Environmental Requirements Document

For The

Herschel/Planck Projects

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Herschel/Planck

Environmental Requirements Document

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1.0 INTRODUCTION

1.1. PURPOSE

This document defines the environmental design and verification requirements for the Herschel (Far InfraRed and Submillimetre Telescope)/Planck JPL-deliverables. These deliverables include: for Herschel: HIFI (Heterodyne Instrument for Herschel) amplifiers, multipliers, and mixers, SPIRE (Spectral and Photometric Imaging Receiver) detector, and the Telescope, and for Planck: HFI (High Frequency Instrument) detector, LFI (Low Frequency Instrument) designs, and the Sorption Cooler (supports HFI and LFI). Implementation of these requirements will result in Herschel/Planck JPL-deliverable hardware compliance with all mission environments, with exceptions as noted.

The following definitions are used throughout this document:

- "Should" = recommended
- "Will" = strongly recommended
- "Shall" = Required (i.e., non-compliance requires a waiver)

1.2. SCOPE

Included in this document are the Herschel/Planck expected environments and the resulting Environmental Design and Verification Requirements for hardware supplied by JPL.

1.3. APPLICABILITY

Requirements of this document apply to the Herschel/Planck hardware supplied by JPL, either supplied directly from JPL or subcontractors. Requirements herein apply to engineering models (when used for qualification purposes or a potential flight spare), qualification models, flight and flight spare hardware.

1.4. APPLICABLE DOCUMENTS

Requirements from the current version of the following documents will be met, where applicable. In the event of conflicting requirements, the requirements as specified in this ERD shall supersede requirements from the documents below: In the event of conflicting requirements between this document and an approved ETAS, the requirements in the ETAS supercedes the requirements in this document.

NASA HANDBOOKS

NASA-TP-2361 Surface Charging Avoidance

NASA HDBK 4001 Electrical Grounding Architecture for Unmanned Spacecraft

NASA-HDBK-4002 Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects

NASA-HDBK-7004 Force Limited Vibration Testing Handbook

BUSINESS AGREEMENTS

D-16870 Business Agreement concerning the Telescope between the JPL FIRST Project and ESA in Paris, France,

D-16871 Business Agreement concerning HIFI between the JPL FIRST Project and SRON in Utrecht, Netherlands,

D-16872 Business Agreement concerning SPIRE between the JPL FIRST Project and PPARC in London, UK,

D-16864	Business Agreement concerning LFI between the JPL Planck Project and ASI in Rome, Italy,
D-16865	Business Agreement concerning HFI between the JPL Planck Project and PPARC in London, UK,
D-16866	Business Agreement concerning the 20K sorption cooler between the JPL Planck Project and CNES in Paris, France,

STANDARDS

MIL-STD 461C	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
NASA-STD-7001	Payload Vibroacoustic Test Criteria
NASA-TP2361	Surface Charging Avoidance
NASA-STD-7003	Pyroshock Test Criteria
NSS-1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris

JPL PUBLICATIONS

JPL D-560	JPL Standard for Systems Safety
JPL D-19156	Herschel/Planck Contamination Control Plan
JPL D-1348 (Rev D)	JPL Standard for Electrostatic Discharge (ESD) Control
JPL D-15516	Herschel/Planck Integrated First Delivery Project Mission Assurance Plan
JPL D-15967	Herschel/Planck Integrated First Delivery Project Electromagnetic Compatibility Control Plan
JPL D-15517	Herschel/Planck Integrated First Delivery Project Safety Implementation Plan
JPL D-15992	Herschel/Planck Integrated First Delivery Project Electrical Grounding and Interfacing Requirement
JPL 900-434	Standard Environmental Testing Facilities and Practices
JPL D-12509	JPL Standard for Environmental Test
JPL-D-14040	Process & Technical Guidelines for Spacecraft HW Project-Specific Environmental Assurance
JPL D-16642	Mission Assurance Requirements for the Herschel/Planck Project
JPL D-16874	Herschel/Planck Mission Assurance Plan
JPL D-16875	Herschel/Planck Safety Plan

SCI-PT-IIDA-04624	Instrument Interface Document - Part A
PT-04040,	H. Evans Memo: esa/estec/wma/he/Herschel/3, Herschel L-2 Radiation Environment
PL-LFI-PST-SP-002	Planck SORPTION COOLER SPECIFICATION
SCI-PT- IIDB/ HFI-04141	Herschel/Planck Instrument Interface Document Part B, Instrument "HFI"
PT-HIFI-02125	Herschel/Planck Instrument Interface Document Part B, Instrument "HIFI"
SCI-PT-IIDB/ LFI-04142	Herschel/Planck Instrument Interface Document - Part B, Instrument "LFI"
SCI-PT-IIDB/	Herschel/Planck Instrument Interface Document – Part B Instrument "SPIRE"
JPL D-19162	HIFI ESD PLAN
PT-RQ-04671	Herschel Telescope Specification
JPL D-16874	JPL Herschel/Planck Configuration management Plan

JPL FORMS

JPL Form 2566	Environmental Analysis Completion Statement (EACS)
JPL Form 2683	Environmental Test Authorization & Summary (ETAS) (Appendix A)

2.0 ENVIRONMENTAL PROGRAM AND VERIFICATION REQUIREMENTS

2.1. GENERAL

The environmental design and verification program is intended to demonstrate, through design, test, and/or analyses methods, the ability of the design to successfully withstand and/or operate in the ground, transportation, storage, launch, and mission environments.

The Environmental Design Requirements and Verification Levels presented in Section 4 of this document shall be verified according to the Environmental Verification Requirements as shown in Table 2.2 below consistent with the Herschel/Planck Environmental Design and Verification Margin Requirements shown in Table 2.1 below.

2.2. VERIFICATION BY ENVIRONMENTAL TEST

Environmental testing is conducted at two levels, the Board level and the subsystem (integrated assembly with all appropriate interconnects) level. Board level testing is performed prior to delivery for higher level integration into the Engineering Model (EM Qual) or Flight Model (FM) system. Board level testing is the responsibility of the cognizant hardware engineer, contractor, or subcontractor subject to certain requirements, approvals, and reports. Elimination of a test or substitution of an analysis for a test requires approval by the JPL Project Manager using the Project deviation or waiver process contained in JPL D-16874, Herschel/Planck Configuration Management Plan.

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).

Environmental tests are categorized for the purpose of hardware quality verification as *Qualification (Qual)*, *Protoflight* (PF), and *Flight Acceptance (FA)*. Other environmental-related tests may also be performed as outlined below.

2.2.1 QUALIFICATION TESTS.

Qualification testing is performed on a dedicated Qualification (or Engineering) Model of hardware which 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.

2.2.2 PROTOFLIGHT TESTS.

Protoflight testing is performed on flight hardware for which there is no previous qualification heritage. Protoflight testing accomplishes the combined purposes of design qualification and flight acceptance.

Other than dynamic testing, the protoflight test level and duration are equivalent to the qualification test level and duration. Protoflight dynamics test levels are equivalent to qualification test levels, however, the duration is lowered to flight acceptance duration.

2.2.3 FLIGHT ACCEPTANCE TESTS.

Flight Acceptance testing is performed on flight hardware and spares only when a previous protoflight or qualification test has been performed on an identical item.

2.2.4 DEVELOPMENT TESTS

To gain insight into design compatibility or functionality in expected environments, development environmental tests may be performed on a dedicated Engineering Model (EM) to demonstrate the design adequacy and quality workmanship (e.g., a proof of concept test model of the Herschel/Planck may be assembled for the purposes of structural and thermal verification). Such testing is the responsibility of the Cognizant Engineer (CogE). While development testing is not a part of the formal environmental test program, it may have a significant impact on the program (e.g., may result in revision of test margins). Therefore, development environmental testing should be coordinated with the Project ERE. If any development test includes flight hardware, the testing shall use an approved ETAS form. If there is a possibility that engineering models could be used for qualification purposes or a potential flight spares then the testing shall use an approved ETAS form.

2.2.5 LIFE TESTING.

Life testing may be performed on selected assemblies or collections of assemblies to identify and study hardware failure modes, which are mission lifetime-related. Flight articles prone to wear out or fatigue are obvious candidates of life testing. Life testing objectives should include:

1. The influence of time and the space environment on the assembly/subsystem design integrity.
2. The support of in-flight problem diagnosis.
3. The influence of duty cycle, when applied to moving devices.
4. Test acceleration should be considered, but should be implemented only after it is deemed (or concurred) by the Environmental Requirements Engineer (ERE).
5. The collection of information indicating the nature and extent of flight hardware degradation.

Approved life tests shall be formally controlled and shall meet the formal requirements associated with the environmental test program.

2.3. TEST OF FLIGHT SPARE HARDWARE

Preferably the spare hardware should be environmentally tested well before the possible need date, to guard against schedule delays due to spare or flight units failure. Spare hardware which has been used as a qualification unit shall be evaluated upon completion of testing to determine the need for refurbishment prior to commitment of the hardware for use as flight spare hardware. Consultation with the ERE regarding hardware evaluation is encouraged. Refurbished hardware is subjected to environmental retesting to screen workmanship defects or to requalify the hardware, as appropriate. The appropriate retest is defined jointly by the Cog-E and the ERE.

2.4. OPERATING ALLOWABLE FLIGHT TEMPERATURES (AFT)

Operating Allowable Flight Temperatures (AFT) are the mission temperature limits (including allowance for prediction uncertainties) in a worst case powered-on, operational (operating within functional specifications) mode that the thermal control is designed to maintain for specified assemblies and subsystems (hot or cold). For electronic assemblies these temperatures are measured at their mounting surface.

2.5. NON-OPERATING ALLOWABLE FLIGHT TEMPERATURES (AFT)

Non-operating Allowable Flight Temperatures (AFT) are the mission temperature limits (including allowance for prediction uncertainties) in a worst case powered-off, non-operational mode that the thermal control is designed to maintain for specified assemblies and subsystems (hot or cold). For electronic assemblies these temperatures are measured at their mounting surface.

2.6. 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.

2.7. ENVIRONMENTAL ANALYSES

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

For each required analysis, an Environmental Analysis Completion Statement (EACS, JPL Form 2566) shall be prepared, typically by the hardware cognizant engineer. In lieu of an EACS, the analysis may be documented by IOM or Project Design File Memo (DFM). Approvals by the cognizant Technical Manager or Program Element Manager (PEM) and the Environmental Engineer (ERE) are required on the EACS or DFM. Additionally, since analysis results could affect other designs and environments, all EACSs for a given configuration item shall be submitted prior to environmental testing.

For the following specific design environments, a single EACS stating how the assembly design complies with these environments may be submitted:

1. Ground handling - vibration and shock
2. Ground handling - temperature
3. Ground handling - humidity
4. Explosive atmosphere
5. Launch pressure profile
6. Thermal shock

Special considerations such as humidity effects to optical mirror surfaces, or other moisture sensitive coatings are not encompassed in these documents.

2.8. REQUIRED TESTS AND ANALYSES

Table 2.1 specifies applicable environmental design and test margin requirements, whereas Table 2.2 specifies the environmental test and analysis program for Herschel/Planck.

Table 2-1 Applicable Environmental Design and Test Margin Requirements

Environment	Design	**Qual**	**PF**	**FA**
Acoustics (2) Level Duration	 MEFL + 3 dB 2 min	 MEFL + 3 dB 2 min	 MEFL + 3 dB 1 min	 MEFL 1 min
Random Vibration (2) Level Duration	 MEFL + 3 dB 2 min/axis	 MEFL + 3 dB 2 min/axis	 MEFL + 3 dB 1 min/axis	 MEFL 1 min/axis
Sine Vibration Level Duration	 1.4 x FA level 2 octaves/min	 1.4 x FA level 2 octaves/min	 1.4 x FA level 4 octaves/min	 MEFL 4 octaves/min
Pyro Shock (3) Level or Firings	1.4 x MEFL/axis or 3 firings	1.4 x MEFL/axis or 3 firings	1.4 x MEFL/axis or 1 firing	 MEFL/axis
Thermal: spacecraft bus electronics	Note (1)	Note (1)	Note (1)	Note (1)
Thermal: spacecraft mechanisms	Note (1)	Note (1)	Note (1)	Note (1)
Thermal: instrument electronics	Note (1)	Note (1)	Note (1)	Note (1)
Ionizing Radiation Design Factor (RDF)	RDF = 2 x Radiation Exposure			
EMC Susceptibility	Expected Levels + 6 dB	Expected Levels + 6 dB	Expected Levels + 6 dB	Expected Levels
EMC Emissions	Expected Levels – 6 dB	Expected Levels – 6 dB	Expected Levels – 6 dB	Expected Levels
Magnetic Susceptibility	Expected Levels + 6 dB	Expected Levels + 6 dB	Expected Levels + 6 dB	Expected Levels
Magnetic Emissions	Expected Levels – 6 dB	Expected Levels – 6 dB	Expected Levels – 6 dB	Expected Levels

MEFL = Maximum Expected Flight Level

Because the Herschel/Planck equipment operates at cryogenic temperatures, no general rules for design margins can be stated. Each part has been evaluated on an individual basis. The test temperatures are shown in Table 4-4 through Table 4-7.

