shipping and transportation should be handled in such a way that the environment experienced by hardware in the containers shall be less severe than the worst of the launch, separation, or mission dynamics environments.

For potential handling points which may be needed by the sensors, the following limit loads shall be assumed: Vertical: $\pm$2 g; Horizontal: $\pm$1.5 g.

1.2 Launch Dynamics

The following are the launch dynamic requirements. The specifications are design and test levels to be input at the mounting location of the hardware.

Random vibration is mainly induced from acoustic vibration on the spacecraft. The acoustic vibration requirements are based on enveloping the environments of several launch vehicles (Space Shuttle, Delta II, Delta III, Atlas III), including various configurations of these launch vehicles and anticipated spacecraft mass properties and fairing fill factors. Currently, the difference in acoustic environment between the anticipated missions is less than 6dB, which is equal to the test tolerance. For this reason, the random vibration and acoustic vibration specifications are not a function of the individual launch vehicles.

1.2.1 Sinusoidal Vibration

Sinusoidal vibration design requirements are imposed to cover the various low-frequency (5-140 Hz) launch vehicle-induced transient loads. If the instrument mounting surface has a natural frequency below 140 Hz, the sinusoidal test shown in Table 1 needs to be performed in each axis. If the instrument mounting surfaces do not have a natural frequency below 140 Hz, the sinusoidal vibration test can be eliminated.

Table 1: Sinusoidal Vibration Specification for the Instrument Mounting Surface

Frequency (Hz)	Design/Qual, PF Test	FA Test
5-20 20-100	0.5 g's in Double Amplitude 7 g's	0.33 g's in Double Amplitude 4.66 g's

Sweep Rate: 6 octaves / minute, one sweep up

1.2.2 Random Vibration

The random vibration design and test requirements are specified in Table 2 and Figure 1. These spectra shall be applied in each of the three orthogonal axes at the science instrument mounting points. The response of the hardware at its resonant frequencies may be limited so as not to exceed 15 dB above the input specification by selective narrow band reduction of the input level at those resonant frequencies or by force limiting. To effect the response limits, an accelerometer shall be mounted near the point of maximum movement on the science instrument mounting surface to measure its response.

Table 2: Random Vibration Specification

Frequency (Hz)	Design/Qual, PF Test	FA Test
20	0.032 g^2/Hz	0.016
20-70	+6.0 dB/Octave	+6.0 dB/Octave
70-300	0.40 g^2/Hz	0.20 g^2/Hz
300-400	-6.0 dB/Octave	-6.0 dB/Octave
400-800	0.20 g^2/Hz	0.01 g^2/Hz
800-2000	-9.0dB/Octave	-9.0dB/Octave
Overall	16.7 grms	11.8 grms

Duration: Design/Qual 3 minutes in each of 3 orthogonal axes
PF, FA: 1 minute in each of 3 orthogonal axes

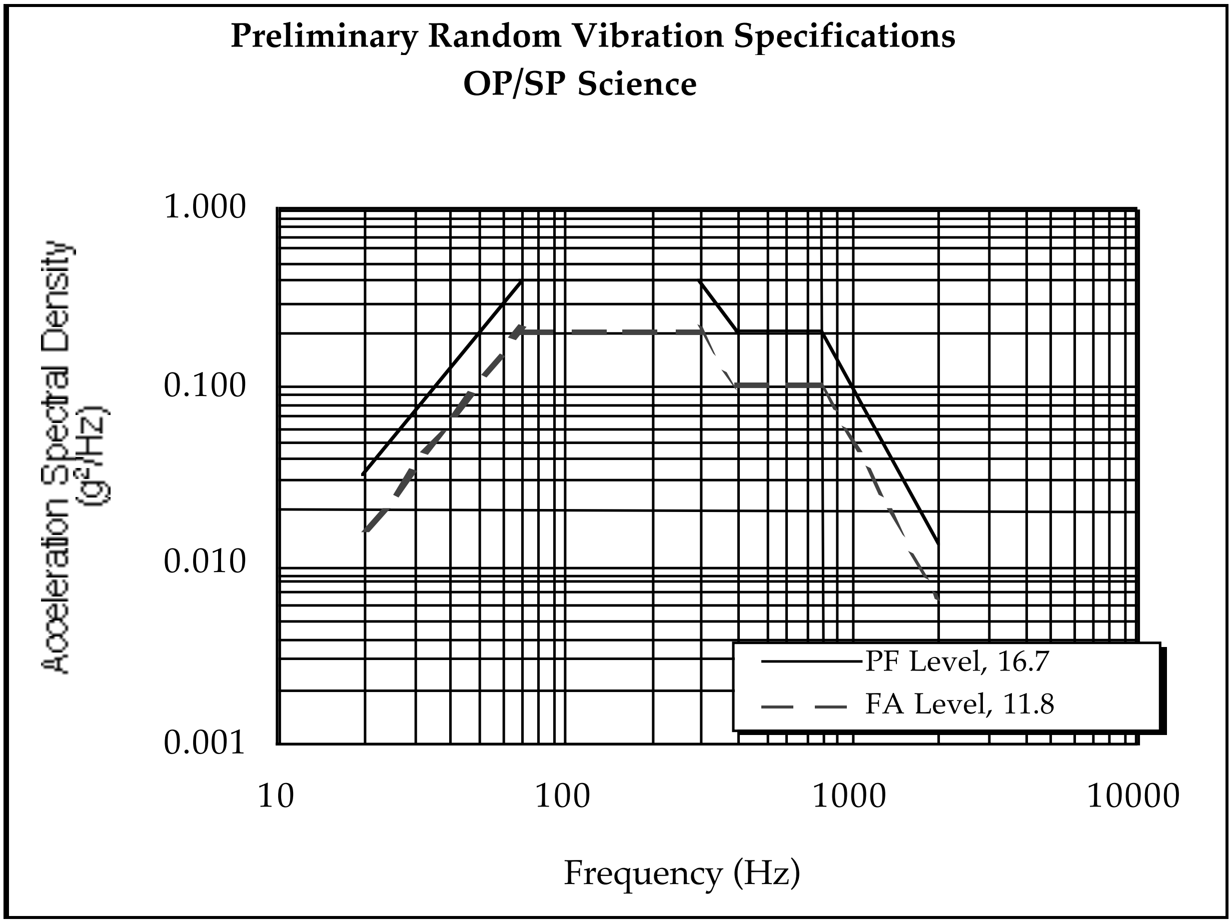


Figure 1: Random Vibration Specification

Note that this random vibration test provides an input to the S/C bus that is intended to create the same response that it will see during system level acoustic vibration testing.

1.2.3 Acoustic Vibration

The acoustic vibration environment specification is shown in Table 3 and Figure 2.

Table 3: Acoustic Vibration Specification

1/3 Octave Band Center Frequency (Hz)	Design, PF Sound Pressure Level (dB, ref. 20µ Pa))	Test Tolerances (dB)
31.5	125.0	+5, -3
40	127.0	+5, -3
50	129.5	+5, -3
63	131.0	± 3
80	131.5	± 3
100	132.5	± 3
125	133.0	± 3
160	133.0	± 3
200	134.0	± 3
250	134.5	± 3
315	135.5	± 3
400	134.5	±3
500	132.5	± 3
630	131.3	± 3
800	129.3	± 3
1000	126.4	± 3
1250	124.3	± 3
1600	123.3	± 3
2000	122.0	± 3
2500	120.7	± 3
3150	120.0	± 3
4000	118.6	± 3
5000	117.3	± 3
6300	116.8	± 3
8000	117.0	± 3
10000	118.0	± 3
Overall	144.4	± 1

Duration: 3 minutes

1.2.4 Pyroshock

The pyroshock design and test requirement for the Outer Planets/Solar Probe missions, is specified in Figure 3. Three shock pulses, with the shock response spectrum (SRS) level specified below, shall be applied at the instrument mounting interface in each of three

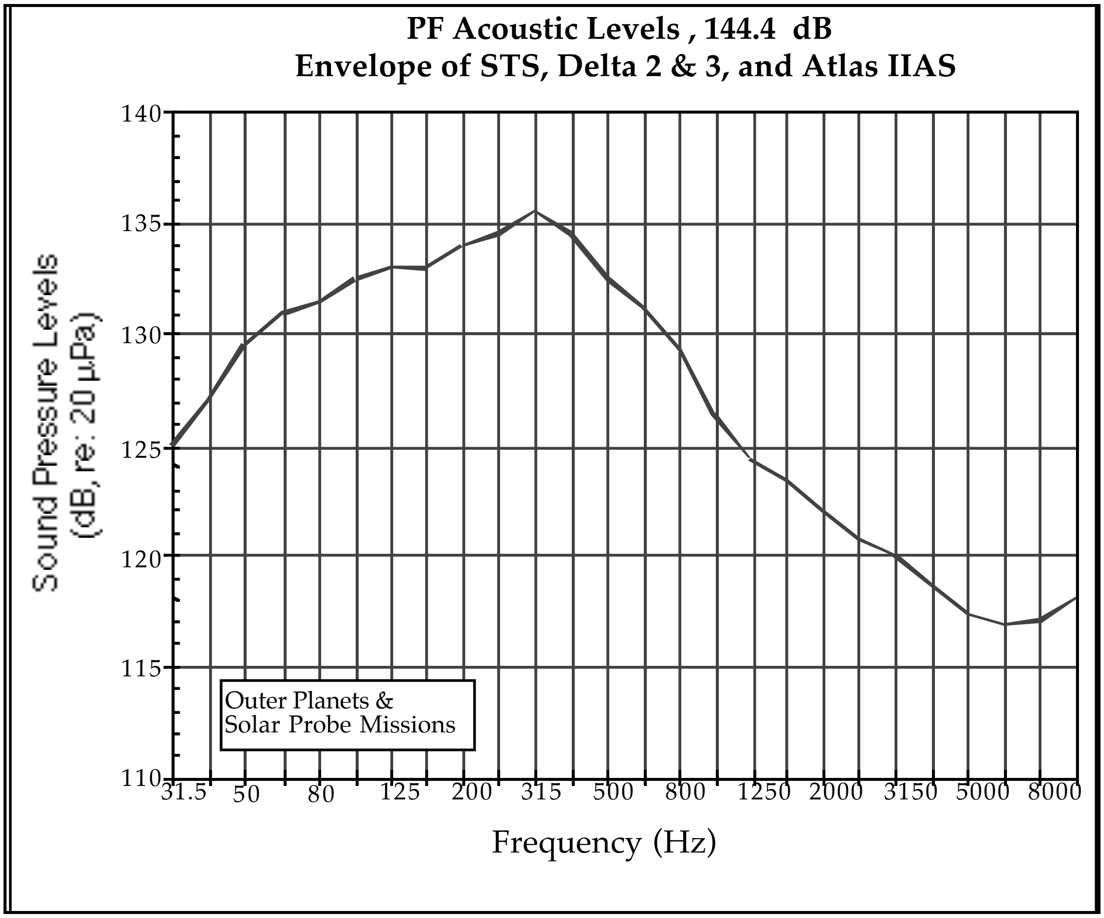


Figure 2: Acoustic Vibration Spectrum

orthogonal axes. For design purposes, the waveform of the transient defined by the SRS may be assumed to be an exponentially decaying complex sinusoid with approximately a 7-msec decay time. Pyrotechnic shock design specifications are intended to represent the structurally transmitted transients from explosive devices used to achieve various separations, including the separation from the upper stage motor.