1. NASA STD-7001, Payload Vibroacoustic Test Criteria
2. NASA STD-7002, Payload Test Requirements

Table 2-2 Herschel/Planck Environmental Verification Requirements

Herschel/Planck JPL Hardware - Test & Analysis Requirements

HARDWARE ITEM	Test Program Type	Static Load		Earth Handling			Dynamics				Thermal													EMC						
		Static Loads	Quasi-static acceleration	Package Drop & Trans Vibration	Humidity	Explosive Atmosphere	Acoustic	Vibration - sine	Vibration - Random	Pyro. Shock/Simulated Drop Shock	Contamination	Temp. ground handling	Thermal Shock	Launch Press Profile	Temp./ Atmosphere	Thermal Vac.	Ionizing Dose	Displacement Damage	Low Dose Rate	EUV	Single Event Effects	Solid Particles	Orbital Debris Generation	EMC Conducted susc. Note 3	EMC Radiated susc.	EMC Cond Emissions	EMC Radiated Emission	ESD Susceptibility	Magnetic	EMC Isolation
Herschel																														
Telescope (Eri Cohen)	PF	X	A	Z	Z	Z	X	X	X	X	Z	A	A	A		X	A	A	A	A	A	A	A	X	X	X	X	X	X	X
Primary Mirror (m1)	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Secondary Mirror (m2)	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Actuator Motor and Controls	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	X	X	X	X	X	X	X
Flexures	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Metering Struts "Tripod legs"	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	X	X	X	X	X	X	X
Support Structures,etc.	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
MLI, Heaters,Al Shield,etc.	PF	H	A	Z	Z	Z	H	H	H	H	A	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
HIFI (John Pearson)												A	A	A			A	A	A	A	A	A	A					A		
Development SIS Mixer	D	N	N	Z	Z	Z	N	H	H	N	Z	Z	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
Devemopment HEB Mixer (OPT*)	D	N	N	Z	Z	Z	N	H	H	N	Z	Z	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
Flt SIS Mixer Block (1 & 2)	PF	A	A	Z	Z	Z	N	C	C	X	Z	X	H	H	N	Note 1	Note4	N	Note4	Note4	Note4	H	H	H	H	H	H	Z	H	H
Flt HEB Mixer Block (1 & 2) (OPT*)	PF	A	A	Z	Z	Z	N	C	C	X	Z	X	H	H	N	Note 1	Note4	N	Note4	Note4	Note4	H	H	H	H	H	H	Z	H	H
Development Power Amps	D	N	N	Z	Z	Z	N	Z	Z	Z	Z	Z	H	H	N	Note1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
LO Power Amps (1-4) (TRW)	PF	A	A	Z	Z	Z	N	X	X	X	Z	X	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
Diodes	PF	N	N	Z	Z	Z	N	N	N	N	Z	Z	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	H	H	H
Development Band 5 LO Multiplier Chain	D	N	N	Z	Z	Z	N	H	H	N	Z	Z	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
Flt Band 5 LO Multiplier Chain	PF	A	A	Z	Z	Z	N	X	X	X	Z	X	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
Flt Band 6a LO Multiplier Chain (OPT*)	PF	A	A	Z	Z	Z	N	X	X	X	Z	X	H	H	N	Note 1	N	N	N	N	N	H	H	H	H	H	H	Z	H	H
SPIRE (Jerry Lilienthal)												A	A	A			A	A	A	A	A	A	A							
Qual Cold Electronics JFET Module	Q	A	A	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Proto Flt Cold Electronics JFET Module	PF	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Flt Spare Cold Electronics JFET Module	FA	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Qual Photometer Assembly	Q	A	A	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Flt Spare Photometer Assembly	PF	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Proto Flt Photometer Assembly	FA	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Qual Spectrometer Assembly	Q	A	A	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Proto Flt Spectrometer Assembly	PF	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
Flt Spare Spectrometer Assembly	FA	A	A	Z	Z	Z	N	X	X	N	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	X
PLANCK																														
20K Cryocooler (Al Nash) (Parker Cowgil)												A	A	A		X	A	A	A	A	A	A	A	H	H	H	H	H	H	X
Cold End																														
Flight Unit 1	PF	A	A	Z	Z	Z	H	X	X	X	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Flight Unit 2	PF	A	A	Z	Z	Z	H	X	X	X	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Piping																														
Flight Unit 1	PF	A	A	Z	Z	Z	H	H	H	H	Z	H	H	H	N	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Flight Unit 2	PF	A	A	Z	Z	Z	H	H	H	H	Z	H	H	H	N	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Compressor																														
Flight Unit 1	PF	A	A	Z	Z	Z	H	X	X	X	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Flight Unit 2	PF	A	A	Z	Z	Z	H	X	X	X	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
HFI (Jerry Lilienthal) (Jamie Bock)		A	A									A	A	A			A	A	A	A	A	A	A							
CQM Bolometer Module (Cryo Qual Model)note 2																														
Low Frequency (3 units)	PF	H	H	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
High Frequency (3 Units)	PF	H	H	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Flight Bolometer Module																														
Low Frequency (217, 143, 100 gHz)	FA\PF	H	H	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H
High Frequency (857, 545, 353 gHz)	FA\PF	H	H	Z	Z	Z	N	X	X	SD	Z	H	H	H	N	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H

PT=	Pressure Testing
SD =	Simulated Drop Shock
C=	Cold Vibration Test (4 deg K)
OPT*=	This Hardware may be built, but is not yet Approved
Z=	No Test or Analysis Required if Approved Procedures are Followed and Acceptable Environmental Conditions are Maintained
N=	Neither Test or Analysis Required
H=	Test or Analysis Req at the Higher Level of Assembly or One Analysis Performed for The Group
X=	Test Required
A=	Analysis Required
Note 1	Normal Operation is cold and in vacuum
Note 2	Cyro Qual Bolometers Will be Tested at Proto Flight Levels and Delivered for Use in the Instrument Qualification Tests
Note 3	Test in 4.9.4.1.2 and 4.9.4.1.3 will be omitted
Note 4	Need for test will be determined, Test if Necessary or No Test
	Termp. Ground Handling is thermal cycles for HIFI

3.0 ENVIRONMENTAL TEST POLICIES

3.1. GENERAL

This section establishes the implementation, control, and reporting policies for environmental testing of the JPL-responsible Herschel/Planck hardware, as derived from Document JPL-D-14040 " Process and Technical Guidelines for Spacecraft Hardware Project – Specific Environmental Assurance". These policies apply to all environmental testing at JPL or subcontractor facilities.

3.2. IMPLEMENTATION POLICIES

All flight hardware will be environmentally tested in accordance with the requirements of this document. Testing shall be done only in JPL-approved facilities in accordance with JPL 900-434. The test setup, hardware configuration, and modes of operation shall be identical for each specific test of a given assembly. The test configuration will be identical to the delivered configuration and will include electrical cabling, connectors, and other fittings associated with the assembly.

3.2.1 ASSEMBLY OPERATION/FUNCTIONAL TEST

During test, the assembly will be operated in functional modes demonstrating that the assembly performs to specification when exposed to the test environment. Operational sequences will correlate with mission modes and expected environments. The assembly will operate in logic and power states that validate the integrity of all electrical circuits and interfaces, 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 Herschel/Planck system. Functional test procedures shall ensure all electrical circuits and interfaces are adequately exercised.

3.2.2 POWER-ON

Assemblies shall be un-powered during assembly dynamic testing.

3.2.3 TEST SEQUENCE

The Qual or PF tests for an assembly shall be completed before the FA tests for the same assembly. Normally, dynamics test should proceed thermal test (in order of flight exposure). This sequence of environmental tests (i.e., acoustics, vacuum, etc.) Shall be established by the cognizant engineer and concurred by the 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 each environment on other environmental characteristics. EMC test may be conducted when convenient; however, any anticipated work due to the EMC concerns (e.g. connector backshell rework and gasket installations) shall be done prior to dynamics and thermal tests. Magnetics testing at the flight assembly level must be performed as the last step prior to delivery to bonded stores or for assembly at a higher level of integration.

3.2.4 DEVELOPMENT TESTING

Development environmental tests which include flight or flight spare hardware must be constrained to the levels and duration specified herein unless specifically approved by JPL on the ETAS form. Furthermore, such testing that includes deliverable hardware must comply with all formal environmental program, Problem/Failure Reporting, and Quality Assurance policies and requirements

3.2.5 VOLTAGE/TEMPERATURE, FREQUENCY MARGIN TESTING

If voltage/temperature, frequency margin testing (VTFMT) is to be performed in lieu of a worst case analysis for delivered hardware, concurrence of the Cognizant Engineer and Project ERE are required for the test parameters to be used, and shall be documented on the Environmental Test Authorization and Summary (ETAS) form.

VTFMT may be applied to the EM hardware for the purpose of demonstrating the robustness of the circuit and hardware design, and to use multiple stresses to accelerate key failure mechanisms.

3.3. ENVIRONMENTAL TEST PROGRAM CONTROLS

Approval of an Environmental Test Authorization and Summary is required to authorize an environmental test on qualification, protoflight, and flight hardware prior to test. Figure 3-1 illustrates this process.

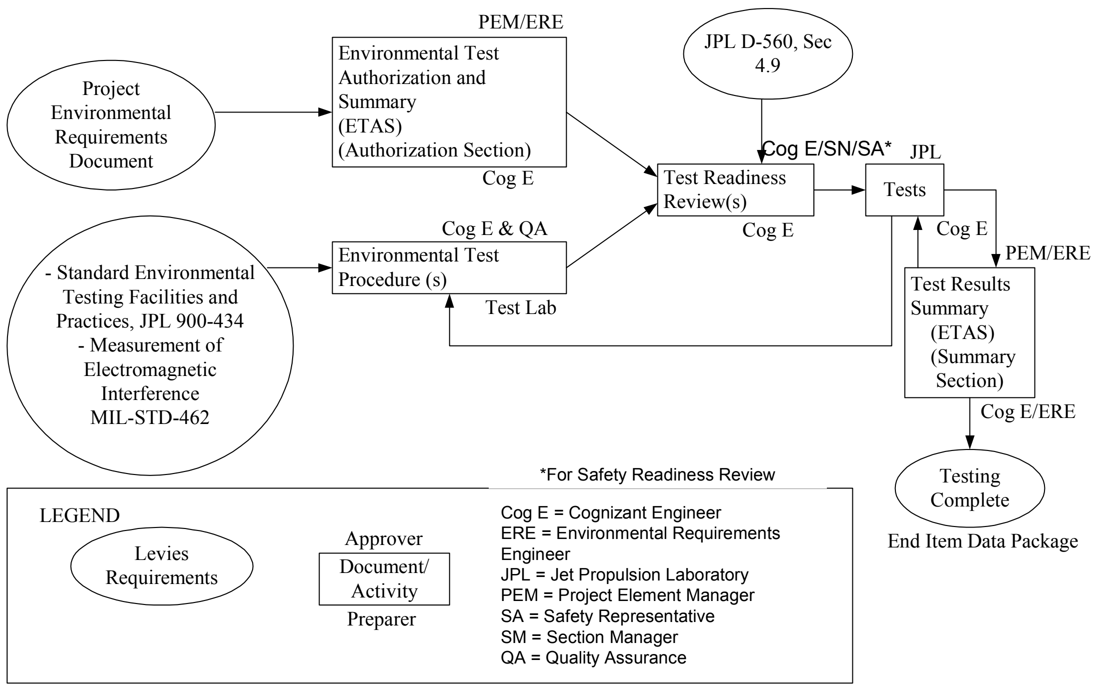


Figure 3-1 Environmental Test Program Flow

3.3.1 ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

The cognizant engineer shall use the ETAS form to convey technical instructions to the Test Agency and to summarize the tests performed. The Authorization portion of this form shall be filled out and approved by the ERE, for each serial number of the hardware prior to performing environmental testing. Attachments are used to describe any deviations from the approved project requirements, and authorizations are received to begin environmental testing. After concluding the environmental tests, an entry into the Summary portion of the form is completed. Required additional attachments include a description of any anomalies recorded during each test, along with the associated PFRs, as well as the actual test parameters used. Appendix A contains a sample ETAS form.

An approved ETAS shall take precedence over requirements specified in any other environmental document, including this document.

In addition, the Cognizant Engineer may elect to prepare a Detailed Environmental Test Specification which will require ERE approval. For contracted assemblies, contractor test specifications/plans/test reports may be submitted for ERE approval in lieu of an ETAS.

3.3.2 ENVIRONMENTAL TEST STANDARDS

The environmental test requirements stated herein meet the intent of JPL D-12509, JPL Standard for Environmental Test. Test Agencies shall perform environmental testing in accordance with JPL 900-434, Standard Environmental Testing Facilities and Practices. These minimum standards apply to test facilities at JPL, at a contractor's site, at an independent test laboratory, or other government facilities. JPL and off-laboratory test facility conformance will be reviewed and approved by JPL Environmental Test Facility Engineers, System Safety, and Quality Assurance representatives. Test standards applicable to EMC/magnetic tests are presented in MIL-STD-462.

3.3.3 ENVIRONMENTAL TEST PROCEDURES

Environmental tests of flight hardware shall be accomplished in accordance with approved Facility Environmental Test Procedures. Environmental Test Procedures are prepared by the Test Agency and approved by JPL. Assembly Environmental Test Procedures should be submitted to the hardware Cognizant Engineer for approval at least 7 days prior to scheduled test start when test is performed at JPL.

Functional test procedures for the test article may be assembly bench test procedures or procedures written specifically for the environmental test operations. These procedures require approval by the hardware Cognizant Engineer, and should be comprehensive enough to adequately characterize the assembly's performance during the environmental test. Failure criteria should be well established prior to test initiation.

3.3.4 DEVIATION FROM TEST AND ANALYSIS REQUIREMENTS

Changes and exceptions to the environmental test requirements noted on the ETAS and approved by the ERE do not require a supporting Engineering Change Notice. Revisions to the ETAS shall be submitted to the ERE for approval before beginning the test.

Approval is required from the project manager for a desired change or deviation from the formal analysis requirements contained in this document, via the Project deviation or waiver process.

3.3.5 TEST FAILURE

Failure, malfunction, or out of specification performance of an assembly or the system during formal environmental testing is interpreted as a test failure. The test may be continued, if upon review by the Cognizant Engineer continuation is of diagnostic value and will not damage the assembly. Test continuation shall be approved by the Program Element Manager and ERE or a designee. The I&T Manager or a designee shall determine whether to interrupt a system level environmental test in the event of failure or malfunction. If a destructive analysis is deemed necessary, the ERE, PEM, Mission Assurance Manager and Cognizant Engineer shall concur that no additional testing in the failed state is required before a destructive analysis is performed.

An assembly level environmental test need not be interrupted because of problems or failures associated with the test equipment if the hardware Cognizant Engineer, Test Agency Engineer and System Safety agree that the test should continue and the flight hardware safety is assured.

3.3.6 RE-TESTING REQUIREMENTS

Failure of hardware resulting from formal environmental testing shall invalidate the test. Re-testing to the prescribed environment shall be required. Furthermore, any design change, modification, or configuration change occurring after completion of testing may invalidate the test and, depending on the nature of the change, be the cause for assessment of re-test of certain selected environments. The ERE will recommend whether or not a re-test is required with inputs from the CogE, MAM and PEM, and if so which environmental test to repeat and what levels the test will use (FA, PF or Qual). Approval by the ERE of documentation for a re-test is required. The documentation can consist of an attachment to the ETAS for that particular assembly.

3.3.7 TEST ARTICLE HANDLING AND SAFETY

The handling of a test article in an environmental test facility, including attachment of any test fixture, is the responsibility of the hardware Cognizant Engineer. Environmental Test Agencies shall provide adequate protective devices on test facilities and test articles, to limit over testing. Such devices shall be functionally checked prior to each test. Hardware Cognizant Engineers are responsible for controlling all the environments their hardware experiences prior to delivery to I&T.

3.3.8 QUALITY ASSURANCE MONITORING

A Quality Assurance (QA) representative shall witness all formal assembly and system level environmental testing involving formal delivery hardware in total or in part. The QA representative must be notified by the hardware Cognizant Engineer of pending assembly and subsystem environmental tests. The QA representative, JPL or designated contractor personnel, will perform his/her duties in conformance with the Herschel/Planck Mission Assurance Plan JPL D-16874.

3.4. ENVIRONMENTAL TEST REPORTING

3.4.1 FLIGHT CERTIFICATION

All environmental testing for each assembly shall be reported as part of the Hardware Review/Certification Requirements (HR/CR) documentation package for the engineering qualification unit, and flight hardware.

3.4.2 TEST STATUS REPORT

The ERE (Environmental/Reliability Engineer) will periodically report the status of required tests and re-tests to the Project Manager.

3.4.3 TEST AGENCY REPORT

After completion of each required environmental test on an assembly or system, the Testing Agency shall prepare a Test Agency Report. This report should include the environmental levels and durations for the tested hardware, all response data, along with any changes or deviations from the approved Test Procedures.

3.4.4 ENVIRONMENTAL TEST SUMMARY

The ETAS form shall be used to report the results of tests on each serial number assembly. Attachments will be used to describe any test anomalies and any related PFRs. The completed ETAS shall be submitted to the ERE for review and appraisal within three days after completion of the environmental tests.

For contracted assemblies, contractor test reports may be submitted in lieu of an ETAS.

3.4.5 PROBLEM/FAILURE REPORT (PFR)

Failure or malfunction of a test article, test software, or test facility during environmental test shall be reported within 24 hours. Reports shall be rendered electronically on the PFR Web Site (https://problemreporting/) or via contractors failure recording system, in accordance with PFR documentation requirements of the Herschel/Planck Mission Assurance Plan, JPL D-15516. If deliverable hardware could have been impacted by an environmental test facility failure, two PFRs shall be written: one for the test article, and one for the environmental test facility. The Q/A representative shall be informed of the initiation of PFRs by the Cognizant Engineer.

3.4.6 PASS/FAIL CRITERIA

All test-related PFRs for a specific environment shall be listed on the ETAS. The probable disposition of test-related PFRs shall be known prior to a test pass/fail determination.

The Cognizant Engineer shall present the pass/fail position to the ERE for Project approval. As a part of this review/approval, any re-testing requirements will be identified. The process should be completed prior to hardware delivery for next-level integration.

4.0 ENVIRONMENTAL DESIGN REQUIREMENTS AND VERIFICATION TEST LEVELS

4.1. GENERAL

The environmental requirements contained within this section are established to assure design compatibility of the Herschel/Planck hardware with the specified environments and corresponding mission modes. In general, the design requirements are the same as the qualification test requirements. Any deviation from this rule will be included in this document, as the definition of the assemblies and the specific technologies used are further identified.

4.2. HANDLING AND GROUND OPERATION ENVIRONMENTS

The ground operations and handling environmental design requirements encompass the environments that the flight hardware will 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 HANDLING AND TRANSPORTATION VIBRATION

Shipping containers and transportation procedures for the flight hardware shall be designed so that transportation vibration, acceleration, and shock environments are less severe than launch phase environments specified herein.

4.2.2 HANDLING, TRANSPORTATION AND STORAGE: THERMAL, PRESSURE, AND RELATIVE HUMIDITY ENVIRONMENT

The thermal environment, relative humidity, and pressure experienced by the flight hardware shall not exceed Levels listed in Table 4-1.

Table 4-1 Thermal Environment for Handling, Transportation, and Storage

Control Parameter	Low Limit	High Limit
Temperature Temperature Change Rate Pressure Relative Humidity	+5°C -5°C/h 6.9×10^4 N/m^2 (520 torr) ≥30% (2)	+45°C (1) +5°C/h 1×10^5 N/m^2 (760 torr) ≤70%

NOTES:
(1) 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 Protoflight test level is not exceeded.
(2) Could be as low as 0% relative humidity during shipping or storage.
(3) HEB will require N2 Purge

4.2.3 MAGNETIC FIELD CONTRAINTS

No Magnetic field requirements.

4.3. LAUNCH ENVIRONMENT COMPATIBILITY

Herschel/Planck JPL deliverables shall be compatible with the thermal and dynamic requirements of the Ariane V Launch Vehicle.

4.4. ATMOSPHERIC ENVIRONMENT

4.4.1 EXPLOSIVE ATMOSPHERE

The assemblies shall be designed to operate without igniting an explosive atmosphere within the pressure and temperature ranges and the minimum auto-ignition temperature specified in Table 4-2.

Table 4-2 Range of Explosive Atmosphere Physical Characteristics

Explosive Atmosphere Physical Characteristics	Range
Pressure	1.32×10^4 N/m^2 (1.32×10^1 kPa or 100 torr) to 1.06×10^5 N/m^2 (1.06×10^2 kPa or 800 torr)
Atmospheric Temperature	5 to 45°C
Surface Minimum Auto-ignition Temperature	216°C (80% Auto-ignition temp of Hydrazine at STP)
Chemical Constituents	Hydrazine, Hydrogen (reference fuels) and air (oxidizer) combined in any potentially explosive ratio.

4.4.2 LAUNCH PRESSURE PROFILE

Herschel/Planck assemblies shall be designed for the launch pressure reduction profile of the Ariane V launch vehicle as specified in the latest issue of "Ariane V User's Manual" Dated March 2000 Issue 3. The design for the launch pressure profile shall be verified by a venting analysis of the Herschel/Planck JPL deliverables as appropriate. The design factor of safety for this analysis shall be 2.
Ariane V launch vehicle pressure requirements during launch are that: the assemblies shall be designed to withstand a maximum atmospheric pressure decay rate profile shown in Figure 4-1

Figure 4-1 Ariane V launch Pressure Profile.

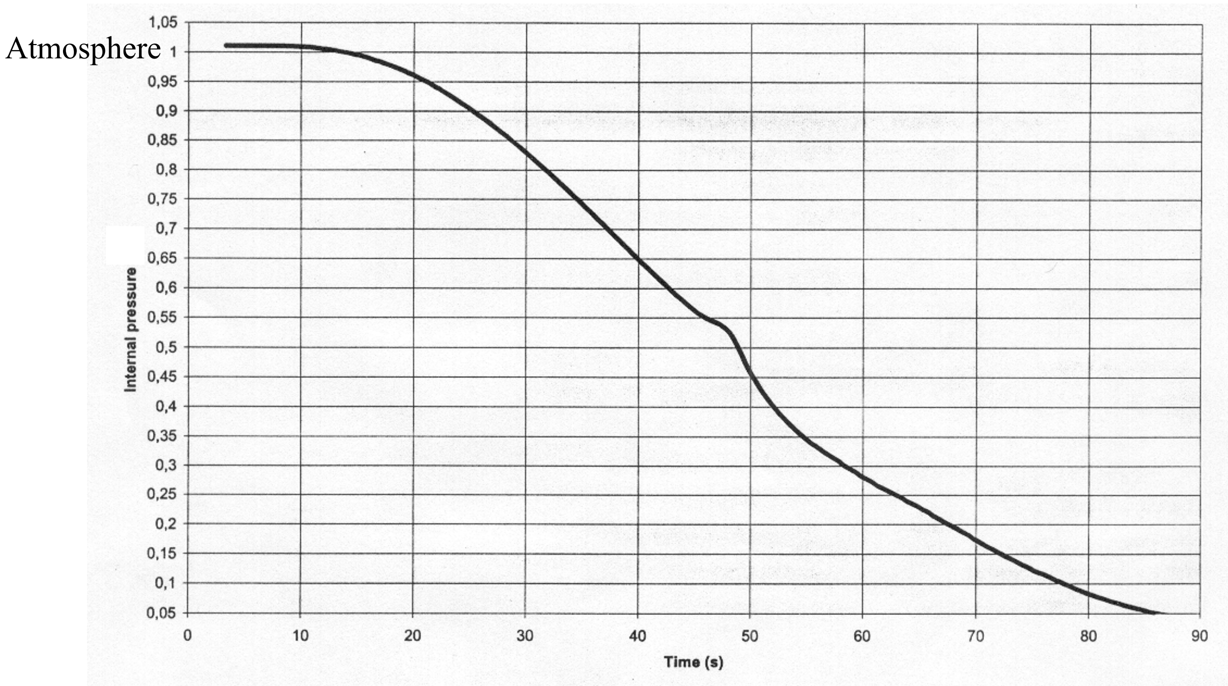


Figure 4-2 Ariane V Versions G and ES Launch Heat Flux Profile

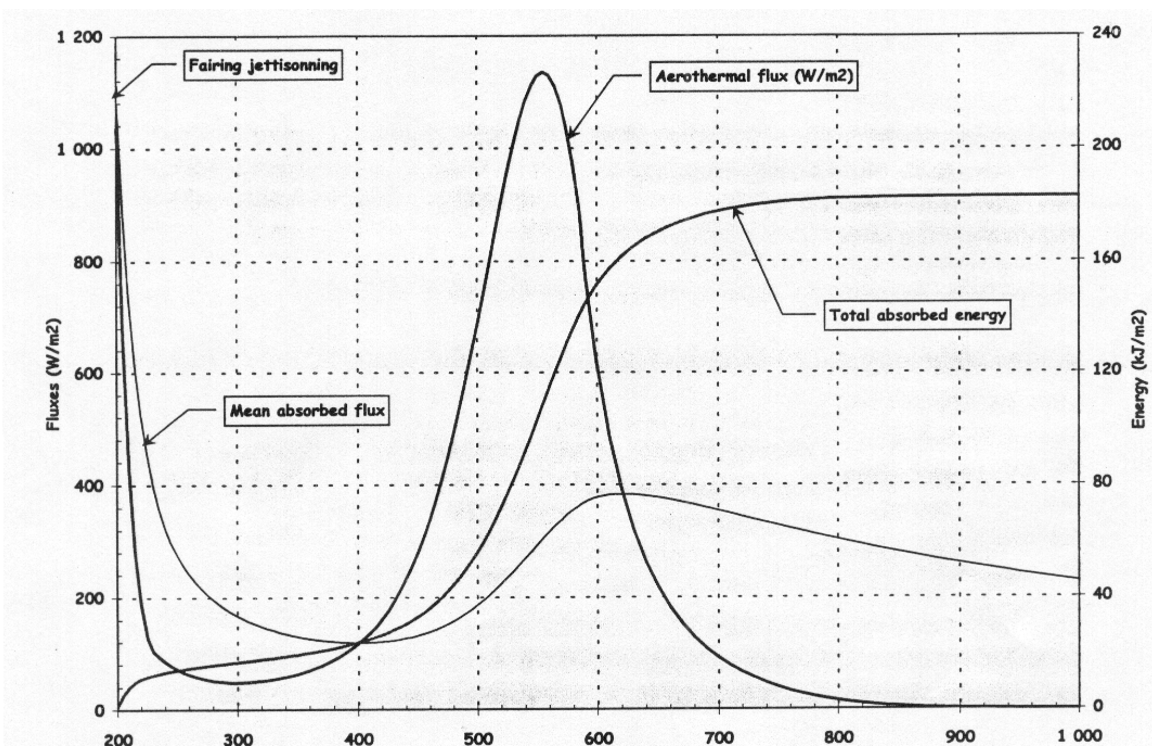
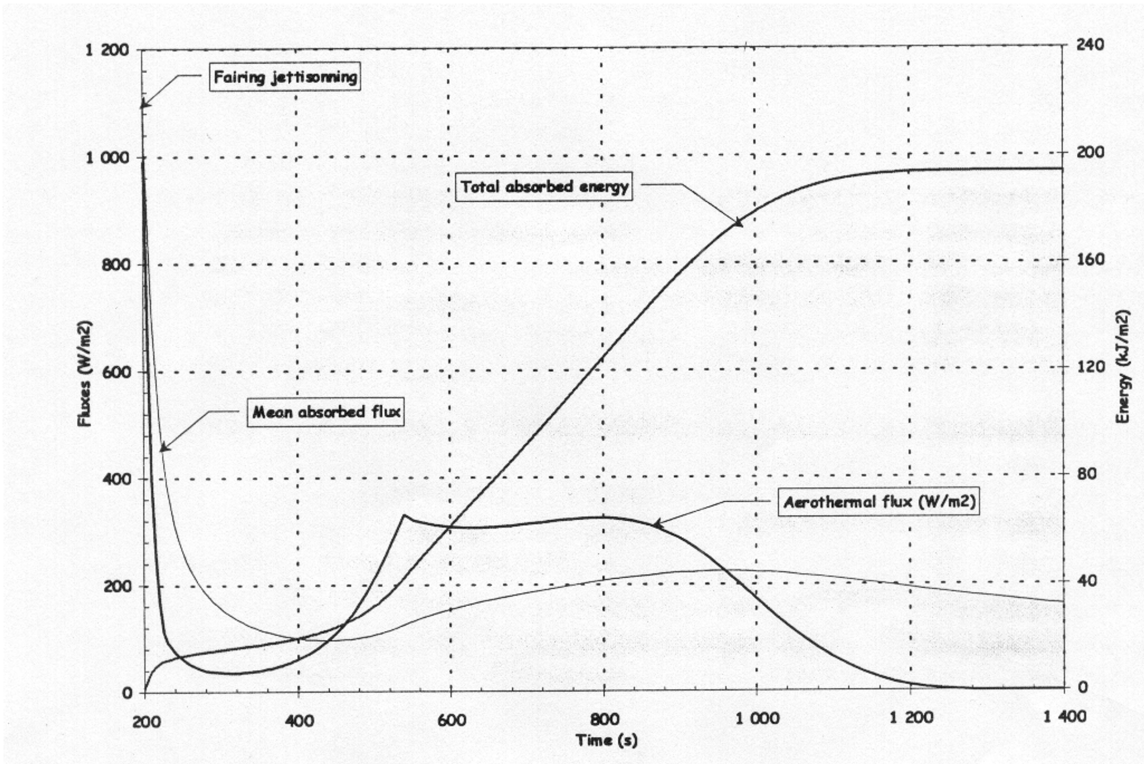


Figure 4-3 Ariane V Version ECA Launch Pressure Profile



4.5. THERMAL ENVIRONMENT

4.5.1 Temperature Definitions

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

Operating Allowable Flight Temperature
Operating Allowable Flight Temperatures are the mission temperature limits (including allowance for prediction uncertainties) in a worst case powered-on, operational (operating within functional specifications) mode that thermal control is designed to maintain specified assembly (hot or cold).