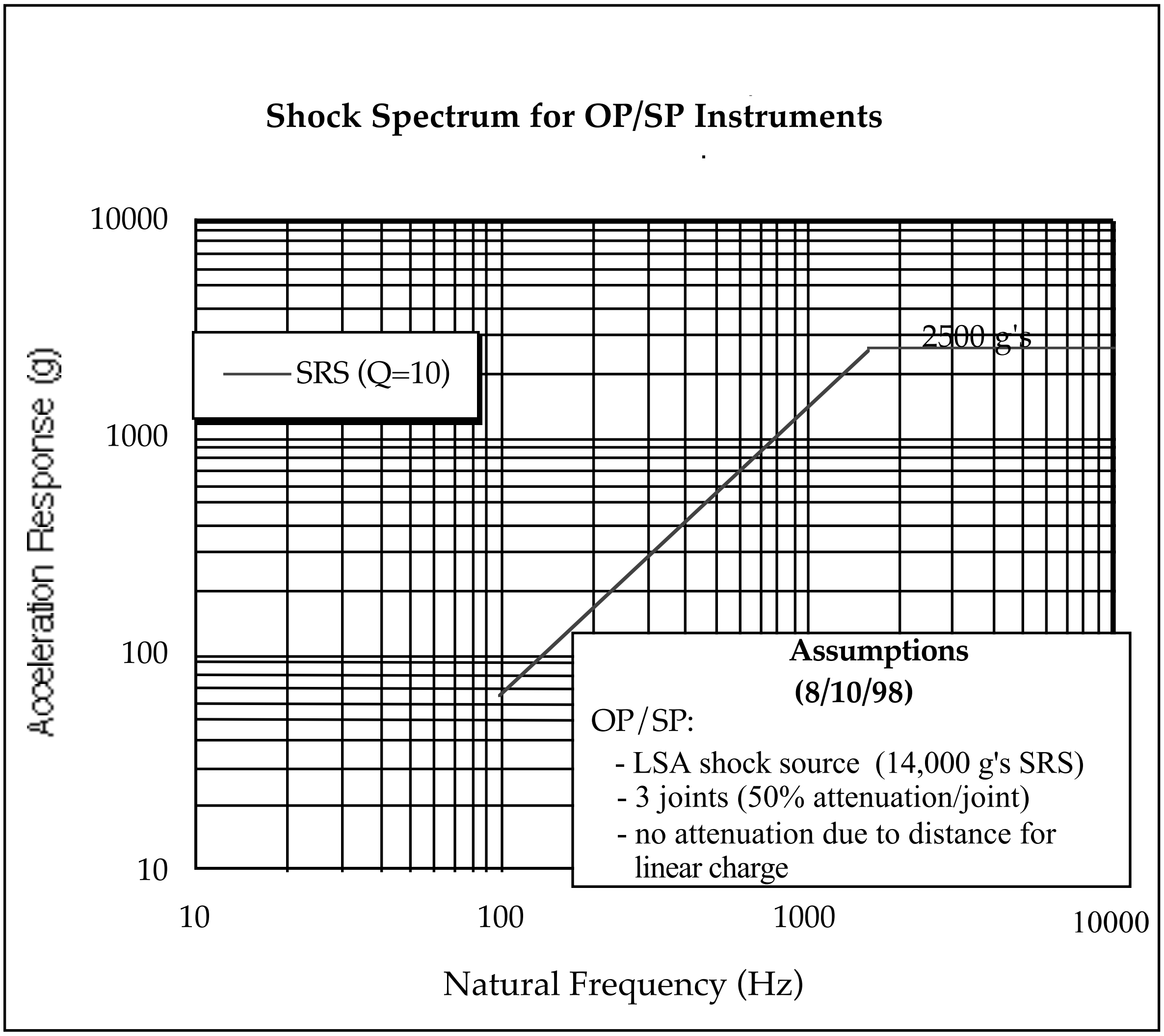


Figure 3: Shock Response Spectrum

2. Environmental Tolerances

Parameters shall not exceed the following tolerances, unless otherwise specified.

2.1 Thermal/Vacuum and Temperature/Atmosphere Test Tolerances

The thermal/vacuum and temperature/atmosphere test tolerances shall be as follows:

a. Pressure: +2 to -5 percent from atmospheric to 10 percent of atmospheric. At vacuum conditions, tolerances shall be such that a pressure of $1x10^{-5}$ torr or less is assured.
b. Time: ±15 minutes
c. Temperature: ±2°C
d. Time Rate of Temperature Change: ±10°C/hr

2.2 Electromagnetic compatibility (EMC)

All hardware shall be designed to be compatible with the requirements for electromagnetic interference presented in this section. Design and analysis of the assemblies shall be done to meet the EMC/EMI requirements that follow.

2.2.1 Emissions Limits

Conducted Emissions, Power Line Ripple - Assemblies shall not produce noise on the spacecraft DC power bus in excess of the levels depicted in Figure 4 below.

Conducted Emissions, Power Line Transients - Assemblies shall not produce transient voltage spikes on the spacecraft DC-power bus in excess of the limits specified Figure 5.

Radiated Emissions, E-Fields - Assemblies shall not radiate electric fields in excess of those described in Figure 6. Figure 6 includes the launch vehicle receiver frequency, and it should be noted that more frequencies might be added to accommodate science instruments. Note: Transmitters are exempt from this requirement at their transmit frequencies.

Radiated Emissions, Low Frequency H Fields - Low-frequency H-field emissions shall be no greater than the levels indicated in Figure 7.

Radiated Emissions, Low Frequency E Fields - Low-frequency E-field emissions shall be no greater than the levels indicated in Figure 8.

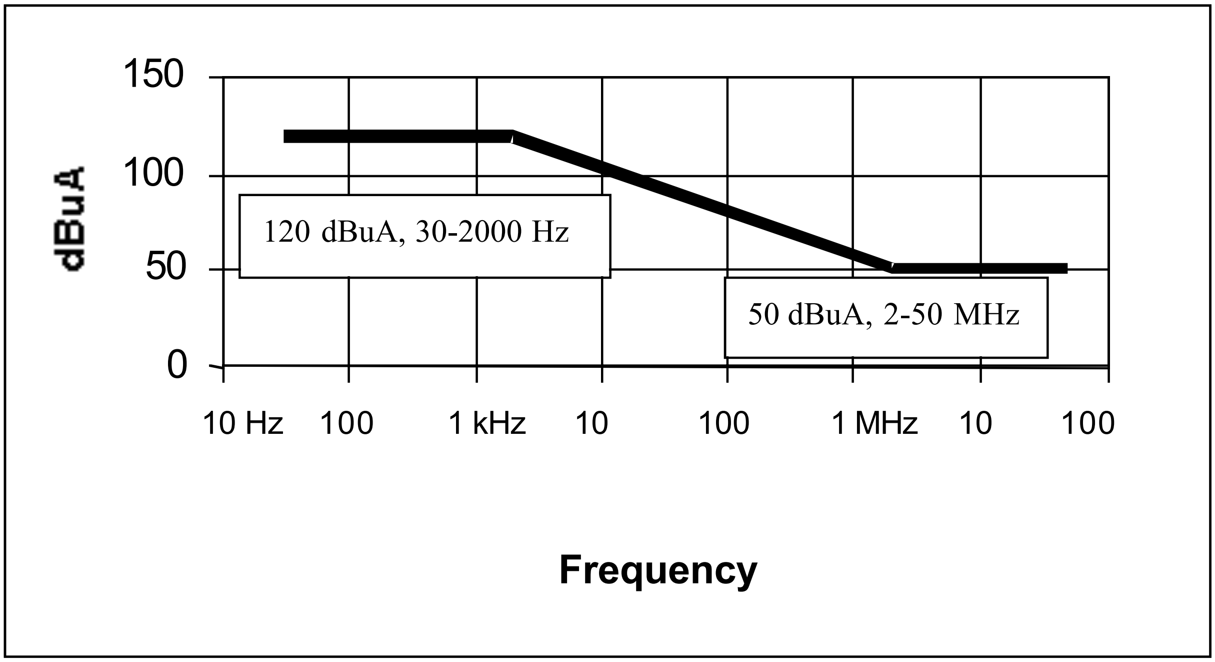


Figure 4: Conducted Emissions, Power Bus Ripple

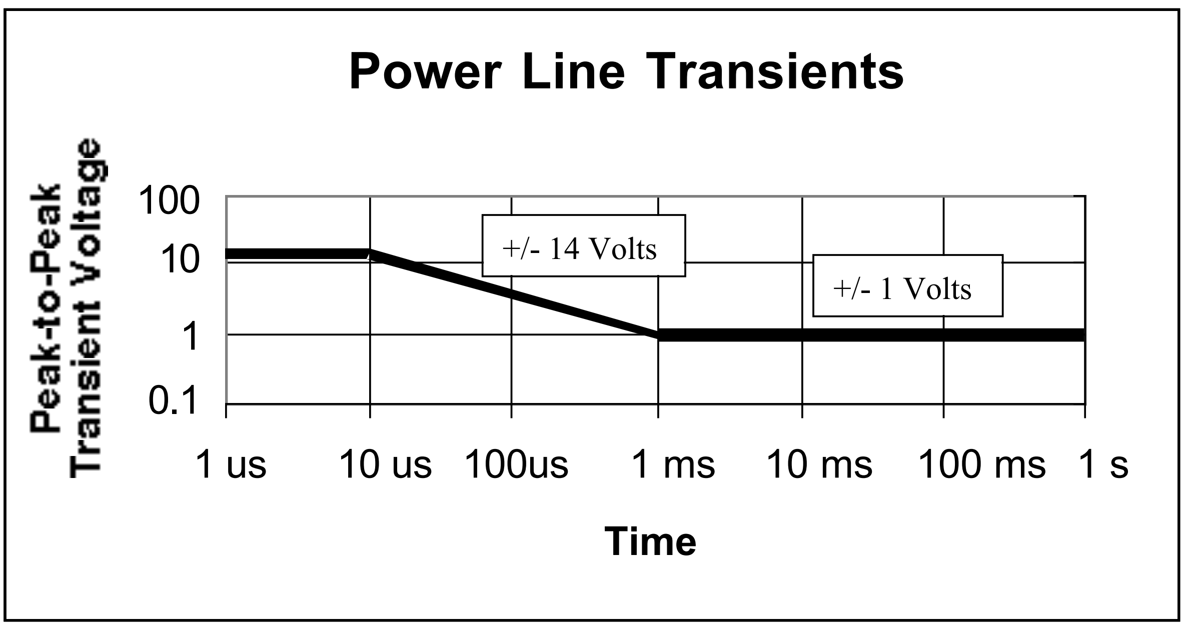


Figure 5: Conducted Emissions, Power Line Transients.

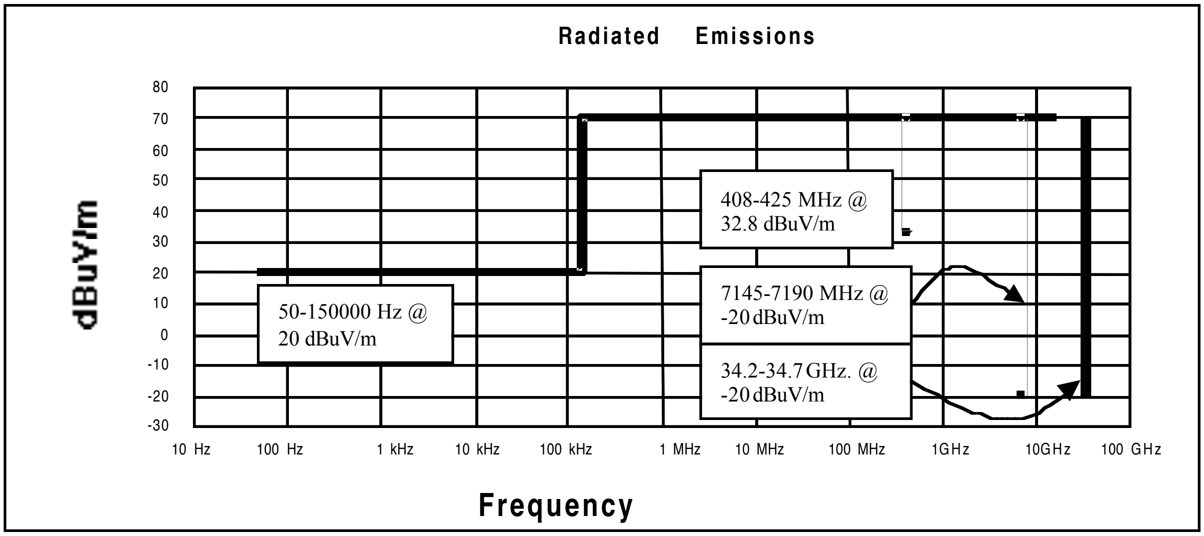


Figure 6: Radiated Emissions, E-Field.

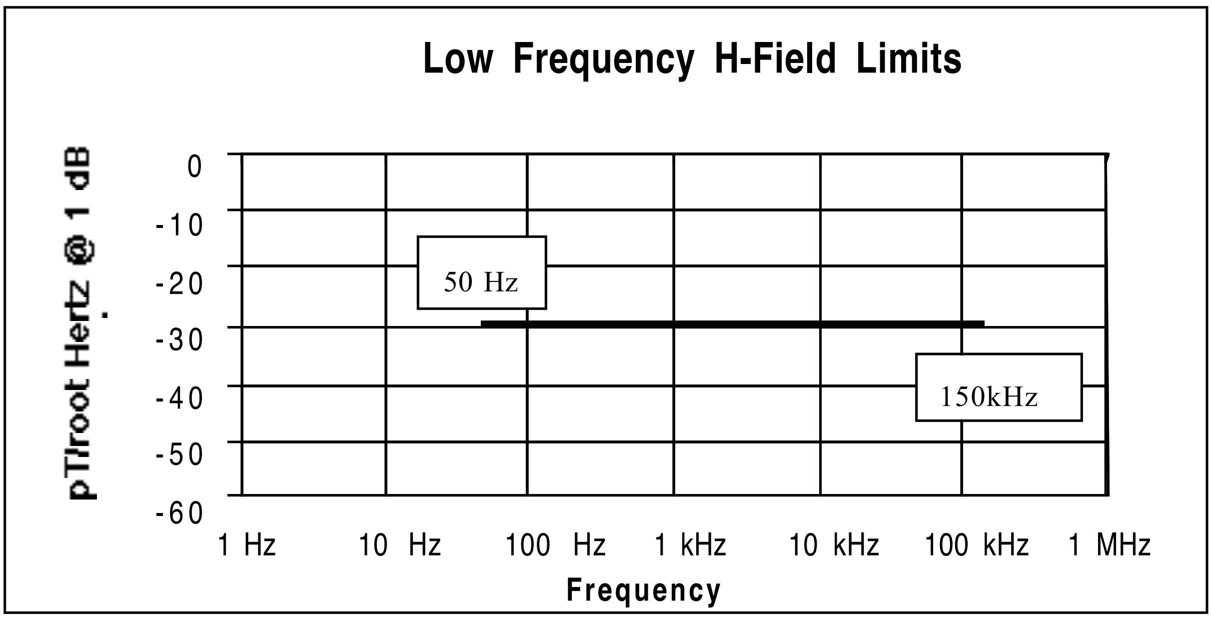


Figure 7: Radiated Emissions, Low Frequency H-field.

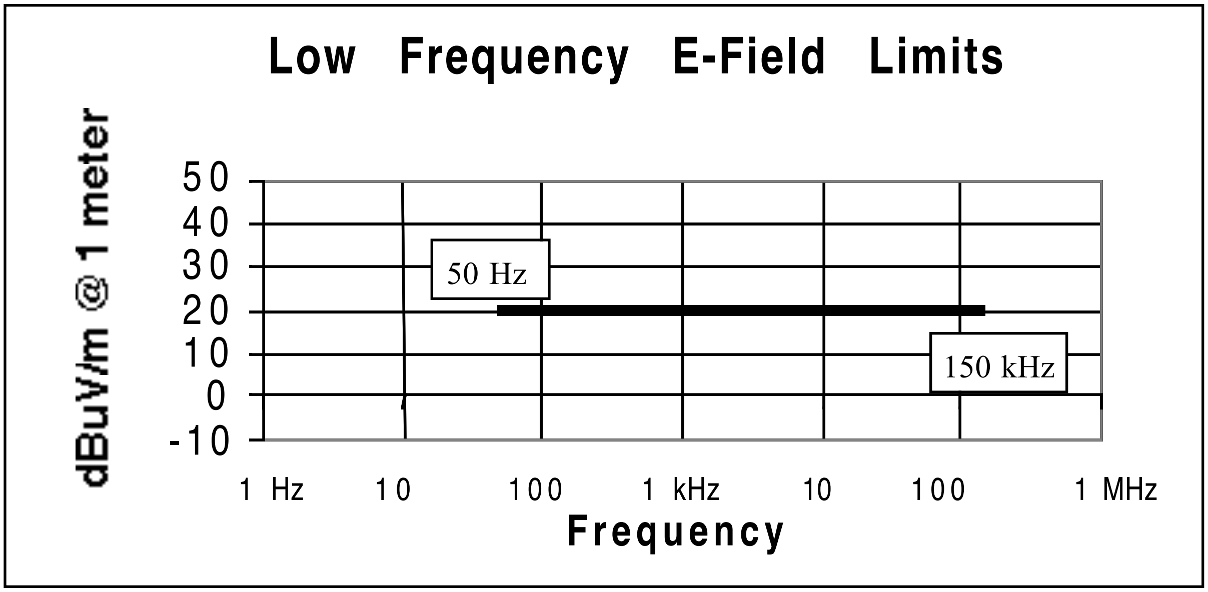


Figure 8: Radiated Emissions, Low Frequency E-field.

2.2.2 Susceptibility Limits.

Conducted Susceptibility, Power Line Differential Voltage Ripple - The assembly components connected to the power bus shall operate nominally under the following bus conditions of sine-wave voltage ripple added to any DC voltage:

- 2 V p-p with frequency 30 Hz to 2 kHz
- 2 V p-p at 2 kHz declining log-linearly to 1 V p-p at 2 MHz
- 1 V p-p with frequency 2 MHz to 50 MHz,

as shown in Figure 9.

Conducted Susceptibility. Signal Line Interface Noise Susceptibility Levels - All applications shall be able to withstand noise on signal lines in accordance with the levels of voltage and current defined in Figures 10 and 11.

Conducted Susceptibility. Power Line Differential Transient Tests - The assembly shall operate within specification when the input power leads are subjected to the power line transients illustrated in Figure 12, and as specified in Table 4.