Non-Operating Allowable Flight Temperature
Non-operating Allowable Flight Temperatures are the mission temperature limits (including allowance for prediction uncertainties) in a worst case powered-off, non-operational mode that thermal control is designed to maintain specified assembly (hot or cold).

Protoflight (PF) Temperature limits (Operating and Non-Operating):
These are the temperature levels over which the units will be tested to verify the design (i.e., functionality within specification), and workmanship. They are non-damaging to flight hardware, serve to qualify the design and workmanship processes, with margin, as well as accept the test articles for flight.

4.5.2 Launch Thermal Environment

4.5.2.1. Free Molecular Heat Fluxes

Herschel/ Planck assembly temperature control shall be designed to maintain the assembly temperature within the non-operating allowable flight temperature limits when the assembly is exposed to the free molecular heating fluxes after the jettison of the payload fairing of Ariane V during launch. This flux is defined in Figure 4-2 & 4-3.

The verification of this design condition will be by analysis. It shall be shown by analysis that the assembly will not experience temperatures beyond the non-operating allowable flight temperatures during this phase of the mission.

4.5.2.2. Payload Fairing Wall Temperatures

Herschel/ Planck assembly temperature control shall be designed to maintain the assembly within its allowable non-operating flight temperature limits when exposed to the heat fluxes of 1000 w/m^2 max.from the payload fairing interior walls of Ariane V during launch.

The verification of this design condition will be by analysis. It shall be shown by analysis that the Herschel/ Planck assembly will not experience temperatures beyond the non-operating allowable flight temperature limits during this phase of the mission.

4.5.3 Space Thermal Environments

4.5.3.1. External Heat Sources

Direct solar fluxes, reflected solar fluxes, and planetary emission in the IR range which the Herschel/Planck assemblies will experience in flight are shown in Table 4-3 for all phases of the mission.

4.5.3.2. External Heat Sink (Deep Space Temperature)

The temperature of deep space shall be considered to be a constant of 4K for all flight hardware that has a view factor to deep space.

Table 4-3 External Heat Sources

External Heat Sources

Heat Sources	Minimum	Maximum
Direct Solar	1367.5 - 4 (W/m^2) @ 1 A.U.	1367.5 + 4.0 (W/m^2) @ 1 A.U.
Reflected Solar from the Earth (Albedo) (As a fraction of direct Solar)	0.28	0.32
Long Wave Length Emission from the Earth (Effective Black Body Temperature)	252 K	255 K

Notes:

(1) Inverse square relationship is applicable.

(2) Shading by the spacecraft assemblies must be included.

4.5.3.3. Vacuum

Herschel/Planck assemblies shall be designed for a space vacuum condition of 1.0×10^{-14} torr.

4.5.3.4. Internal Heat Sources

The internal heat source for a Herschel/Planck assembly is defined as the minimum and maximum heat dissipation (thermal watts) of the assembly of the Herschel/Planck projects for all the mission operating modes. The internal power distribution in the thermal environmental test of the assembly shall be measured to the level of the electronic boards and the high-powered parts. The test shall have dedicated temperature measurements for critical boards and parts as determined by the Cognizant Engineer and the Thermal Engineer.

4.5.4 Thermal Test Temperature Requirements

Tables 4-4 through Table 4-7 define the interface test temperatures for Herschel and Planck hardware delivered by JPL. Figures 4-4 and 4-5 show the HFI temperature test profiles.

Table 4-4 Thermal Test Temperature Requirements For SPIRE

Thermal Environmental Test Requirements						
	Allowable Flight Temps		Flt Accept. Test Temps		Qual (PF) Test Temps	
Assembly/ Subsystem	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot
Herschel Spacecraft	na	na	na	na	na	na
SPIRE Instrument	na	na	na	na	na	na
Focal Plane Unit (FPU)	na	na	na	na	na	na
STM (Structural Thermal Model)	0.3K and 2K	353K (6)	na	na	0.3K and 2K	353K (6)
Bolometer Detector Ass'y (BDA) Mass Dummy Units (Focal Plane, 2K Struct, .3K Struct)	"	"	"	"	"	"
RF Filter Modules	4K	"	"	"	4K	"
FTS Calibrator	15K	"	"	"	(5)	"
CQM (Cryogenic Qualification Model)	0.3K and 2K	353K (6)	na	na	0.3K and 2K	353K (6)
BDA Qual Units (Focal Plane, 2K Struct., .3K Struct.)	"	"	"	"	"	"
RF Filter Modules	4K	"	"	"	4K	"
Heaters, Thermometer Components	15K	"	"	"	(5)	"
JFET Modules	"	"	"	"	15K	"
Harnesses and Connectors	"	"	"	"	(5)	"
GSE, Thermal Sources, Photometer, Calibrators	"	"	"	"	(5)	"
PFM (Protoflight Model) & FS (Flight Spares)	0.3K and 2K	353K (6)	0.3K and 2K	353K (6)	na	na
BDA Qual Units (Focal Plane, 2K Struct., .3K Struct.)	"	"	"	"	"	"
RF Filter Modules	4K	"	4K	"	"	"
Heaters, Thermometer Components	15K	"	(5)	"	"	"
JFET Modules	"	"	15K	"	"	"
Harnesses and Connectors	"	"	(5)	"	"	"
GSE, Thermal Sources, Photometer, Calibrators	"	"	(5)	"	"	"

Notes

(1) The mission thermal duty profile for the Bolometer Detector Assembly (BDA) is assumed to consist of two main phases:
(i) One-time cooldown to operating cold condition; and
(ii) Steady state operating cold condition for the remainder of the mission.

(2) The packaging verification testing (i.e., at lower level of assembly) is to consist of:
(i) Coupon test? Housing test?
(ii) Non-Operational thermal cycling test of one bolometer module, 12 cycles between 293 K (room ambient) and 77K (LN_2 immersion);
(iii) Non-Operating thermal cycling test of one RF Filter module, 12 cycles between 293 K (room ambient) and 77K (LN2 immersion)
Why not LHe?

(3) Thermal Environmental Tests shall be as follows:
(i) Module-level tests for (1) RF Filter at 4K; and (2) JFET at 15K
The remainder of the modules or subassemblies will be tested at the BDA level of assembly.
(ii) Assembly-level test for the Bolometer Detector Assembly at 0.3K and 2K (Including the JFET at 15K)
Testing after integration as a Focal Plane Assembly in not in the scope of this program.

(4) The test margins are defined as follows:
(i) The margins for the STM and the CQM shall be +1,-0 degrees above 0.3K and 2K at the structures.
(ii) The margins for the PFM shall be +1,-0 degrees above 0.3K and 2K at the structures.

(5) This hardware item will be tested when assembled with the STM, CQM, PFM, or FS Model.
(6) Non-operating instrument level bakeout temperature of 353 K.
(7) Reference Qualification Plans JPL D 19152 and D 19153

Thermal Environmental Test Requirements for HFI Bolometer Detector Module							
No.		Allowable Flight Temps		Flight Accept. Test Temps		Qual (PF) Test Temps	
of Unit	Assembly/ Subsystem	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot
15	TCM Bolometer Detector Modules (Thermal cyc Models or Thermal Qual Models)	0.1K (1)/ 0.1K (1)	0.1K(1) / 353K (2)	na	na (4)	80K / 300K, 60 cycles; 2 hrs/2 hrs Dwell each Cycle (5); Aging Test TBD	na (4)
20	CQM Bolometer Detector Modules (Cryo Qual Models)	"	"	80K / 300K, 3 cycles, 2 hrs/ 2 hrs Dwell each cycle (5)	"	na	"
50	FM Bolometer Detector Modules (Protoflight Models)	"	"	"	"	na	"
50	FS Bolometer Detector Modules (Flight Spares)	"	"	"	"	na	"
-	Resistors & Capacitors (Impedance Loads)	"	"	(3)	(3)	(3)	(3)

Notes:

(1) The mission thermal duty profile for the Bolometer Detector Assembly (BDA) will consist of two main phases:
(i) One-time cooldown to operating cold condition; and
(ii) Steady state operating cold condition for the remainder of the mission.

(2) Non-operating instrument level bakeout temperature of 353 K.

(3) This hardware item will be environmentally tested when assembled with the TCM, CQM, FM, or FS Module.

(4) There will be no non-operating tests.

(5) Dwell is defined as the test time period at each hot and cold plateau after thermal equilibrium is established.
Functional verification is performed during this dwell period.
Estimated cumulative dwells for the qual test is 120 hours hot/120 hours cold; for FA tests 6 hours hot/ 6 hours cold.

(6) See Appendix B, Figures B-1and B-2 for test profile and test implementation details.

(7) Reference Qualification Plan JPL D 19154

Table 4-5 Thermal Test Temperature Requirements For HFI

Figure 4-4 HFI and HIFI Assemblies Thermal Qualification Test Profile
(All 15 Thermal Cycling/Qual. Assemblies for HFI)
(FM/FS for HIFI)

Note: HIFI temperatures defined in Table 4-7

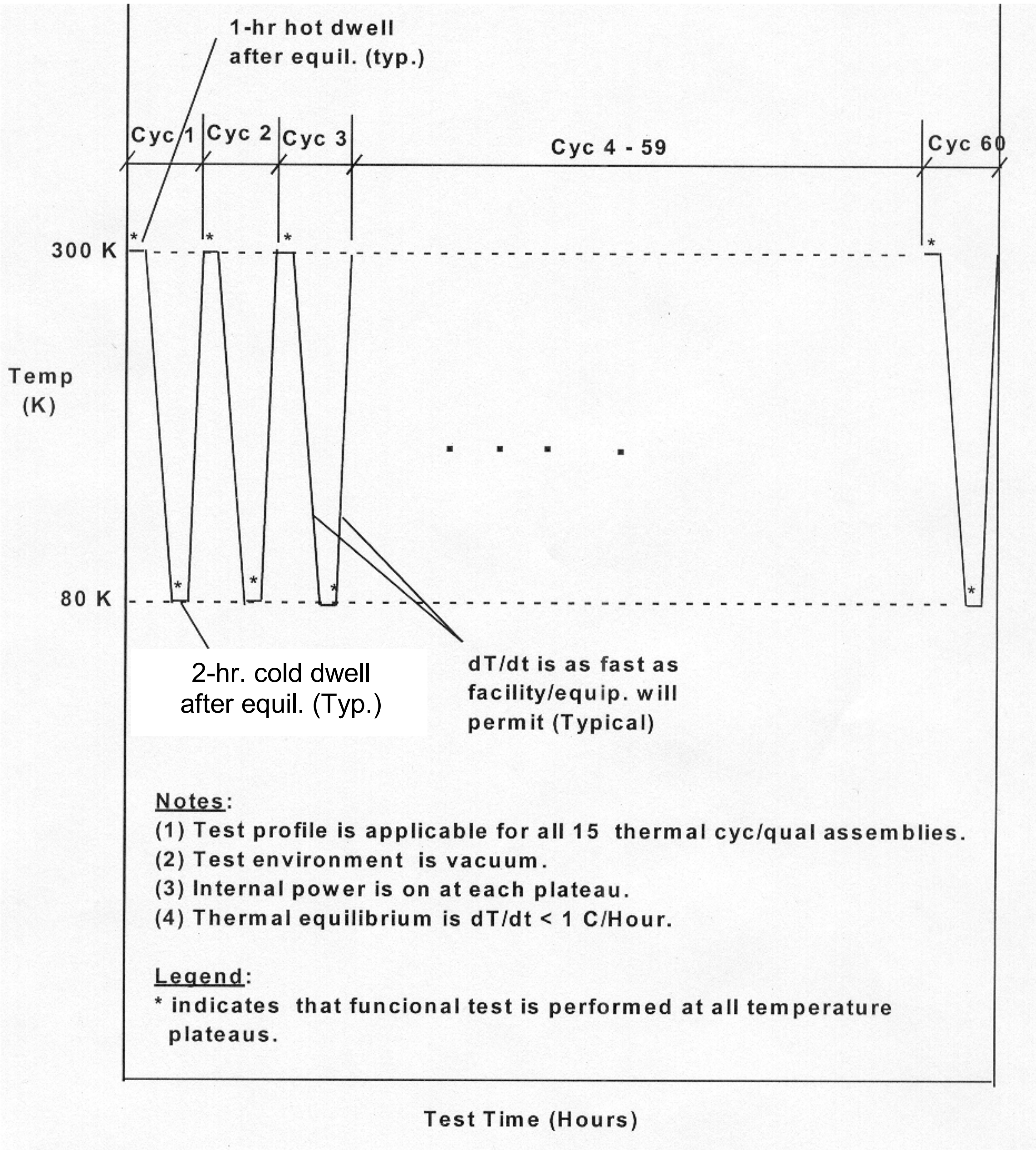
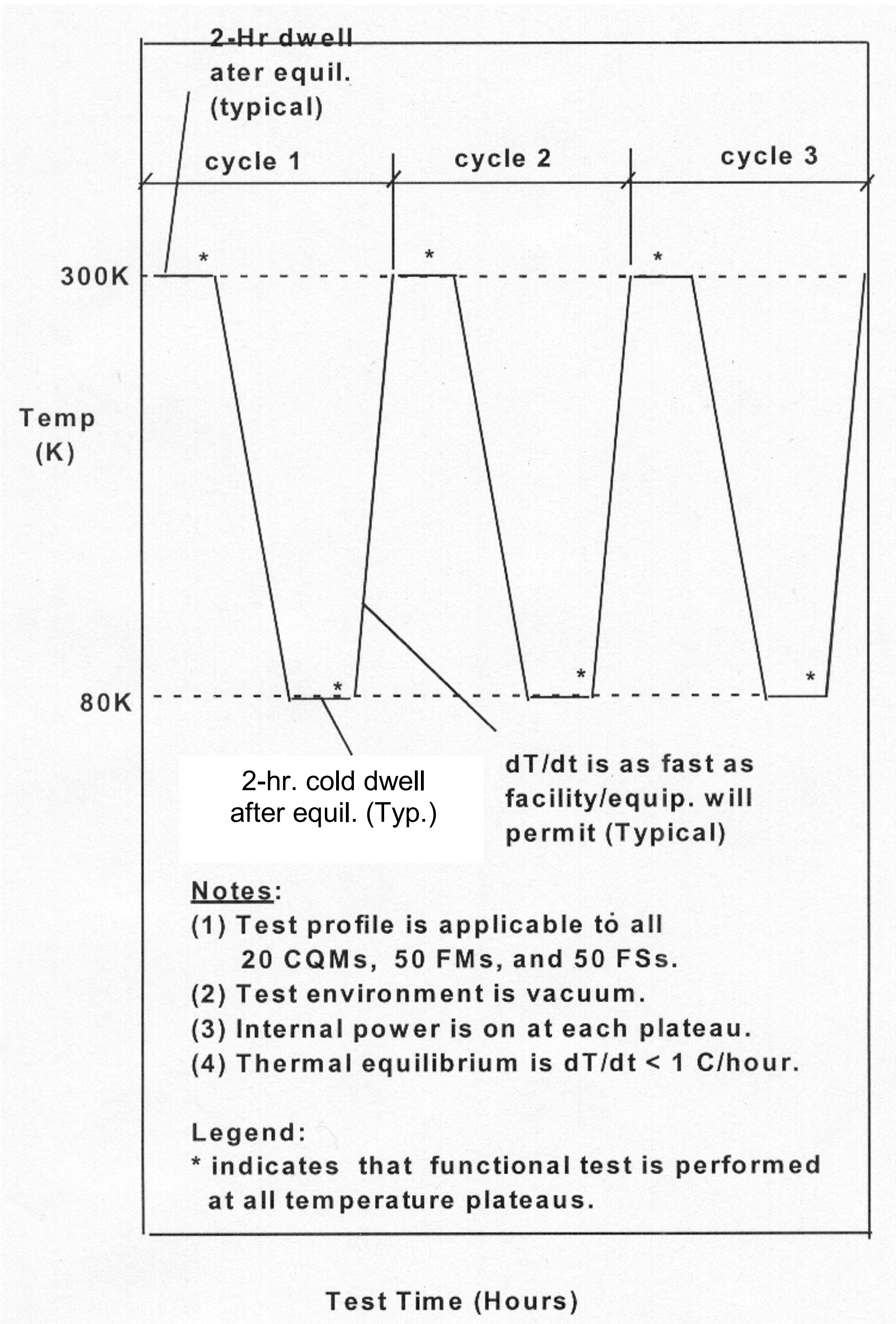