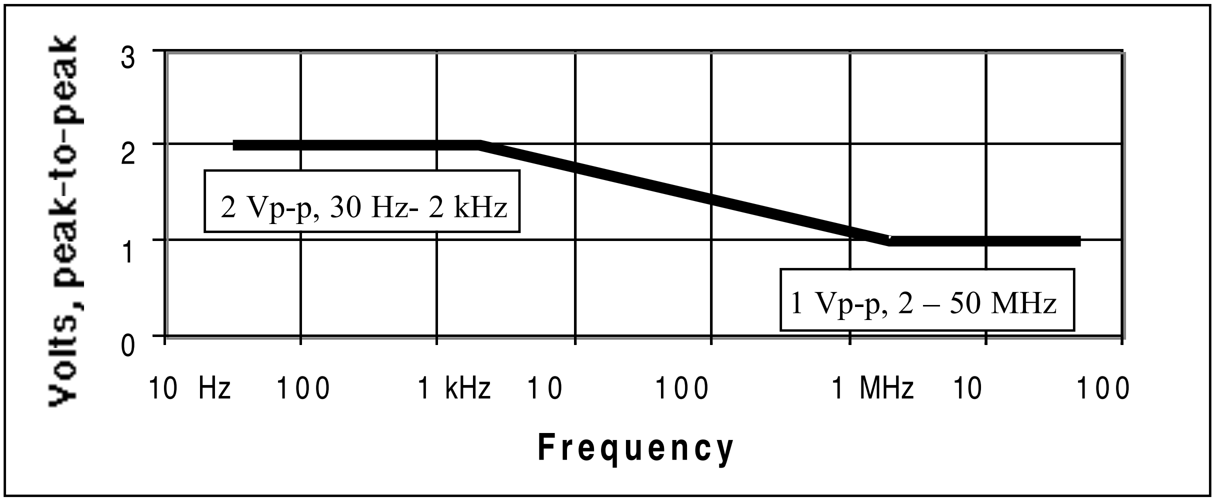


Figure 9: Conducted Susceptibility, Power Line Ripple

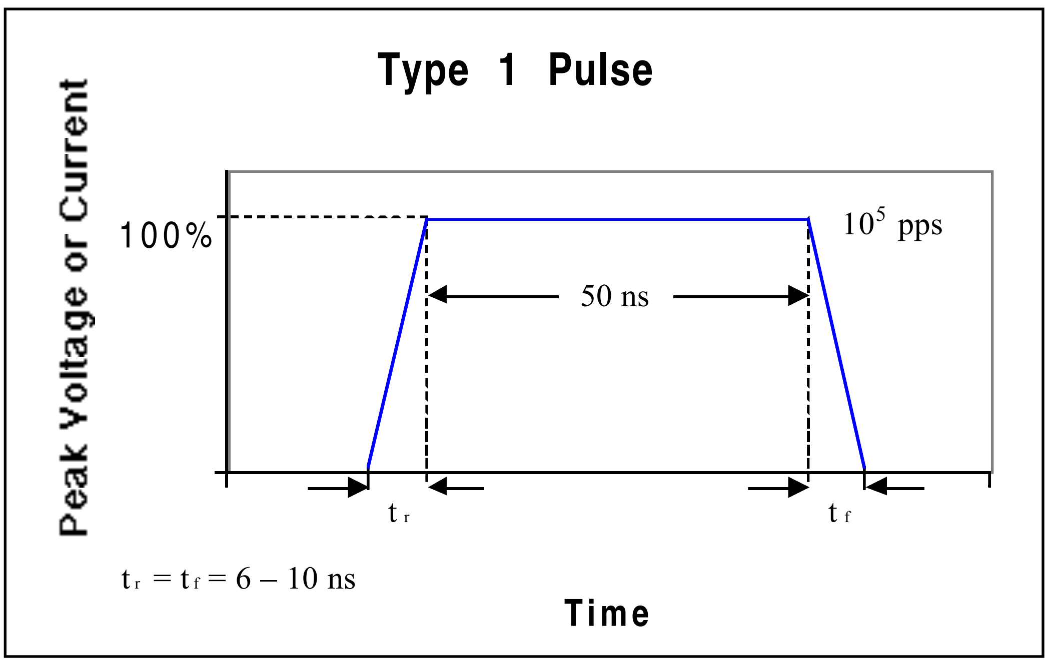


Figure 10: Signal Line Pulse 1

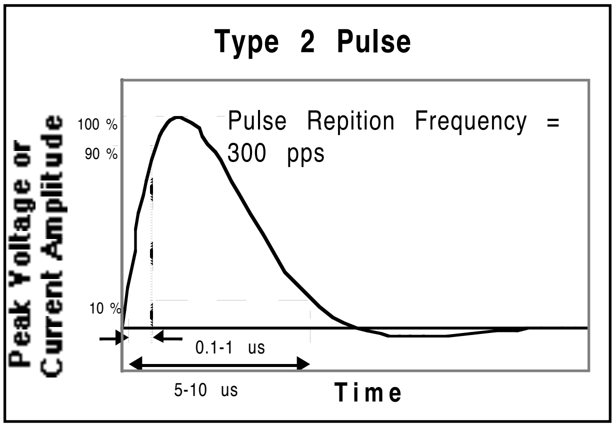


Figure 11: Signal Line Pulse 2

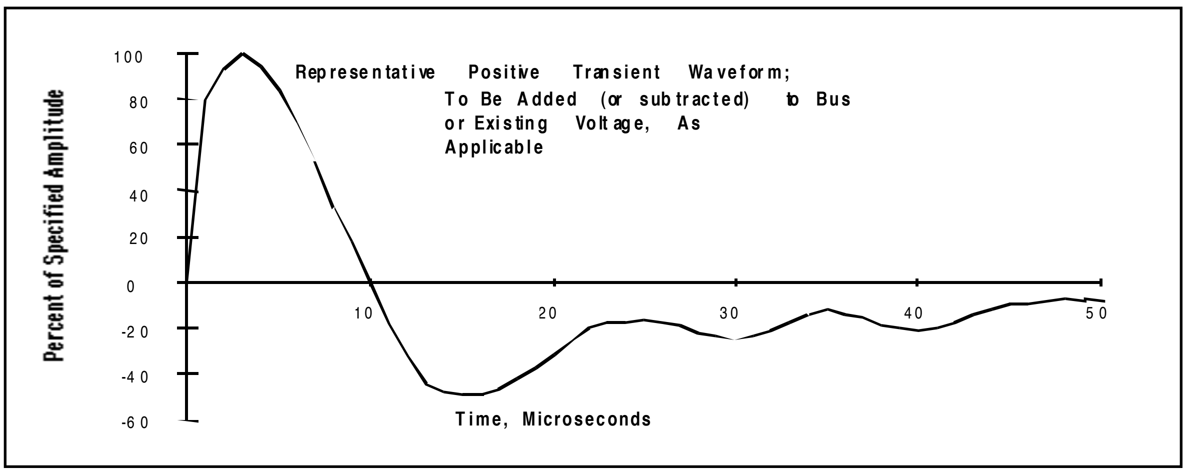


Figure 12: Voltage Transient (Representative, Positive).

Table 4: Potential Power Line Transients

Transient Polarity	DC Line Voltage	Repetition Rate	Duration
Positive Transient	+28 Volts	About 100 Hz or Less	5 Minutes
Negative Transient	-28 Volts	About 100 Hz or Less	5 Minutes

The transient shall be 28 volts, 0-p, making the maximum differential voltage 56 volts with the positive transient, and making the minimum differential voltage 0 volts with a negative transient. These transients represent the effects of bus transients caused by subsystem in-rush currents and other load step changes.

Conducted Susceptibility. Power Line Common Mode Transient Tests - The assembly shall operate within specification when the input power leads are subjected to common mode power line transients of amplitude -14 volts (negative ONLY), with waveform as shown in Figure 12. The test represents the effects of bus voltage changes caused by asymmetric switching ON of instruments with input filter capacitors, or possible fault current during pyro firing.

Radiated Susceptibility, E-Fields - The hardware shall perform within specification when subjected to the electric (E) fields defined in Figure 13 and under the stated conditions. Above 1 MHz, the applied field shall be modulated with a 1 kHz AM square wave, 100% depth as default unless otherwise specified. The applied field shall be 10 V/m from 14 kHz to 10 GHz. The larger field strengths and bandwidths are associated with range radar and launch vehicle transmitter. Science instruments, which are not powered on during launch, only have to survive exposure to the launch site radar sources. These requirements do not include any shielding provided by the L/V fairing. Note that more frequencies may be added once the S/C transmitter and radar requirements are known.

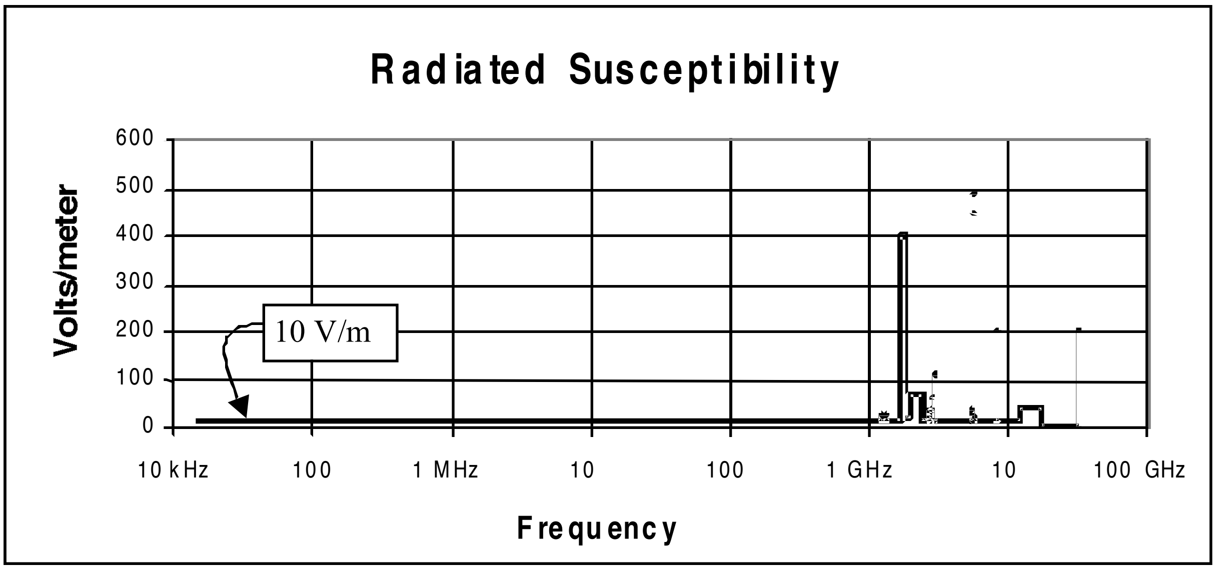


Figure 13: Radiated Susceptibility, E-Field

The I^2C bus operating at 100 kHz may act as a TBD noise source for instruments. Instrument designs that are not sensitive to such noise are advisable.

2.2.3 Electrical Isolation.

Electrical isolation of power line, command, data, and telemetry interfaces shall exceed 1 megaohm DC, and coupling capacitance shall be less than 400 picofarads for isolated interface circuits in the spacecraft, unless otherwise specified.

2.3 Electrostatic Cleanliness Requirements

In no instance shall more than 1.0 volt DC exist during flight from any exterior conductive surface to the System Reference Plane

All electronics (passive or active) shall reside within a closed metallic "box" (Faraday chamber) grounded to the System Reference Plane. This box shall form an all enclosing shield for electromagnetic fields generated by the internal equipment.

Viewing apertures (e.g., optics) shall be covered with either a grounded mesh, or a grounded conductive film such as ITO as used on optical lenses.

All internal metallic elements, including wires, unused conductors of cable, connectors, circuit board traces, spot shields, and other conductive elements greater than 3 cm^2 in surface area or longer than 25 cm, shall have a conductive path to structure with a resistance <1E8 ohms when measured in air or <1E12 ohms when measured in vacuum.

All external (exposed to space) metallic elements > 0.5 cm^2 shall have a conductive path to structure with a resistance <1E8 ohms when measured in air or <1E12 ohms when measured in vacuum.

External spacecraft non-metallic materials shall satisfy one of the following:

a. Partially conductive and in contact with a grounded substrate shall satisfy the following relation:

   $\rho t \leq 2E10$, where ρ = material resistivity in ohm-cm, and t = material thickness in cm.

b. Partially conductive surface over a dielectric and grounded at edge shall satisfy the following relation:

   $\rho h/t \leq 4E10$, where h is the greatest distance across surface from ground in cm and ρ and t are as in "a" above.

To avoid the occurrence of space charging caused ESD, which can disrupt the operation of the assemblies, each conductive layer of any thermal blankets on an instrument shall be grounded.

2.4 Corona

The test articles shall be designed to prevent corona or other forms of electrical breakdown at pressures >1.33 x 10^{-3} N/m^2 (10^{-5} torr). RF/high-voltage circuitry is subject to multipacting/arcing damage at critical pressure.

2.5 Magnetic Field Constraints

For Solar Probe and Europa Orbiter only, magnetic field requirements will be 25 nT at 1 meter. This is due to the fact that the Solar Probe mission is expected to be flying a magnetometer and Europa Orbiter may also. This requirement can be adjusted depending on the magnetometer/boom configuration. For design guidelines and general reference, see JPL D-7726 Magnetics Control Plan (CRAF/Cassini).

2.6 Shuttle Bay Cleanliness Level

The space shuttle contamination control plan is described in "Shuttle Facility/Orbiter Contamination Control Plan," Document # KVT-PL-0005. This document describes responsibilities, requirements, training, facility requirements and orbiter contamination and cleanliness control. As stated in this document, the payload bay is cleaned on a daily basis during vehicle processing when the payload bay is accessible. Prior to installation of payloads, all accessible areas in the payload bay will be inspected and cleaned to a "Standard Level" as defined by Johnson Space Center (JSC) Specification SN-C-005. This level of "Standard" visibly clean (VC) is an inspection from 5-10 feet at 50 foot candles minimum lighting, where the VC criterion is defined as the absence of all particulate and non-particulate matter visible to the normal unaided (except corrected vision) eye. This level requires precision cleaning methods, but no particle count. Particle counts are conducted on the payload bay. This is the baseline level of cleanliness that is provided by the contractor.

Historically, the VC level is equivalent to a cleanliness of Level 750B, per Mil-STD-1246C. For reference, Table 1 illustrates the particle distribution for Level 750B. These particulate cleanliness levels are log-log based. For a more exact description, refer to the original specification.

Table 1: Surface cleanliness levels (excerpted from SN-C-005, Table A.1)

Level 750	Particle size (microns)	Quantity/ft^2
	<250	unlimited
	250 - 500	205
	>500 – 750	9
	>750	0

Nonvolatile Residue (NVR) Level B: Less than 2 mg per square foot

3. Radiation Environments.

The following radiation environments are based on a proposed Advanced Radioisotope Power Source (ARPS) with five General Purpose Heat Source (GPHS) modules repackaged from a spare Cassini RTG. A potential OP/SP power subsystem has two separate units each containing nine GPHS modules ("bricks"); therefore, the flux, fluence, and dose rate data presented in this section must be scaled by a factor of 9/5, and the contributions from each unit summed for the appropriate instrument distances. The data presented are for general guidance only; if radioisotope power is utilized, the actual radiation exposure of an instrument assembly will depend upon its configuration on the spacecraft and will require a radiation transport analysis.

3.1 Total Ionizing Dose (TID) Radiation Environment

In the event that radioisotope power is selected for these missions, the TID is due to both the induced power subsystem radiation environment and the natural space radiation environment. See Paragraph 3.3 for a detailed 3-dimensional description of the "5 brick" power subsystem neutron and gamma ray environment. Figure 14 presents the primary total ionizing dose versus shielding curves for the natural space environment for the Pluto mission. Figures 15-19 give the space radiation environment data for Europa, and Figure 20 gives the Solar Probe dose vs. shielding curve. These dose curves are best estimate values with no safety margin included.