Figure 4-5 HFI and HIFI Assemblies Thermal Acceptance Test Profile
(All 20 CQMs, 50 FMs, and 50 FSs for HFI)
(FM/FS for HIFI)

Note: HIFI temperatures defined in Table 4-7



Thermal Test Temperature Requirements For Planck Sorption Coolers

Assembly/ Subsystem	Allowable Flight Temps Op Cold/Hot	Allowable Flight Temps Non-Op Cold/Hot	FA Test Temps Op Cold/Hot	FA Test Temps Non-Op Cold/Hot	Qual Test Temps Op Cold/Hot	Qual Test Temps Non-Op Cold/Hot
Planck Sorption Cooler Systems	1.102 w @ 20 K: < 0.1 K peak-to-peak stability; (270 K Warm Radiator; 60K/100K/160K Pre-Cooling)	253K/353 Note (1)	1.102 w @ 20 K: FA Test	1.102 w @ 20 K: FA Test	1.102 w @ 20 K: EBB Test	1.102 w @ 20 K: EBB Test
Compressor Subsystem		"	SFA	SFA	EBB	EBB
Compressor Elements	260/280 K	-20C/+50C	"	"	MCS	MCS
High Pressure Stabiliz. Tanks	260/280 K	-20C/+50C	H	H	"	"
Low Pressure Stabiliz. Bed	260/280 K	-20C/+50C	"	"	"	"
Check Valves	260/280 K	-20C/+50C	"	"	"	"
Valves, Filters, Sensors, etc.	260/280 K	-20C/+50C	H	H	H	H
Piping Subsystem		"	SFA	SFA	EBB	EBB
Precooler 1	120/160 K	120/323	"	"	"	"
Precooler 2	80/100 K	80/323	"	"	"	"
Precooler 3	40/60 K	40/323	"	"	"	"
Heat Exchangers		"	"	"	"	"
Charcoal Filter		"	"	"	MCS	MCS
Sensors, etc.		"	H	H	H	H
Cold-End Subsystem		"	H	H	EBB	EBB
18K Liquid Reservoir	18/60 K	"	"	"	"	"
20K Liquid Reservoir	18/60 K	"	"	"	"	"
24K Liquid Reservoir	18/60 K	"	"	"	"	"
Joule-Thomson Expander		"	"	"	MCS	MCS
0.01 micron Particle Filter		"	"	"	MCS	MCS
Sensors, etc.		"	H	H	H	H
Electronics Subsystem	Note (2)	Note (2)	Note (2)	Note (2)	Note (2)	Note (2)
Cabling Subsystem	"	"	"	"	"	"

Legend:
MCS = "**M**aterials and **C**omponents **S**election" Tests by R. Bowman; ETAS form is applicable.
EBB = **E**legant **B**read **B**oard Testing for Cooler system; ETAS form is applicable.
SFA = **S**ubsystem **F**light **A**cceptance tested at subsystem level by Dr. David Pearson; ETAS form is applicable.
H = Flight Acceptance tested at the system level (cooler level) with control electronics and software; ETAS form is applicable.

Notes:
(1) Non-Operating cold temperature is -20 C (253 K) for ground handling, transportation, and storage;
Non-Operating hot temperature is +80 C (353 K) for the process.
(2) Qual and flight acceptance tested at ISN.

Table 4-6 Thermal Test Temperature Requirements For Cyrocooler

Table 4-7 Thermal Test Temperature Requirements For the Herschel Telescope and HIFI

Thermal Test Requirements (K except where indicated otherwise)

Assembly/ Subsystem	Allowable Flight Temps		Flight Accept. Test Temps		Qual (Protoflight) Test Temps	
	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot	Op Cold/Hot	Non-Op Cold/Hot
Herschel	na	na	na	na	na	na
Telescope	70/90	353[4]	65/100 in steps & in cycles [8]	353[4]	na	na
Primary Mirror	Note (7)	Note (7)	Note (7)	Note (7)	"	"
Secondary Mirror	"	"	"	"	"	"
Actuator Motor and Controls	"	"	"	"	"	"
Flexures	"	"	"	"	"	"
I/F Triangle, Tripod, etc.	"	"	"	"	"	"
MLI, Heaters,Al Shield,etc.	"	"	"	"	"	"
HIFI	na	na	na	na	na	na
Band 5 SIS Mixer (1 & 2)	1.7 +/- 0.3	na	4.2	na/353[4]	4.2	na/353[4]
Band 6 HEB Mixer (1 & 2)	"	"	"	"	"	"
LO Power Amps (1-4)[1]	120 -20/+30[2]; dT/dt<1C/Hr	na	77[5]/300[6]	300[6]/ 353[4]	77[5]	353[4]
Band 5 LO Multiplier Chain (1& 2	" [3]	"	"	"	"	"
Band 6 LO Multiplier Chain 1	"	"	"	"	"	"
" Chain 2	"	"	"	"	"	"
" Chain 3	"	"	"	"	"	"
" Chain 4	"	"	"	"	"	"

Notes
(1) Different Frequencies; Identical Packaging
(2) Measured on the case
(3) Measured at the first stage
(4) Bakeout Temperature Level
(5) LN_2 Temperature
(6) Room Ambient Temperature
(7) Tested at the telescope level of assembly
(8) Number of steps is TBD; Number of cycles to be based on test results from the development model.
(9) Operation will be at room Temperature, thermal tested at system level
(10) Cooler system tested with simulated precooling radiators @ 160, 100 & 50-60K, respectively.
(11) Thermal testing performed at ESA.
(12) Tested at the cooler system level
(13) Operating test will be themal cycle test; Number of cycles is 3 times the mission cycles; Levels/Durations are TBD
Boundary Condtionts will be based on Interface document : PT-HFI-04141
The Non-Operating temperature is the bakeout temperature and will be limited by the Indium Bumps.
It will be 70C or 80C pending determination from Materials Group
(14) Thermal Testing performed at the next higher level of assembly
(15) Reference Qualification Plans JPL D 19157, JPL D 19158, JPL D 19159 and JPL D 19160

4.6. STRUCTURAL LOADS

All assemblies/instruments and assembly interfaces shall be designed in accordance with the Mass Acceleration Curve (MAC) limit load values shown in Figure 4-6. The minimum design factors of safety are 1.25 for yield and 1.4 for ultimate for metallic structure. For non-metal materials, the factor of safety for yield shall be 1.4 and the factor of safety for ultimate shall be 2.0. The factor of safety for buckling shall be 2.0.

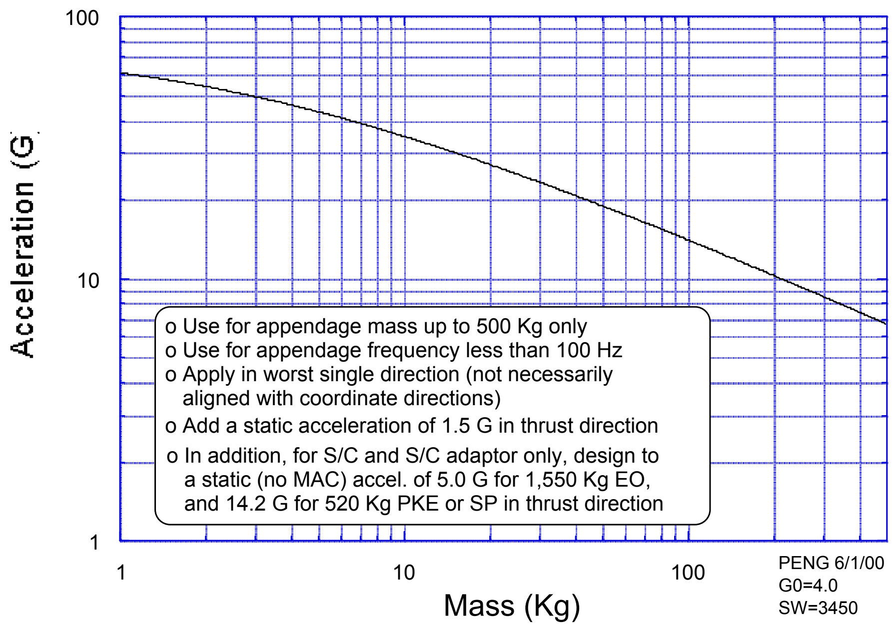


Figure 4-6 Preliminary Physical Mass Acceleration Curve for Spacecraft Equipment

4.6.1 Launch Structural Limit Loads

The hardware shall be designed to survive the Launch Static Limit Loads shown in Table 4-8.

Table 4-8 Launch Static Limit Loads

Location	Case	Longitudinal [g]	Lateral [g]
Herschel Optical Bench Instr.	1	20	2
	2	-	14
Herschel CVV LOU	1	25	5
	2	-	14
Herschel CVV BOLA	1	20g (any direction)	
Herschel SVM	1	25g (any direction)	
Planck LFI/HFI (FPU)	1	20g (any direction)	
Planck HFI JFET box	1	25g (any direction)	
Planck Sorption Cooler Compressor Assembly	1	25g (any direction)	
Planck SVM and BEU	1	25g (any direction)	

4.7. DYNAMICS

4.7.1 Launch Vibration

4.7.1.1. Sinusoidal Vibration

Sinusoidal vibration design requirements are imposed to cover low-frequency (5-100 Hz) launch vehicle-induced transient loading. The sine vibration requirements stop at 100 Hz because random vibration is expected to dominate the flight environment above 100 Hz. Spacecraft assemblies with resonant frequencies below 100 Hz shall be tested to the sinusoidal vibration requirements in Tables 4-9 and 4-10. These requirements will be applied at the assembly mounting interface in each of three orthogonal axes and the maximum accelerations at the hardware C.G. should not exceed 1.25 times the assembly limit load values. The measured base reaction force will be used to effect this limit.

Table 4-9 Protoflight Sinusoidal Vibration Amplitudes

Location		Axis	Frequency	Level [g]
Herschel	**FPU**	**Longitudinal**	**5 - 40 Hz** **40 - 100 Hz**	**20** **10**
		Lateral	**5 – 100 Hz**	**14**
	LOU	**Longitudinal**	**5 - 80 Hz** **80 - 100 Hz**	**25** **5**
		Lateral	**5 – 100 Hz**	**14**
	BOLA	**Long/Lat**	**5 - 100 Hz**	**20**
	SVM	**Long/Lat**	**5 - 100 Hz**	**25**
Planck	**FPU**	**Long/Lat**	**5 - 100 Hz**	**20**
	JFET	**Long/Lat**	**5 - 100 Hz**	**25**
	SCC and BEU	**Long/Lat**	**5 - 100 Hz**	**25**
	SVM	**Long/Lat**	**5 - 100 Hz**	**25**

Protoflight sweep rate is 2 Oct/min.

Acceptance sweep rate is 4 Oct./min. From 5 to 18 Hz levels will be limited to 0.75 inch displacement double amplitude.