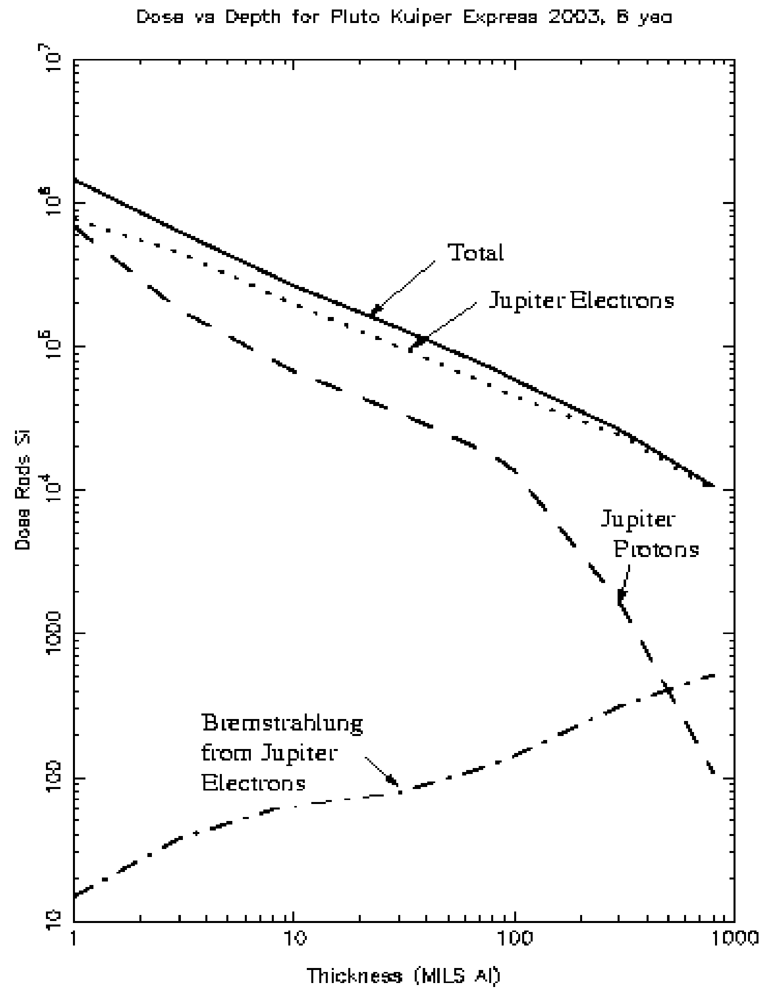


Figure 14: Total Ionizing Dose vs. Aluminum Shielding Thickness for 8-year Pluto Mission launched in November 2003.

If a material other than aluminum is used for radiation shielding, determine the aluminum-equivalent thickness, which is the material total thickness times the material-to-aluminum mass density ratio. For graphite/epoxy composite material, which has an estimated mass density of 1.55 g-cm^{-3}, a 40-mil material thickness times a mass density ratio of 1.55/2.70 would yield a radiation shielding equivalent to 23 mils of aluminum.

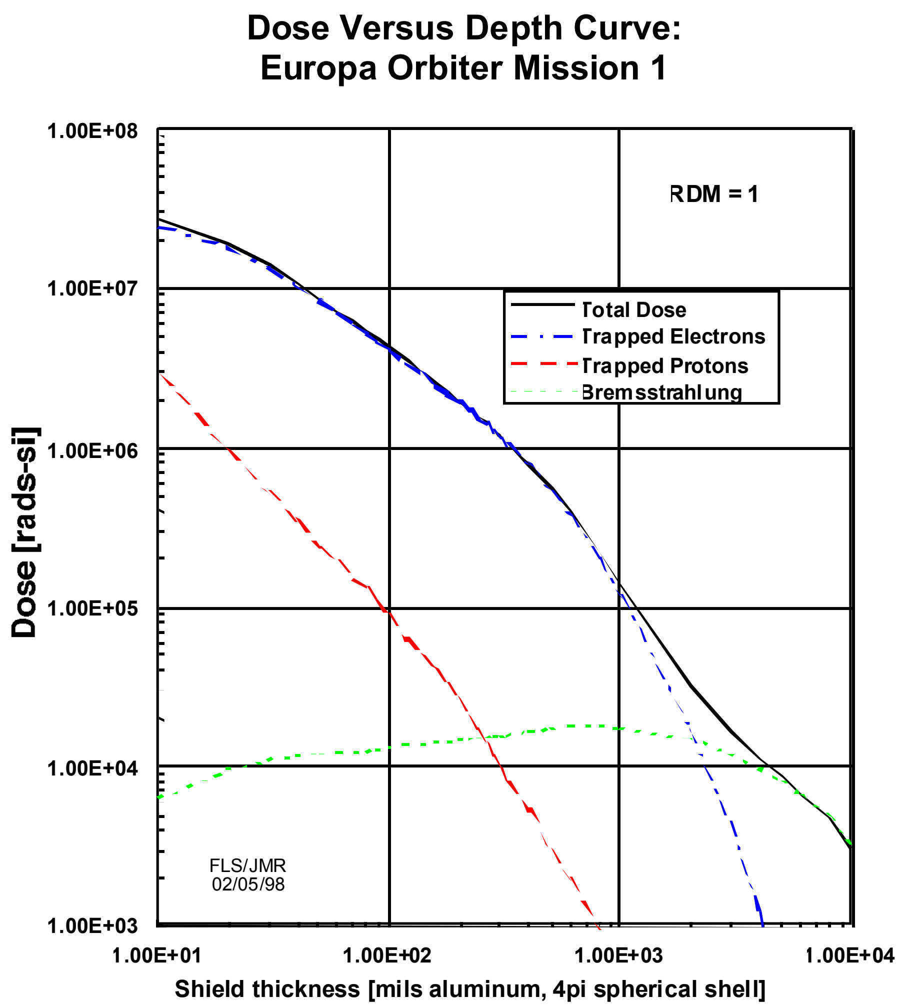


Figure 15: Total Ionizing Dose vs. Aluminum Shielding Thickness for Europa Mission.

Figures 16 - 19 show the unshielded integral mission fluence and peak flux of energetic electrons and protons incident on the Europa Orbiter spacecraft.

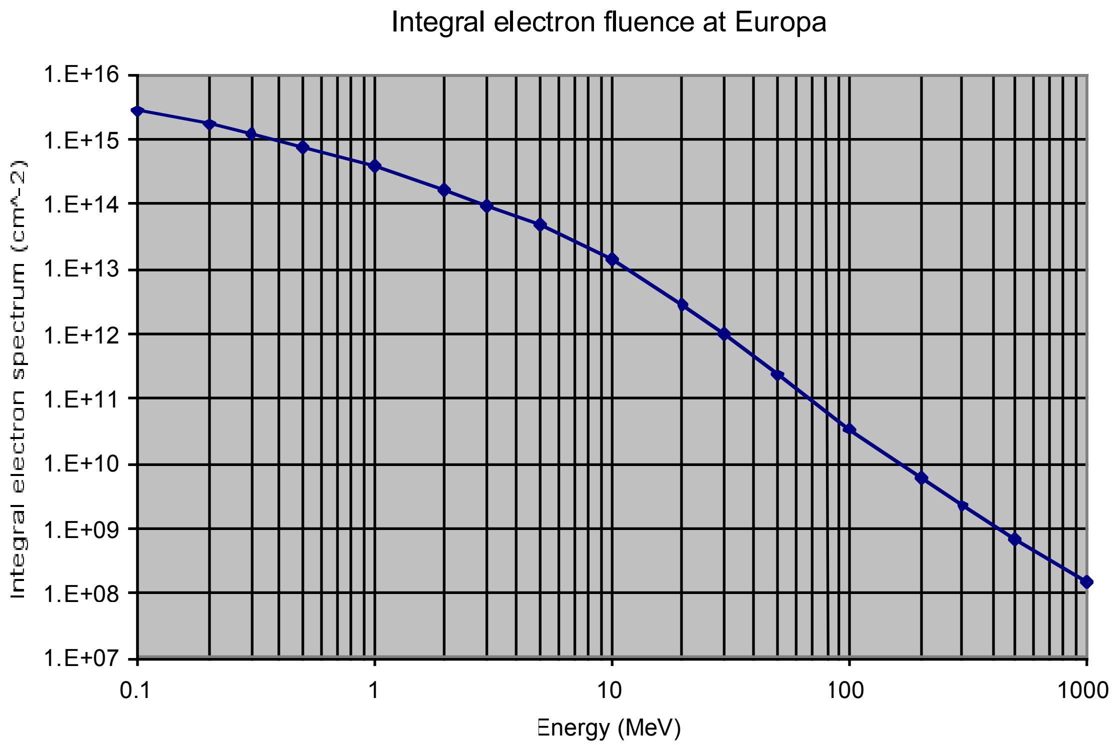


Figure 16: Unshielded integral electron fluence on the Europa Orbiter over the course of the mission

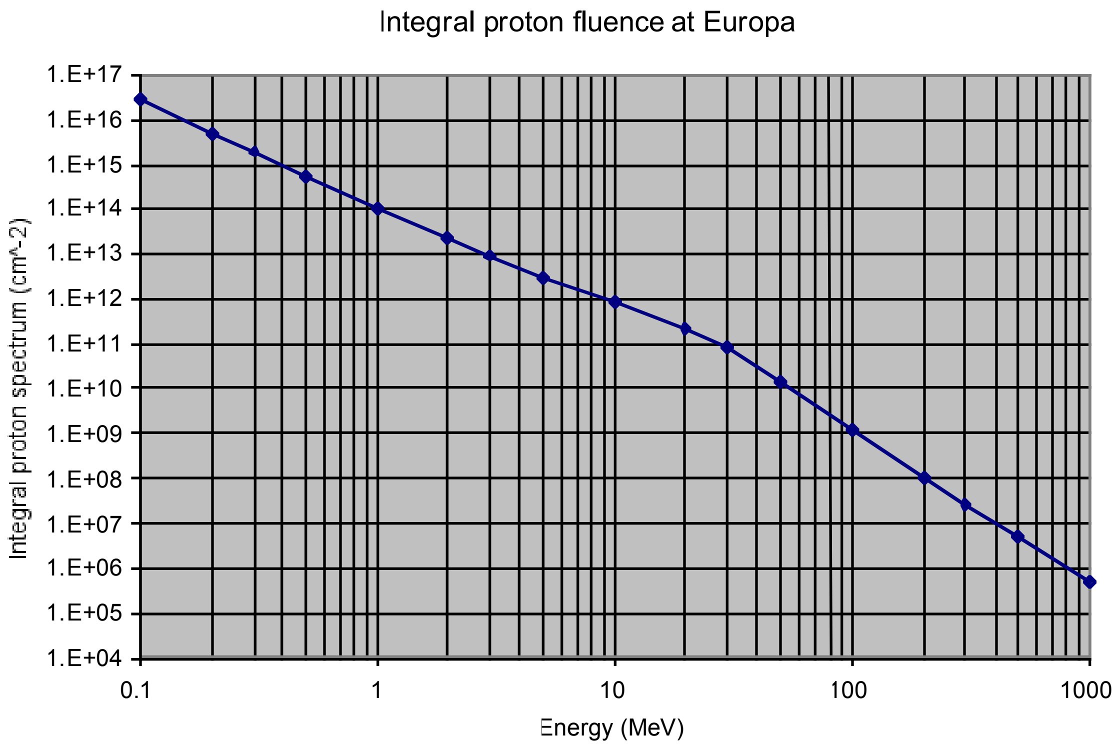


Figure 17: Unshielded integral proton fluence on the Europa Orbiter over the course of the mission