Table 4-10 Acceptance Sinusoidal Vibration Amplitudes

Location		Axis	Frequency	Level [g]
Herschel	**FPU**	**Longitudinal**	**5 - 40 Hz** **40 - 100 Hz**	**13** **6.5**
		Lateral	**5 – 100 Hz**	**9**
	LOU	**Longitudinal**	**5 - 80 Hz** **80 - 100 Hz**	**16**
		Lateral	**5 – 100 Hz**	**9**
	BOLA	**Long/Lat**	**5 - 100 Hz**	**13**
	SVM	**Long/Lat**	**5 - 100 Hz**	**16**
Planck	**FPU**	**Long/Lat**	**5 - 100 Hz**	**13**
	JFET	**Long/Lat**	**5 - 100 Hz**	**16**
	SCC and BEU	**Long/Lat**	**5 - 100 Hz**	**16**
	SVM	**Long/Lat**	**5 - 100 Hz**	**16**

Acceptance sweep rate is 4 Oct./min. From frequencies 5 to 18 Hz levels will be limited to 0.5 inch displacement double amplitude frequencies. Resonance search shall be carried out before and after vibration test for each axis between 5 to 2000 Hz with a level of 0.25 g (sweep rate: 2 Oct./min.).

4.7.1.2. Launch Vehicle Induced Transients

Herschel/Planck shall be designed to survive and fulfill its mission after application of launch vehicle-induced transient environments.

4.7.1.3. Random Vibration

Deliverable assemblies shall be tested to the random vibration zone requirements per Table 4-11, and shall be "force limited" to reduce over-test at hard mount resonance frequencies. These spectra shall be applied in each of the three orthogonal axes at the mounting points of the unit under test.

Table 4-11 Herschel/Planck Random Vibration Design and Verification Levels

Location		Axis	Frequency	Protoflight Level	Acceptance
Herschel	**FPU**	**Long/Lat**	**20 – 100 Hz 100 – 300 Hz 300 – 2000 Hz Grms**	**+6 dB/Oct 0.05g^2/Hz -6 dB/Oct 5.27**	**0.025 g^2/Hz 3.73**
	LOU	**Normal to own radiator plane**	**20 – 100 Hz 100 – 300 Hz 300 – 2000 Hz Grms**	**+6 dB/Oct 0.10g^2/Hz -6 dB/Oct 7.45**	**0.05 g^2/Hz 5.27**
		Other axes	**20 – 100 Hz 100 – 300 Hz 300 – 1000 Hz Grms**	**+6 dB/Oct 0.5g^2/Hz -6 dB/Oct 5.27**	**0.025 g^2/Hz 3.73**
	BOLA	**Long/Lat**	**20 – 100 Hz 100 – 300 Hz 300 – 1000 Hz Grms**	**+6 dB/Oct 0.5g^2/Hz -6 dB/Oct 5.27**	**0.25 g^2/Hz 3.73**
	SVM Units	**Normal to fixation plane**	**20 – 100 Hz 100 – 300 Hz 300 – 1000 Hz Grms**	**+6 dB/Oct 0.30g^2/Hz -6 dB/Oct 12.9**	**0.15 g^2/Hz 9.12**
		Other axes	**20 – 100 Hz 100 – 300 Hz 300 – 1000 Hz Grms**	**+6 dB/Oct 0.05g^2/Hz -6 dB/Oct 5.27**	**0.025 g^2/Hz 3.73**
Planck	**FPU and JFET**	**Long/Lat**	**20 – 100 Hz 100 – 300 Hz 300 – 2000 Hz Grms**	**+6 dB/Oct 0.09g^2/Hz -6 dB/Oct 7.07**	**0.045 g^2/Hz 5.0**
	BEU, SCC and SVM units	**Normal to fixation plane**	**20 – 100 Hz 100 – 300 Hz 300 – 2000 Hz Grms**	**+6 dB/Oct 0.30g^2/Hz -6 dB/Oct 12.9**	**0.15 g2/Hz 9.12**
		Other axes	**20 – 100 Hz 100 – 300 Hz 300 – 2000 Hz Grms**	**+6 dB/Oct 0.05g^2/Hz -6 dB/Oct 5.27**	**0.025 g2/Hz 3.73**

Duration: Design/Qual: 2 minutes in each of 3 orthogonal axes (Force Limiting Required)

Protoflight/ Flight Acceptance: 1 minute in each of 3 orthogonal axes (Force Limiting Required)

Low level sine test shall be performed to determine resonance frequencies to evaluate the behavior of the test fixture and item integrity. Resonance search shall be carried out before and after vibration test for each axis between 5 to 2000 Hz with level of 0.25g (sweep rate: 2 oct/min).

4.7.1.4. Acoustic Noise

Acoustic design requirements are based on maximum internal payload fairing sound pressure level spectra. The maximum acoustic environment occurs during lift-off and transonic flight. The environment is represented as a reverberant acoustic field with random incidence. The telescope and instrument assemblies shall be capable of meeting all performance requirements after exposure to the acoustic requirements given in Table 4-12.

Table 4-12 Acoustic Design and Test Levels (telescope and instrument assemblies)

1/3 Oct. Band Center Frequency, Hz	QUAL, PF SPL (dB, Ref. 2 x 10^{-5} Pascal)	FA SPL (dB, Ref. 2 x 10^{-5} Pascal)	Test Tolerances (dB)
31.5	132.	129.	+4, -2
40.	133.5	130.5	+4, -2
50.	134.5	131.5	+4, -2
63.	135.5	132.5	-1,+3
80.	136.	133.	-1,+3
100.	136.	133.	-1,+3
125.	136.	133.	-1,+3
160.	135.5	132.5	-1,+3
200.	135.	132.	-1,+3
250.	134.5	131.5	-1,+3
315.	133.5	130.5	-1,+3
400.	133.	130.	-1,+3
500.	132.5	129.5	-1,+3
630.	132.	129.	-1,+3
800.	131.5	128.5	-1,+3
1000.	130.	127.	-1,+3
1250.	128.	125.	-1,+3
1600.	125.	122.	-1,+3
2000.	123.5	120.5	-1,+3
2500.	122.	119.	± 4
3150.	120.5	117.5	± 4
4000.	119.5	116.5	± 4
5000.	118.5	115.5	± 4
6300.	117.5	114.5	± 4
8000.	116.5	113.5	± 4
10,000.	116.	113.	± 4
Overall	146.5	143.5	-1,+3

Duration: Design: 2 minutes
PF/FA Test: 1 minute

4.7.1.5. Pyrotechnic Shock

Pyroshock design requirements are intended to represent the structurally transmitted transients from explosive devices used to achieve various separations, including spacecraft separation from the upper stage motor and separation of the two spacecraft. The separation shock environments are defined in terms of Shock Response Spectrum (SRS) for a frequency range of 100 to 10,000 Hz. The shock pulses, with their shock response spectra corresponding to the specification, will be applied at the assembly mounting points in each of three orthogonal axes. The synthesized shock waveform will satisfy both of the following criteria: a) The pulse will be oscillatory in nature, and b) The pulse will decay to less than 10% of its peak value within 20 milliseconds. For design purposes three shocks per axis shall be applied at the interface locations indicated. Herschel/Planck and its assemblies shall be designed to survive the protoflight pyroshock environment shown in Table 4-13.

Table 4-13 Pyrotechnic Shock Design Environment

Assembly	Frequency (Hz)	Design, Qual, Protoflight (PF) Level	Flight Acceptance (FA) Level
Herschel Telescope	100 100 – 1000 1000 – 10,000	20 g 12 dB/octave 2000 g	10 g 12 dB/octave 1000 g
Herschel HIFI (multiple locations)	100 100 – 1000 1000 – 10,000	20 g 12 dB/octave 2000 g	10 g 12 dB/octave 1000 g
Herschel SPIRE	100 100 – 1000 1000 – 10,000	20 g 12 dB/octave 2000 g	10 g 12 dB/octave 1000 g
Planck HFI detectors	100 100 – 1000 1000 – 10,000	20 g 12 dB/octave 2000 g	10 g 12 dB/octave 1000 g
Planck Sorption Cooler	100 100 – 1000 1000 – 10,000	20 g 12 dB/octave 2000 g	10 g 12 dB/octave 1000 g

Duration:

Design/Qual: 3 shocks per axis
PF/FA: 1 shock per axis

4.7.1.6. Mechanical Stiffness Requirement Verification

The Telescope and Planck Sorption Cooler will undergo 0.25 g sine sweep testing in each axis before and after all other dynamic tests. These tests shall verify that the modes, with an effective mass greater than 10% of the total mass, in the launch vector direction are greater than 60 Hz and greater than 45 Hz in the other directions. Torsional modes shall be greater than 31 Hz.

4.8. MAGNETIC FIELDS

The source of these requirements is ESA document SCI-PT-IIDA-04624, dated 12/20/2000, hereafter referred to as "IIDA".

4.8.1 Magnetic Field Emissions

4.8.1.1. AC Magnetic Field Emissions: (IIDA, paragraph 5.14.3.11)

Generated AC fields from the Herschel/Planck shall not exceed 60 dB at a point 1 meter from the unit under test, from 30 Hz to 50 kHz

4.8.1.2. DC Magnetic Field Emissions:

No requirements identified.

4.8.2 Magnetic Field Susceptibility

4.8.2.1. AC Magnetic Field Susceptibility - RS02 (IIDA, paragraph 5.14.3.12)

Herschel/Planck shall not exhibit any malfunction, degradation, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected 140 dB over the frequency range of 30 Hz to 50 kHz.

4.8.2.2. DC Magnetic Field Susceptibility:

No Requirements identified.

4.9. ELECTROMAGNETIC COMPATIBILITY (EMC).

The source of these requirements is ESA document SCI-PT-IIDA-04624, dated 12/20/2000, hereafter referred to as "IIDA". These requirements apply to subsystem electrical interfaces. Internal interfaces inside the same equipment should follow the rules for external interfaces to the maximum extent possible. JPL hardware consists of small subassemblies.

There are no direct EMC requirements applicable to the JPL subassemblies. The EMC requirements of this section are applicable after the subassemblies have been connected together and operate as a complete subsystem.

Developmental tests may be useful for radiation emissions (RE) and radiated susceptibility (RS), but are not required.

Table 4-14 summarizes the EMC requirements for the Herschel/Planck hardware.

Table 4-14 EMC REQUIREMENTS FOR THE Herschel/Planck HARDWARE

Hardware	Sub Assemblies	EMC Tests
Herschel		
Telescope	Actuator Motor, Controls	Isolation, CE only
HIFI	Power Amps, Mixers, Multiplier	Isolation, RE, RS
SPIRE	Warm Electronics	Isolation, CE, CS, RE, RS
Planck		
Cryocooler	Cryostat, Compressor Sys.	Isolation, CE, RE
HFI	Bolometer Module	Isolation, CE, CS, RE, RS

CE=Conducted Emissions, RE= Radiated Emissions, CS=Conducted Susceptibility, RS= Radiated Susceptibility

4.9.1 ELECTRICAL ISOLATION, GROUNDING, AND BONDING

Each electrical power circuit shall be DC isolated from chassis, structure, signal circuits, and all other power circuits by a minimum of 1 megohm when a single point common ground within equipment is not connected to chassis or structure. Coupling capacitance shall be less than 50 nanofarads for isolated interface circuits in the spacecraft, unless otherwise specified.

Each power return circuit shall be independent of other power circuit returns, control circuit returns, and signal circuit returns. Bonding and grounding should be in accordance with NASA-HDBK-4001 "Electrical Grounding Architecture for Unmanned Spacecraft". Additionally, each conductive layer of thermal blankets shall be grounded.

Receiver interface signal circuits shall be isolated from ground by at least 20k at DC and low frequencies. Capacitance to ground shall be less than 75 picofarads. (IIDA, para. 5.14.1.2)

4.9.2 ELECTROSTATIC DISCHARGE REQUIREMENTS

To avoid the occurrence of space charging caused ESD each conductive layer of thermal blankets and all exposed conductive surfaces on the telescope shall be grounded. Confirmation of meeting this requirement shall be made through test.

The HIFI ESD PLAN, D19162, shall govern the handling and testing of the HIFI.

Guidelines on the avoidance of spacecraft charging are provided in NASA-TP2361 "Surface Charging Avoidance" and in NASA-HDBK-4002 "Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects".

4.9.3 EMISSIONS LIMITS

4.9.3.1. Conducted Emissions

4.9.3.1.1. Conducted Emissions, Power Line Ripple. Differential Mode (IIDA, paragraph 5.14.3.1.1)

Herschel/Planck assemblies with input current 1 A or less shall not produce noise on the spacecraft DC power bus in excess of the levels depicted in the Figure 4-7 below.

For assemblies with input current greater than 1 Ampere, the amplitudes in Figure 4-7 shall be relaxed by a factor 10 x Log $_{10}$[I (A)]. I (A) is the nominal input current in Amperes.

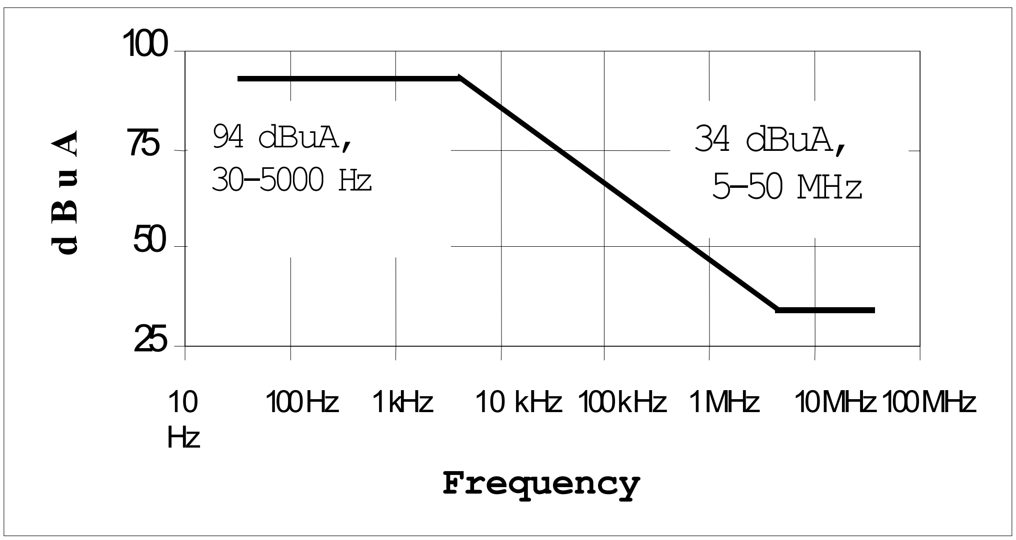


Figure 4-7 Conducted Emission Limit, Power Line Ripple Differential Mode

4.9.3.1.2. Conducted Emissions, Power Line Ripple. Common Mode (Ref. IIDA, para. 5.14.3.1.2)

Herschel/Planck assemblies with input current 1 A or less shall not produce noise on the Spacecraft DC power bus in excess of the levels depicted in Figure 4-8.