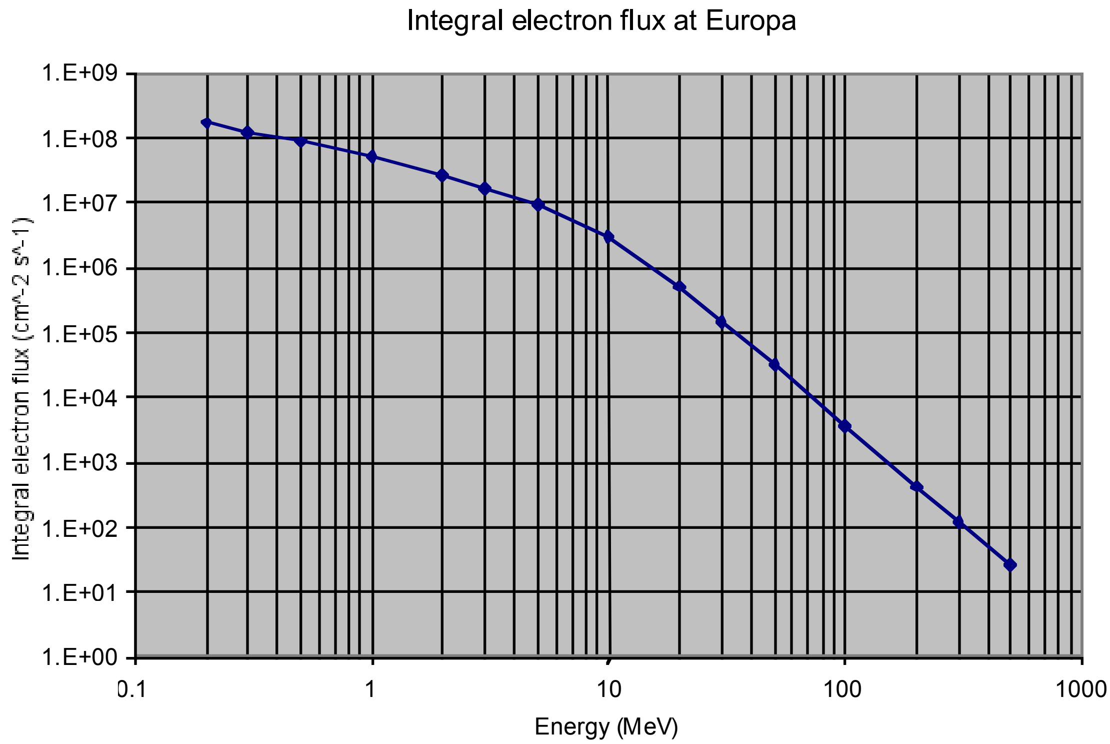


Figure 18: Unshielded integral electron flux on the Europa Orbiter at 9.4 R_J

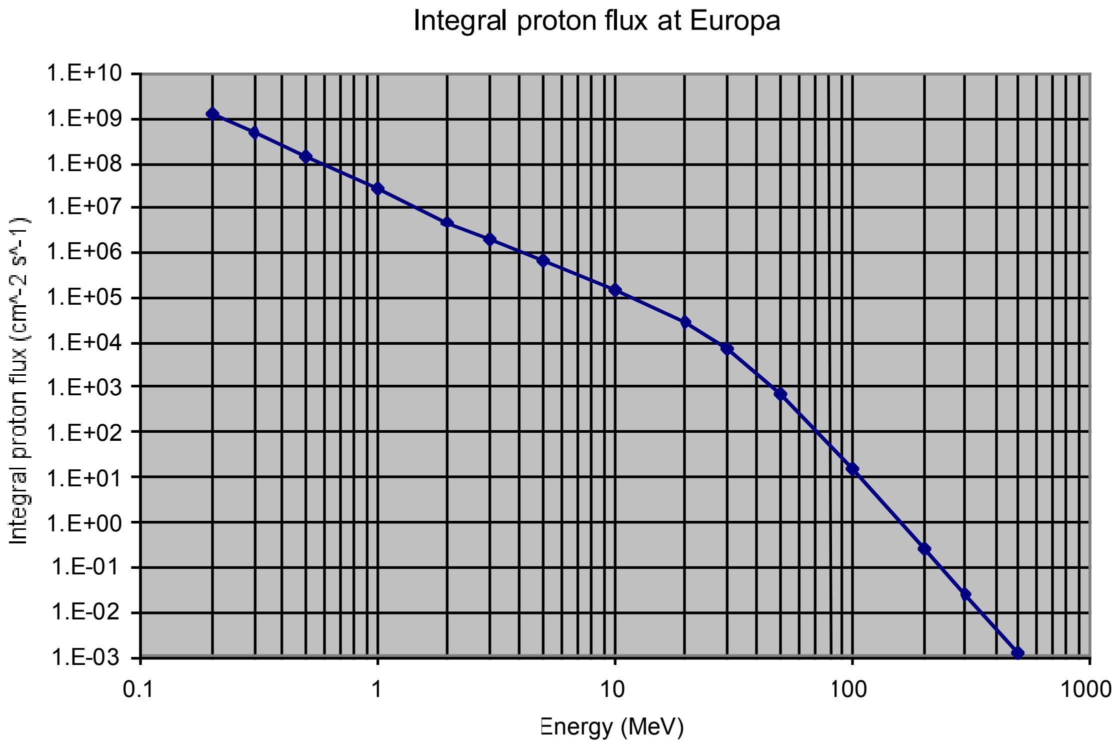


Figure 19: Unshielded integral proton flux on the Europa Orbiter at 9.4 R_J

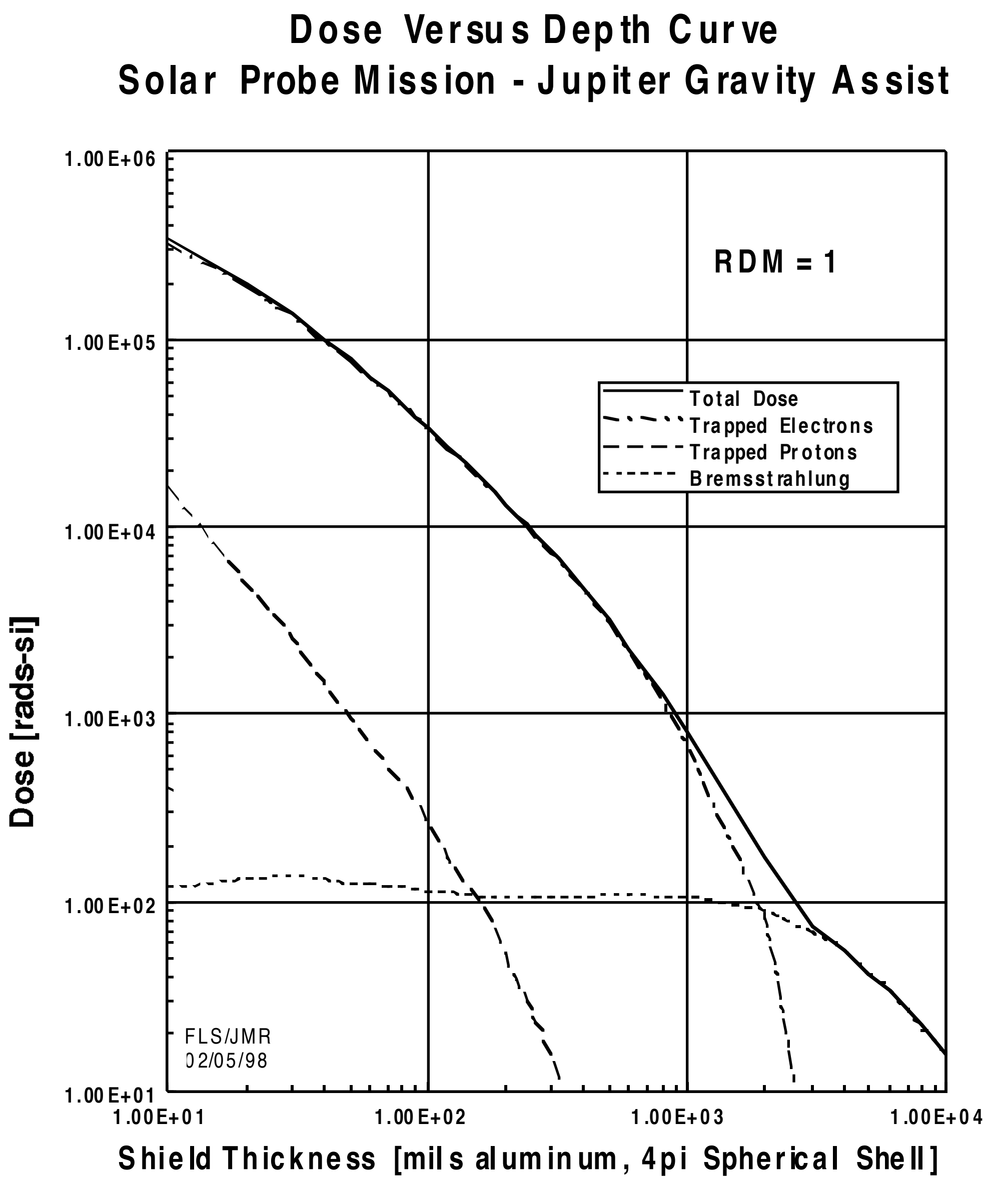


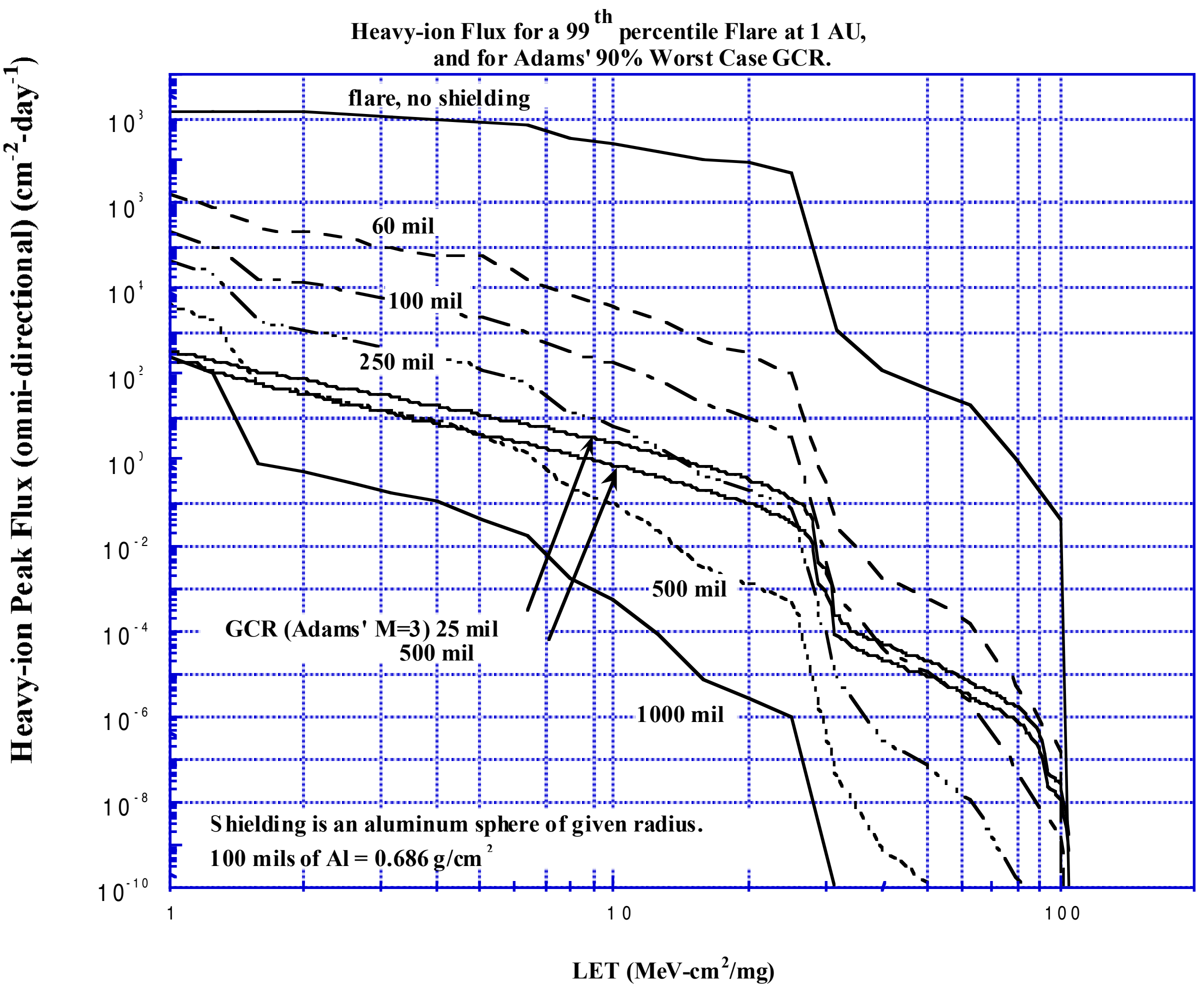
Figure 20: Total Ionizing Dose vs. Aluminum Shielding Thickness for Solar Probe Mission

3.2 Single Event Effects Radiation (SEE) Environment

Single event effects are caused by solar heavy ions and protons and by Galactic Cosmic Rays (GCRs, which are primarily heavy ions). The single event effects (e.g. single event upset and latch-up) environment is represented in Figure 21 in terms of the Heinrich Flux curves for Galactic Cosmic Rays and Solar Cosmic Rays (e.g. solar proton events). The fluxes are for a 99th percentile solar proton event at 1 AU and a 90% worst case GCR environment.