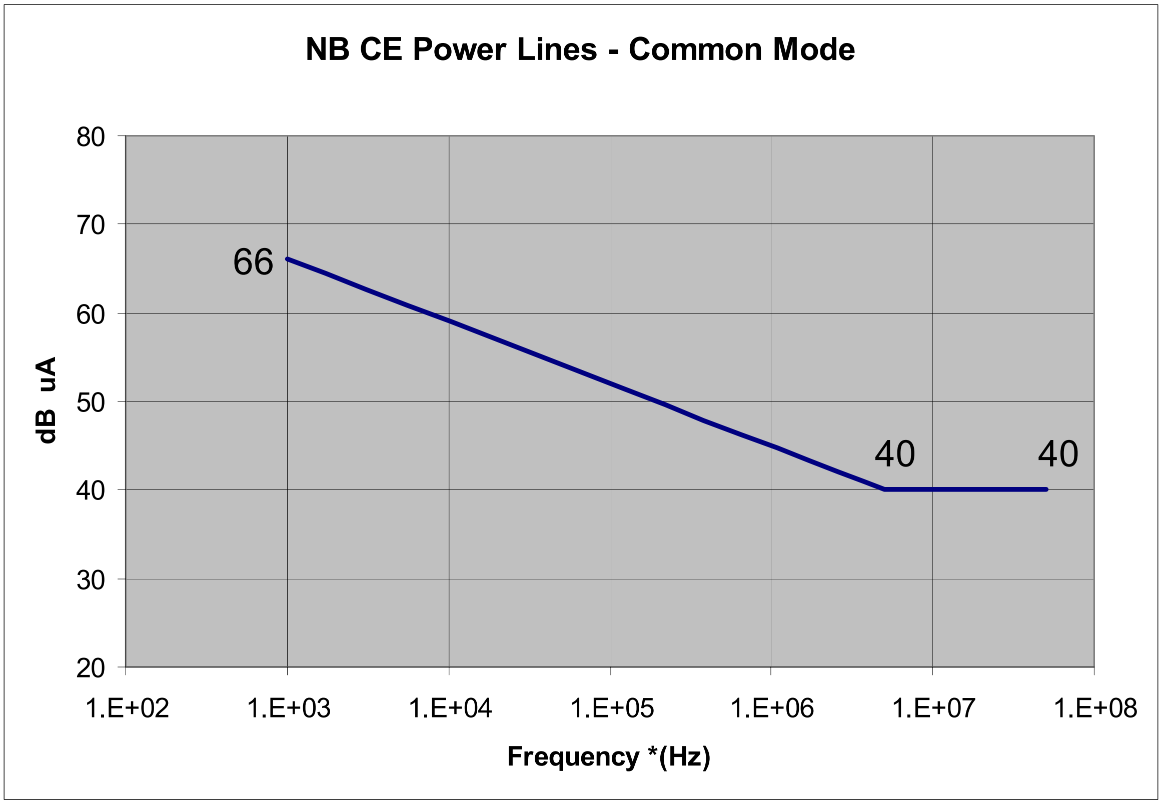


Figure 4-8 Conducted Emission Limit, Power Line Ripple, Common Mode

(B) For assemblies with input current greater than 1 Ampere, the amplitudes in Figure 4-8 shall be relaxed by a factor 10 x Log_{10}[I (A)]. I (A) is the nominal input current in Amperes.

4.9.3.1.3. Conducted Emissions, Power Line Time Domain, Differential Mode IIDA, paragraph 5.14.3.1.3)

Herschel/Planck assemblies with nominal DC input current 1 ampere or less shall not produce current ripple more than 20 mAmp or spikes including ripple more than 60 mAmp.

For assemblies with nominal DC input greater than 1 Ampere, the limits for both ripple and spikes are relaxed by a factor of √I(A), where I(A) in the nominal input current in Amperes.

These emissions shall be measured on both the primary and return power lines with an oscilloscope with at least 50 MHz bandwidth.

4.9.3.1.4. Conducted Emissions, Common Mode Current on Signal Bundles (IIDA, paragraph 5.14.3.2)

Common Mode current shall be measured on selected signal bundles from 10 kHz to 50 MHz. This measurement shall be used to establish the limits for the conducted susceptibility test using a 6 dB margin.

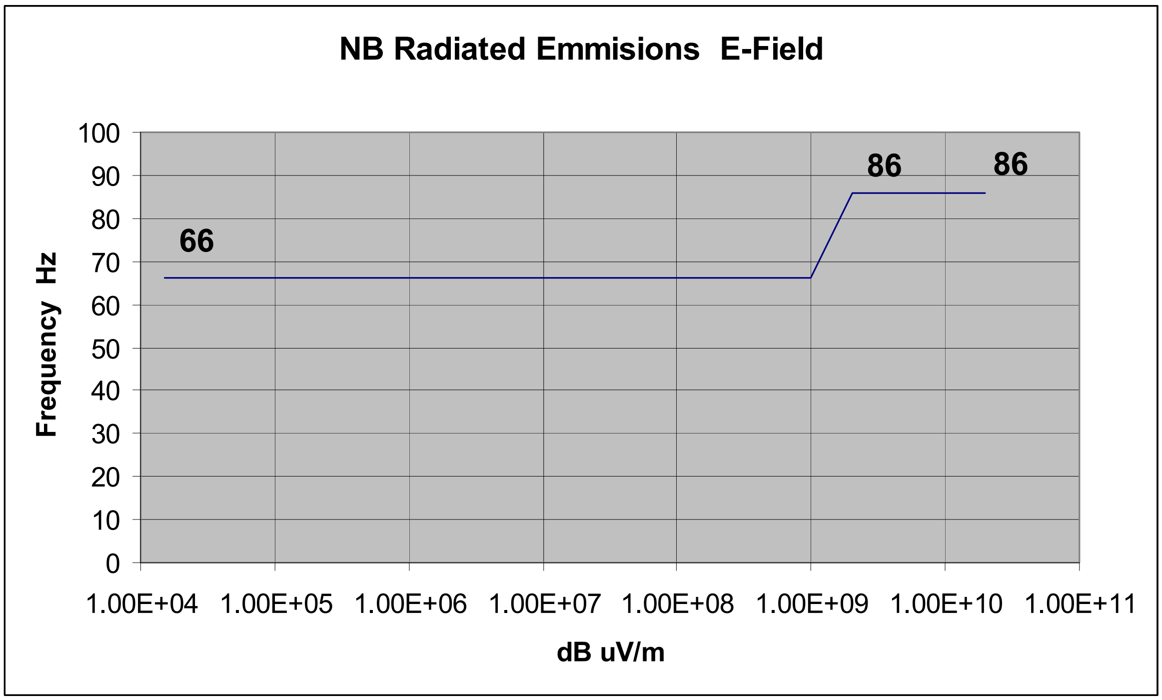
RADIATED EMISSIONS

4.9.3.1.5. Radiated Emissions, E-Fields. (IIDA, paragraph 5.14.3.9)

Herschel/Planck assemblies shall not radiate electric fields in excess of the levels shown in Figure 4-9 from 14kHz through 18GHz Frequencies may be added to accommodate the launch vehicle and science instruments.

Note: Transmitters are exempt from this requirement at their transmit frequencies.

Figure 4-9 Radiated Emission Limit - E field



4.9.4 SUSCEPTIBILITY LIMITS

4.9.4.1. Conducted Susceptibility

4.9.4.1.1. Conducted Susceptibility, Power Line Ripple, Differential Mode (IIDA, paragraph 5.14.3.3)

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:

- 2.83 V p-p with frequency range 30 Hz to 150 kHz
- 2.83 V p-p at 150 kHz declining log-linearly to 1.41 V p-p at 300 kHz
- 1.41 V p-p with frequency range300 kHz to 50 MHz, as shown in Figure 4-10. The sweep rate shall be no faster than 5 min./decade.

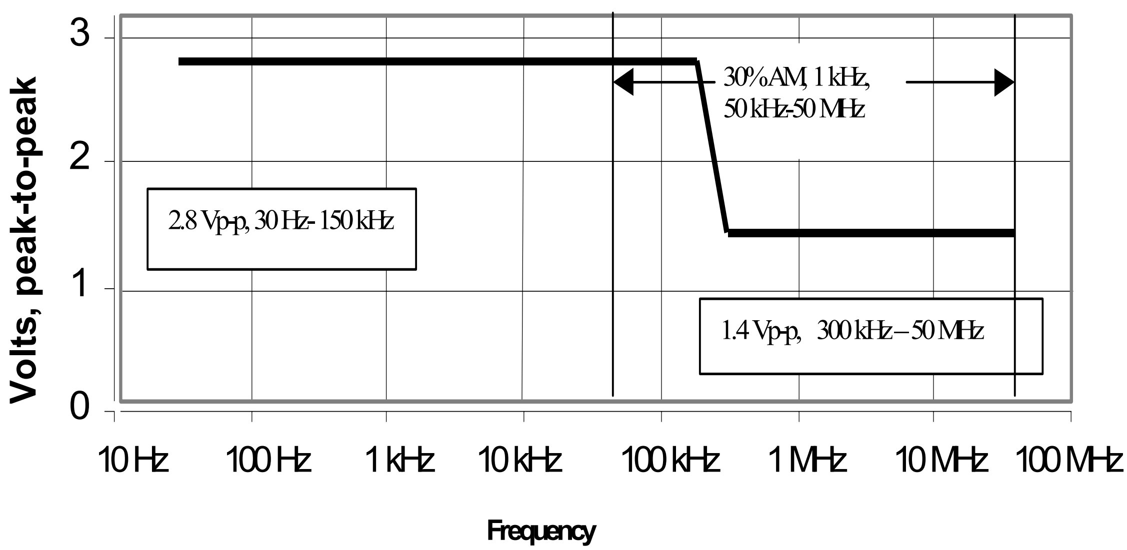


Figure 4-10 CS Ripple, Differential Mode Requirement

4.9.4.1.2. Conducted Susceptibility, Power Lines, Common Mode (IIDA, paragraph 5.14.3.4)

The subsystem shall not exhibit any malfunction, degradation, or deviation beyond tolerance when current is injected by Bulk Current Injection (BCI) into both power lines from 10 kHz to 50 MHz with an amplitude of 86 dBµA for DC current up to 1 Ampere. For higher current, the amplitude should be increased by 10 x Log [I(A)].

4.9.4.1.3. Conducted Susceptibility, Signal Bundles

Common Mode Current (IIDA, paragraph 5.14.3.5) The subsystem shall not exhibit any malfunction, degradation, or deviation beyond tolerance indicated in its individual specification when current is injected by BCI into the signal cable bundle with an amplitude 6 dB higher than the common mode emission measured in paragraph 4.9.3.1.4.

4.9.4.1.4. Conducted Susceptibility, Signal Reference

Common Mode Voltage Ripple (IIDA, paragraph 5.14.3.6)

The subsystem equipment shall not exhibit any malfunction or degradation of performance beyond tolerance when a sinusoidal voltage with a 2 Volt peak-to-peak is applied between the signal reference and chassis ground. Before performing this test, verify that the signal reference is isolated from chassis. The frequency range shall be from 50 kHz to 50 MHz and the sweep rate shall be no faster than 5 minutes per decade.

4.9.4.1.5. Conducted Susceptibility, Signal Reference, Common Mode Voltage Transient (IIDA, paragraph 5.14.3.7)

The subsystem equipment shall not exhibit any malfunction or degradation of performance beyond tolerance when a transient waveform with a ±3 Volt peak across a 50 ohm resistor from a 50 ohm source is applied between the signal reference and chassis ground. A typical waveform is shown in Figure 4-11. The value of T_d in Figure 4-11 shall be between 150 and 250 ns. The repetition rate shall be between 5 and 10 Hz for at least 3 minutes.

Before performing this test, verify that the signal reference is isolated from chassis.

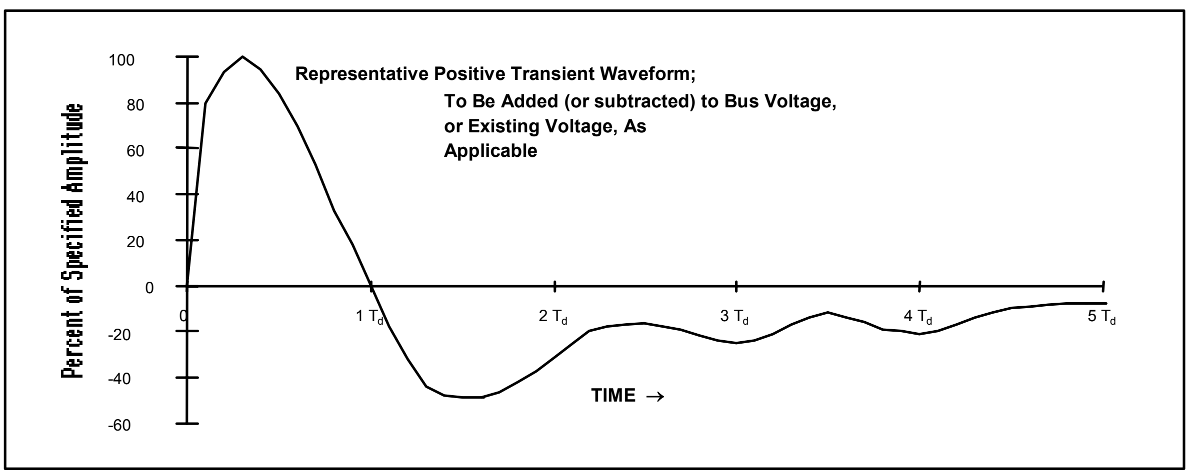


Figure 4-11 Transient Test Waveform

4.9.4.1.6. Conducted Susceptibility, Power Line, Differential Voltage Transient (IIDA, paragraph 5.14.3.8)

The subsystem equipment shall not exhibit any malfunction or degradation of performance beyond tolerance when a transient waveform with a ±2.5 Volt peak is applied between the power line and its return line. A typical waveform is shown in Figure 4-11. The value of T_d in Figure 4-11 shall be 700 µs ±10 %. The repetition rate shall be between 5 and 10 Hz for at least 5 minutes.