The SEE rate for a given electronic part depends upon the part sensitivity as well as the magnitude of particle flux. The part sensitivity is expressed in terms of the threshold Linear Energy Transfer (LET), which is the minimum particle LET value that can cause an SEE event. The particle flux having LET values greater than a specified threshold is described by the Heinrich Flux curves shown in Figure 21.

The SEE environment at ranges as small as 4 R_S, as anticipated for Solar Probe, is currently not known but could be more severe than that of Figure 21. Proposers should make prudent provisions to insure operation down to 4 R_S by selecting parts with ample LET margins and judicious use of spot shielding.



(Does not include effects of Jovian magnetosphere)

Figure 21: Heinrich Flux vs. LET for Solar Heavy Ion Fluxes and Galactic Cosmic Rays for a 99th percentile Solar Proton Event at 1 AU and a 90% worst case GCR Environment.

3.3 Potential Power Subsystem Neutron and Gamma Ray Flux and Dose Rate

This section provides postulated potential radiation levels for a proposed power source (e.g. ARPS). Because the mission power source is not yet firmly defined or selected, several general assumptions were necessary concerning fuel characteristics and power source configuration. Those assumptions are listed below:

1) *RTG Configuration*. The OP/SP power source radiation model is based on a scaled-down GPHS-RTG. It assumes 5 GPHS modules (or "bricks") and a shortened GPHS converter. The RTG converter normally does little to alter RTG radiation predictions. These "5 brick" results can be linearly scaled to meet the final design number. The proposed OP/SP baseline uses 2 units each with 9 bricks.

2) *Fuel Characteristics*. The fuel impurity content and age significantly effect the radiation characteristics. Given the launch date and length of the OP/SP missions, an 18-year-old gamma spectrum was used and considered reasonable.

3) *Shielding*. Power subsystem radiation is difficult to shield due to the lack of charge on the neutrons and the high energy of the gamma rays. Therefore, no shielding from spacecraft components was considered outside that provided by the power subsystem source itself.

4) *Design Margins and Factors*. No attempt was made to include design margins or other factors in these predictions. They represent best estimates in accordance with the assumptions already listed.

The neutron and gamma predictions are presented in Figures 22-25 and Tables 5 and 6. Predictions are given in both flux [particles-cm^{-2}-s^{-1}] and dose rates [rad(silicon)/hr]. Because power source radiation fields are assumed to be essentially symmetric in the radial plane, the axial plane contour plots of Figures 22 through 25 fully describe the potential radiation characteristics. All angles used in these tables are measured from the radial axis to the axial axis. Tables 5 and 6 give the energy spectra of the conceptual power source neutrons and gamma rays.

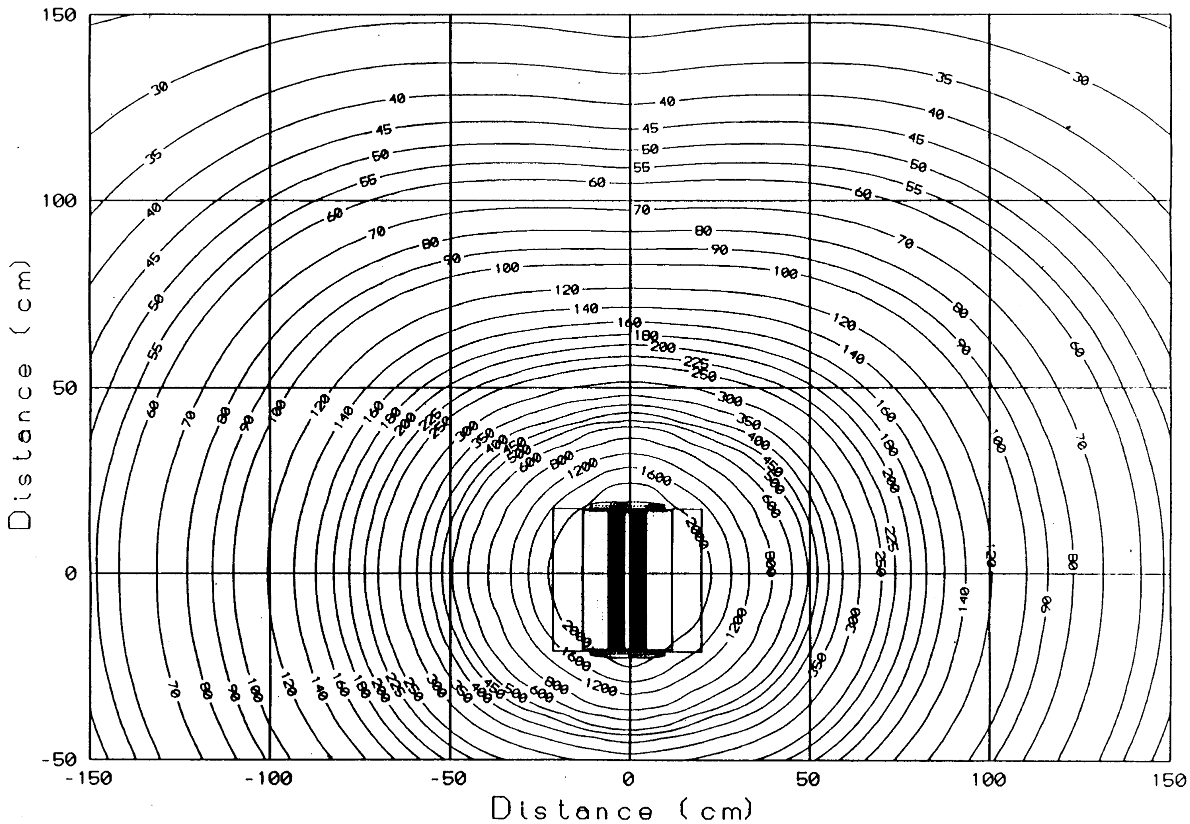


Figure 22: Neutron flux ($cm^{-2}\ s^{-1}$) contours for conceptual "5 Brick" ARPS configuration**.** (Note: Conceptual radiator "fins" shown in this diagram are not expected on the actual flight equipment)

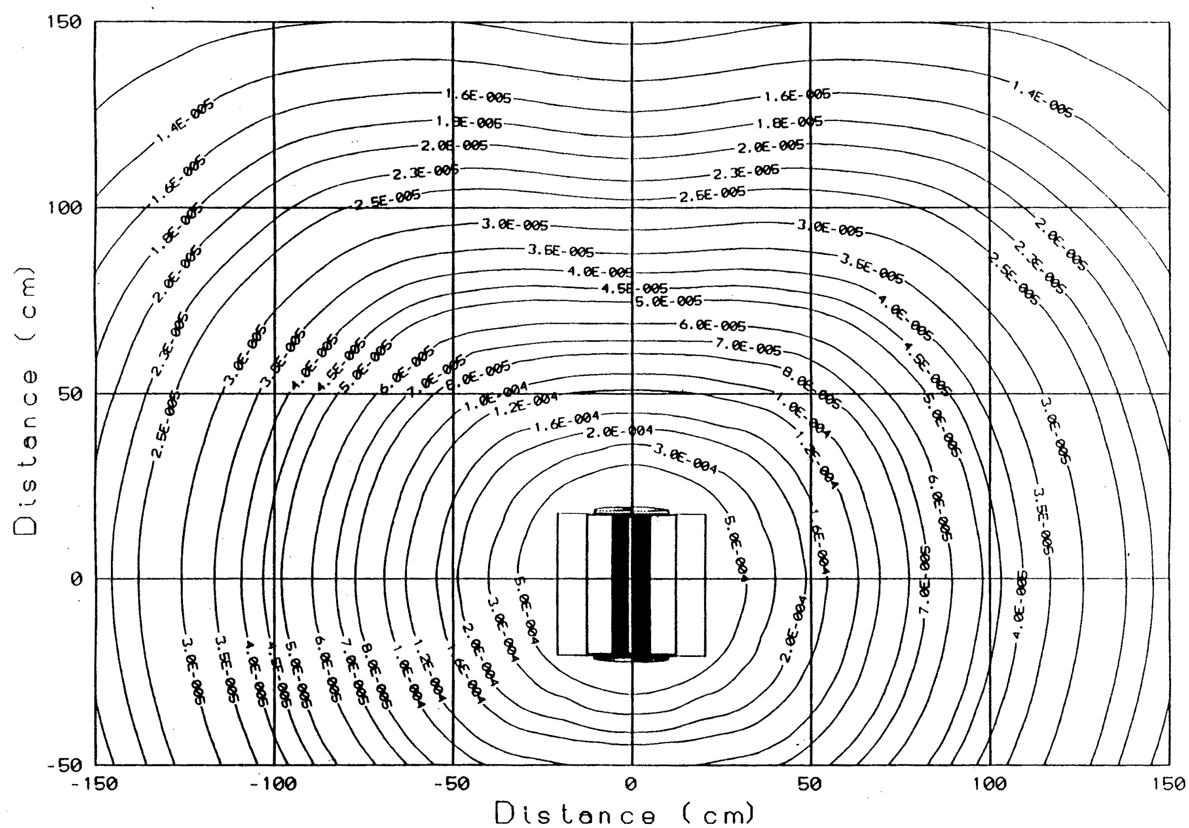


Figure 23: Neutron dosage rate (Rad [Si]/hr) contours for conceptual “5 Brick” ARPS configuration**.** (Note: Conceptual radiator “fins” shown in this diagram are not expected on the actual flight equipment)

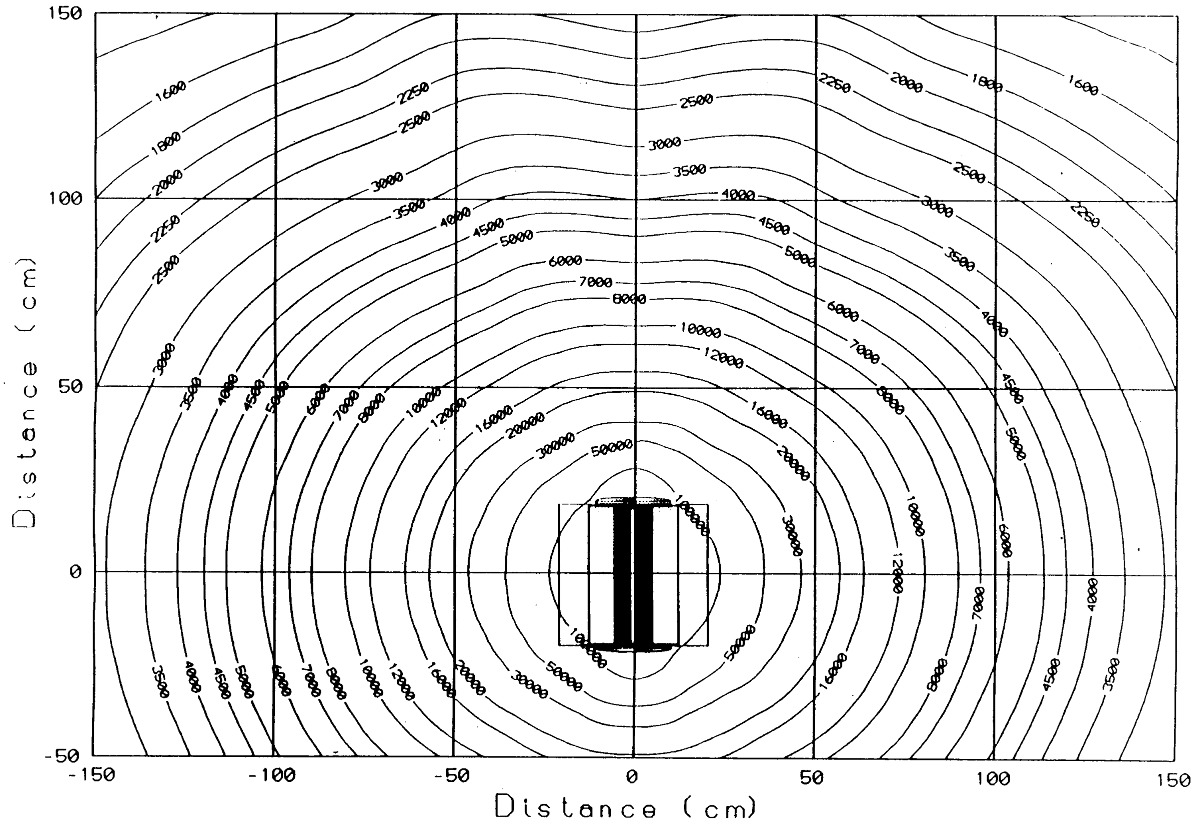


Figure 24: Gamma ray flux ($cm^{-2}s^{-1}$) contours for conceptual "5 Brick" ARPS configuration**.** (Note: Conceptual radiator "fins" shown in this diagram are not expected on the actual flight equipment)

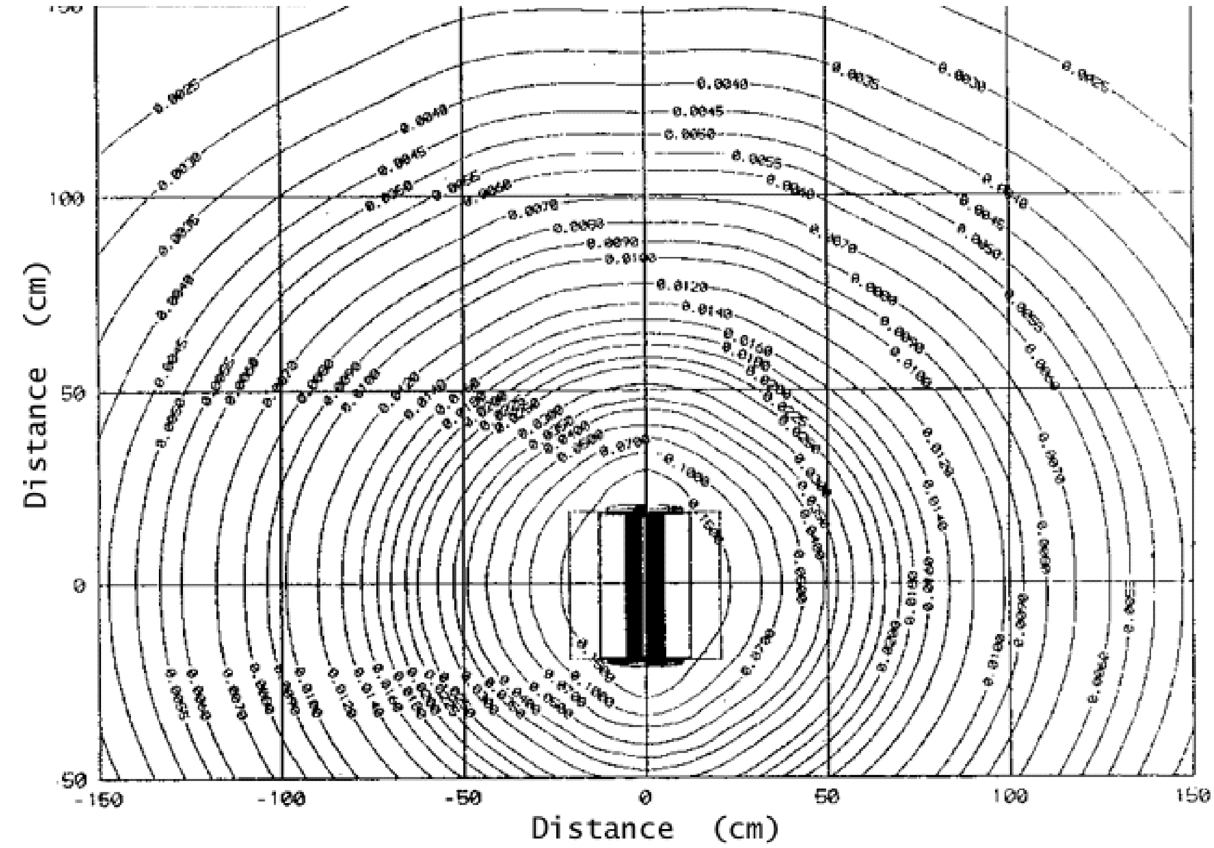


Figure 25: Gamma ray dosage rate (Rad [Si]/hr) contours for conceptual "5 Brick" ARPS configuration. (Note: Conceptual radiator "fins" shown in this diagram are not expected on the actual flight equipment)

Table 5: Normalized ARPS Neutron Flux Spectrum

	Flux	
Energy Bin (MeV)	Individual	Cumulative
0.00E–00 — 2.50E–08	1.9082E–08	1.9082E–08
2.50E–08 — 1.07E–07	2.0360E–07	2.2268E–07
1.07E–07 — 3.00E–06	5.7197E–06	5.9424E–06
3.00E–06 — 3.00E–05	1.7684E–05	2.3626E–05
3.00E–05 — 5.55E–04	3.7125E–04	3.9488E–04
5.55E–04 — 1.70E–02	1.1663E–02	1.2058E–02
1.70E–02 — 4.49E–02	1.6489E–02	2.8547E–02
4.49E–02 — 1.22E–01	4.0214E–02	6.8761E–02
1.22E–01 — 2.01E–01	3.8100E–02	1.0686E–01
2.01E–01 — 3.31E–01	5.3670E–02	1.6053E–01
3.31E–01 — 5.46E–01	7.7570E–02	2.3810E–01
5.46E–01 — 7.02E–01	5.4125E–02	2.9223E–01
7.02E–01 — 9.00E–01	6.1938E–02	3.5416E–01
9.00E–01 — 1.16E+00	7.0702E–02	4.2487E–01
1.16E+00 — 1.49E+00	8.5075E–02	5.0994E–01
1.49E+00 — 1.91E+00	9.5260E–02	6.0520E–01
1.91E+00 — 2.45E+00	1.0875E–01	7.1395E–01
2.45E+00 — 3.14E+00	1.0186E–01	8.1581E–01
3.14E+00 — 4.04E+00	8.2547E–02	8.9836E–01
4.04E+00 — 4.46E+00	3.2346E–02	9.3070E–01
4.46E+00 — 5.18E+00	4.4382E–02	9.7509E–01
5.18E+00 — 6.66E+00	1.6731E–02	9.9182E–01
6.66E+00 — 8.55E+00	6.7205E–03	9.9854E–01
8.55E+00 — 1.00E+01	1.4662E–03	1.0000E+00
Total	**1.0000E+00**	**1.0000E+00**

Table 6: Normalized ARPS Photon Flux Spectrum

	Flux	
Energy Bin	**Individual**	**Cumulative**
1.00E-03 — 5.00E-03	2.8202E-10	2.8202E-10
5.00E-03 — 1.00E-02	2.3903E-14	2.8204E-10
1.00E-02 — 1.60E-02	3.5238E-14	2.8208E-10
1.60E-02 — 1.80E-02	2.2249E-06	2.2252E-06
1.80E-02 — 2.00E-02	1.6284E-06	3.8536E-06
2.00E-02 — 3.00E-02	9.7046E-17	3.8536E-06
3.00E-02 — 4.30E-02	2.7013E-07	4.1237E-06
4.30E-02 — 4.40E-02	9.0962E-08	4.2147E-06
4.40E-02 — 5.00E-02	4.5047E-06	8.7194E-06
5.00E-02 — 5.90E-02	9.3477E-05	1.0220E-04
5.90E-02 — 6.10E-02	1.0566E-04	2.0786E-04
6.10E-02 — 8.00E-02	3.0546E-03	3.2625E-03
8.00E-02 — 9.90E-02	6.6199E-03	9.8824E-03
9.90E-02 — 1.00E-01	6.6552E-04	1.0548E-02
1.00E-01 — 1.25E-01	1.6985E-02	2.7533E-02
1.25E-01 — 1.52E-01	2.4510E-02	5.2043E-02
1.52E-01 — 1.53E-01	7.9549E-03	5.9998E-02
1.53E-01 — 1.75E-01	1.7542E-02	7.7540E-02
1.75E-01 — 2.00E-01	2.1056E-02	9.8596E-02
2.00E-01 — 2.38E-01	3.6140E-02	1.3474E-01
2.38E-01 — 2.39E-01	8.9665E-03	1.4370E-01
2.39E-01 — 2.75E-01	2.5892E-02	1.6959E-01
2.75E-01 — 3.00E-01	2.0149E-02	1.8974E-01
3.00E-01 — 3.50E-01	3.5585E-02	2.2533E-01
3.50E-01 — 4.00E-01	3.2938E-02	2.5827E-01
4.00E-01 — 5.00E-01	6.5962E-02	3.2423E-01
5.00E-01 — 5.84E-01	7.2719E-02	3.9695E-01
5.84E-01 — 5.85E-01	5.0308E-02	4.4726E-01
5.85E-01 — 7.50E-01	8.8802E-02	5.3606E-01
7.50E-01 — 1.00E+00	1.8397E-01	7.2003E-01
1.00E+00 — 1.25E+00	2.3993E-02	7.4402E-01
1.25E+00 — 1.50E+00	1.3825E-02	7.5785E-01
1.50E+00 — 1.75E+00	2.1549E-02	7.7939E-01
1.75E+00 — 2.00E+00	9.7928E-03	7.8919E-01

Table 6: Normalized ARPS Photon Flux Spectrum (continued)

	Flux	
Energy Bin	**Individual**	**Cumulative**
2.00E+00 — 2.61E+00	2.2630E-02	8.1182E-01
2.61E+00 — 2.61E+00	1.8742E-01	9.9924E-01
2.61E+00 — 3.00E+00	2.9355E-04	9.9953E-01
3.00E+00 — 4.00E+00	3.1476E-04	9.9985E-01
4.00E+00 — 5.00E+00	1.0252E-04	9.9995E-01
5.00E+00 — 6.00E+00	3.4735E-05	9.9998E-01
6.00E+00 — 7.00E+00	1.1723E-05	1.0000E+00
Total	1.0000E+00	1.0000E+00

4. Radiation Design Margins

The Radiation Design Margin (RDM) for a given electronic part (with respect to a given radiation environment) is defined as the ratio of that part's capability (with respect to the environment and circuit application) to the environment level at the part's location. It is recommended that science instrument electronics be designed to a RDM of 1.5 for Europa Orbiter and 2.0 for Pluto and Solar Probe. The selected RDM and its rationale should be included in each proposal.

5. Lifetime

Best design practices shall be used in the development of all hardware. Verification methods of operation in the mission environment for the operational life of the mission shall be established. A minimum of 400 hours of flight instrument operation is required prior to delivery for integration on the spacecraft.