4.9.4.2. Radiated Susceptibility

4.9.4.2.1. Radiated Susceptibility, E-Fields

4.9.4.2.2. (IIDA, paragraph 5.14.3.10)

The hardware shall perform within specification when subjected to electric (E) fields of 2 V/m from 14 kHz to 18 GHz. The applied signal shall be 30% amplitude modulated with a 1 kHz sine wave. In addition the assemblies shall be immune from interference at the following discrete frequencies and levels:

- 2.025 to 2.110 GHz at 20 V/m
- 5.5 to 5.9 GHz at 60 V/m

The larger field strengths and frequencies are associated with the range radar and launch vehicle transmitter. Frequencies may be added once the S/C requirements are known. The HFI shall not be operated during radiated susceptibility testing.

4.9.4.2.3. Arc Discharge Susceptibility, (IIDA, paragraph 5.14.3.13)

No malfunction, degradation of performance or deviation beyond the tolerance indicated in its individual specification shall occur when the subsystem equipment and its interface lines are exposed to a repetitive electrostatic arc discharge of at least 5.6 mJ energy at 15 kV.

For conducted test only, if damage risks are envisaged for interface circuits, the voltage can be reduced to 4 kV but the energy shall remain at 5.6 mJ.

4.10. IONIZING RADIATION ENVIRONMENT

The ionizing radiation environment consists of high-energy solar particle events and galactic cosmic rays (GCRs). The contribution from Earth's trapped radiation belts is negligible. The ionizing radiation environment interacts with devices and materials to produce cumulative radiation damage and single event effects (SEE).

The environment fluences within this section represent environments external to Herschel/Planck, and do not include any radiation design factor.

4.10.1 Cumulative Radiation Environment

Herschel/Planck shall be designed to function during and after exposure to the high-energy solar proton environment below. Electronics shall be evaluated for damage from ionizing dose, non-ionizing energy loss (NIEL) (i.e. displacement damage), and enhanced low dose rate effects (ELDR), as applicable to the device type. A radiation design factor (RDF) of 2 shall be used when determining a device's acceptability for use.

The radiation design factor (RDF) is defined as follows:

$$\text{RDF} = \frac{\text{Radiation-resisting capability of a part or component in a given application}}{\text{Radiation environment present at the location of the part or component}} \geq \mathbf{2}$$

If spot shielding is required to reduce the dose to the part, an RDF of 3 shall be provided.

4.10.1.1. Planck MISSION

Mission duration is 1.5 years and an RDF of 1 is assumed for the calculation. Table 4-15 gives the dose for shielding by an Aluminium sphere. The information is plotted in Figure 4-12.

Table 4-15 Dose/Depth Calculations for the Planck Mission.
Dose as a function of shielding thickness is presented. Shielding geometry of a spherical shell is used. Shielding is Aluminum.

Planck Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
1.00E-02	3.70E-02	1.46E+00	2.33E+05
1.26E-02	4.66E-02	1.84E+00	1.91E+05
1.59E-02	5.87E-02	2.31E+00	1.56E+05
2.00E-02	7.39E-02	2.91E+00	1.29E+05
2.51E-02	9.30E-02	3.66E+00	1.08E+05
3.16E-02	1.17E-01	4.61E+00	9.10E+04
3.98E-02	1.47E-01	5.80E+00	7.60E+04
5.01E-02	1.86E-01	7.31E+00	5.93E+04
6.31E-02	2.34E-01	9.20E+00	4.86E+04
6.86E-02	2.54E-01	1.00E+01	4.29E+04
7.94E-02	2.94E-01	1.16E+01	3.74E+04
1.00E-01	3.70E-01	1.46E+01	2.94E+04
1.26E-01	4.66E-01	1.84E+01	2.41E+04
1.37E-01	5.08E-01	2.00E+01	2.16E+04
1.59E-01	5.87E-01	2.31E+01	1.91E+04
2.00E-01	7.39E-01	2.91E+01	1.56E+04
2.06E-01	7.62E-01	3.00E+01	1.43E+04
2.51E-01	9.30E-01	3.66E+01	1.18E+04
2.74E-01	1.02E+00	4.00E+01	1.06E+04
3.16E-01	1.17E+00	4.61E+01	9.23E+03
3.43E-01	1.27E+00	5.00E+01	8.16E+03
3.98E-01	1.47E+00	5.80E+01	7.24E+03
4.12E-01	1.52E+00	6.00E+01	6.68E+03
4.80E-01	1.78E+00	7.00E+01	5.86E+03
5.01E-01	1.86E+00	7.31E+01	5.33E+03
5.49E-01	2.03E+00	8.00E+01	4.86E+03
6.17E-01	2.29E+00	9.00E+01	4.43E+03
6.31E-01	2.34E+00	9.20E+01	4.17E+03
6.86E-01	2.54E+00	1.00E+02	3.80E+03
7.94E-01	2.94E+00	1.16E+02	3.33E+03
8.23E-01	3.05E+00	1.20E+02	3.05E+03
9.60E-01	3.56E+00	1.40E+02	2.70E+03
1.00E+00	3.70E+00	1.46E+02	2.50E+03
1.10E+00	4.06E+00	1.60E+02	2.26E+03
1.23E+00	4.57E+00	1.80E+02	2.04E+03
1.26E+00	4.66E+00	1.84E+02	1.92E+03
1.37E+00	5.08E+00	2.00E+02	1.78E+03
1.51E+00	5.59E+00	2.20E+02	1.63E+03
1.59E+00	5.87E+00	2.31E+02	1.54E+03
1.65E+00	6.10E+00	2.40E+02	1.45E+03
1.78E+00	6.60E+00	2.60E+02	1.34E+03

Table 4-15 (Cont.) Dose/Depth Calculations for the Planck Mission.

Planck Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
1.92E+00	7.11E+00	2.80E+02	1.25E+03
2.00E+00	7.39E+00	2.91E+02	1.18E+03
2.06E+00	7.62E+00	3.00E+02	1.12E+03
2.51E+00	9.30E+00	3.66E+02	9.29E+02
2.74E+00	1.02E+01	4.00E+02	8.38E+02
3.16E+00	1.17E+01	4.61E+02	7.40E+02
3.43E+00	1.27E+01	5.00E+02	6.53E+02
3.98E+00	1.47E+01	5.80E+02	5.62E+02
5.01E+00	1.86E+01	7.31E+02	4.36E+02
6.31E+00	2.34E+01	9.20E+02	3.49E+02
7.94E+00	2.94E+01	1.16E+03	2.73E+02
1.00E+01	3.70E+01	1.46E+03	2.14E+02

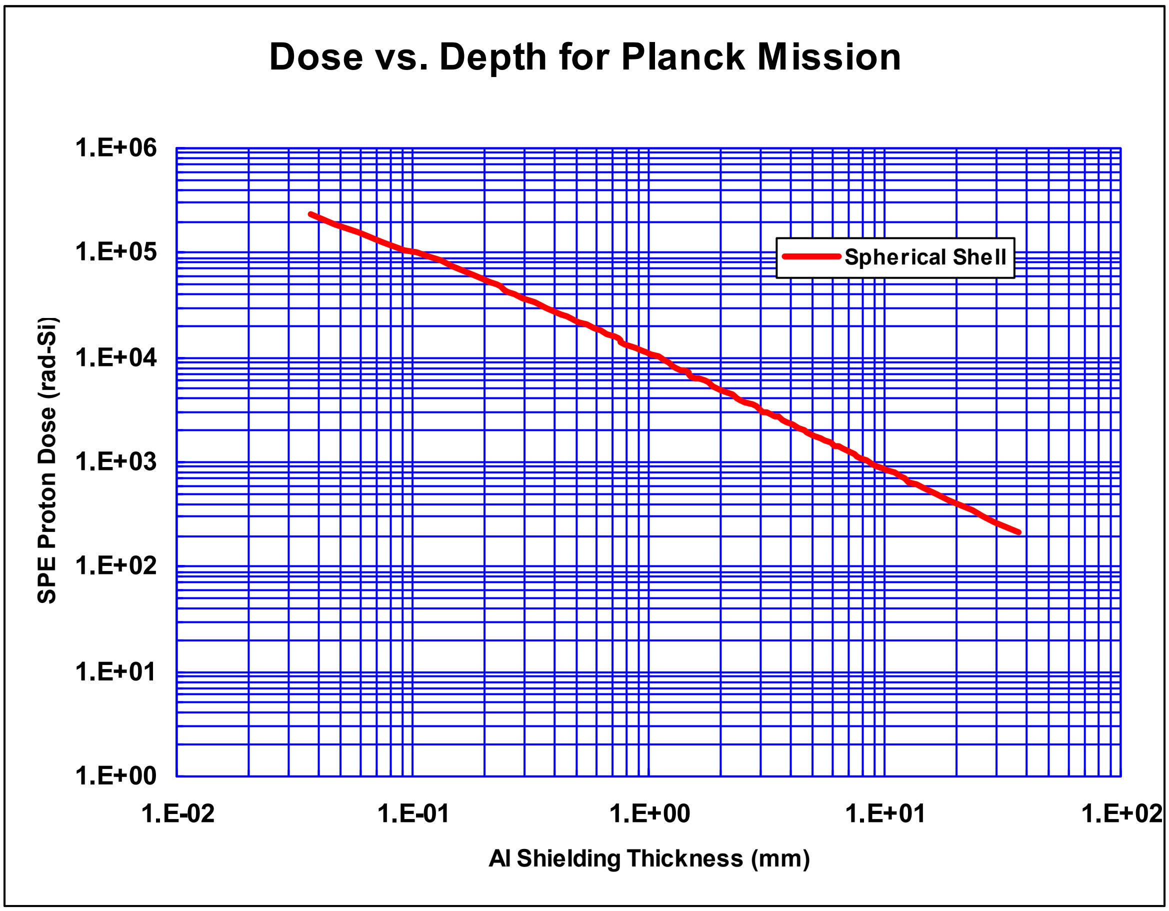


Figure 4-12 Planck Mission – Dose vs. Depth Curve.

The proton dose (rad-Si) from predicted Solar Proton Events (SPE's) is plotted as a function of Al shielding thickness for a spherical shell.

4.10.1.2. Herschel MISSION

Mission duration is 3.0 years and an RDF of 1 is assumed for the calculation. Table 4-16 gives the dose for shielding by a spherical Al shell. The information is plotted in Figure 4-13.

**Table 4-16 Dose/Depth Calculations for the Herschel Mission.
Dose as a function of shielding thickness is presented. Shielding geometry of a spherical shell is used.
Shielding is Aluminum.**

Herschel Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
1.00E-02	3.70E-02	1.46E+00	4.67E+05
1.26E-02	4.66E-02	1.84E+00	3.82E+05
1.59E-02	5.87E-02	2.31E+00	3.11E+05
2.00E-02	7.39E-02	2.91E+00	2.59E+05
2.51E-02	9.30E-02	3.66E+00	2.17E+05
3.16E-02	1.17E-01	4.61E+00	1.82E+05
3.98E-02	1.47E-01	5.80E+00	1.52E+05
5.01E-02	1.86E-01	7.31E+00	1.19E+05
6.31E-02	2.34E-01	9.20E+00	9.72E+04
6.86E-02	2.54E-01	1.00E+01	8.58E+04
7.94E-02	2.94E-01	1.16E+01	7.49E+04
1.00E-01	3.70E-01	1.46E+01	5.87E+04
1.26E-01	4.66E-01	1.84E+01	4.82E+04
1.37E-01	5.08E-01	2.00E+01	4.32E+04
1.59E-01	5.87E-01	2.31E+01	3.82E+04
2.00E-01	7.39E-01	2.91E+01	3.11E+04
2.06E-01	7.62E-01	3.00E+01	2.85E+04
2.51E-01	9.30E-01	3.66E+01	2.37E+04
2.74E-01	1.02E+00	4.00E+01	2.11E+04
3.16E-01	1.17E+00	4.61E+01	1.85E+04
3.43E-01	1.27E+00	5.00E+01	1.63E+04
3.98E-01	1.47E+00	5.80E+01	1.45E+04
4.12E-01	1.52E+00	6.00E+01	1.34E+04
4.80E-01	1.78E+00	7.00E+01	1.17E+04
5.01E-01	1.86E+00	7.31E+01	1.07E+04
5.49E-01	2.03E+00	8.00E+01	9.72E+03
6.17E-01	2.29E+00	9.00E+01	8.87E+03
6.31E-01	2.34E+00	9.20E+01	8.34E+03
6.86E-01	2.54E+00	1.00E+02	7.61E+03
7.94E-01	2.94E+00	1.16E+02	6.67E+03
8.23E-01	3.05E+00	1.20E+02	6.11E+03
9.60E-01	3.56E+00	1.40E+02	5.40E+03
1.00E+00	3.70E+00	1.46E+02	4.99E+03
1.10E+00	4.06E+00	1.60E+02	4.52E+03
1.23E+00	4.57E+00	1.80E+02	4.08E+03
1.26E+00	4.66E+00	1.84E+02	3.85E+03
1.37E+00	5.08E+00	2.00E+02	3.55E+03
1.51E+00	5.59E+00	2.20E+02	3.26E+03
1.59E+00	5.87E+00	2.31E+02	3.08E+03
1.65E+00	6.10E+00	2.40E+02	2.89E+03
1.78E+00	6.60E+00	2.60E+02	2.68E+03
1.92E+00	7.11E+00	2.80E+02	2.51E+03
2.00E+00	7.39E+00	2.91E+02	2.37E+03

Table 4-16 (Cont.) Dose/Depth Calculations for the Herschel Mission.

Herschel Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
2.06E+00	7.62E+00	3.00E+02	2.24E+03
2.51E+00	9.30E+00	3.66E+02	1.86E+03
2.74E+00	1.02E+01	4.00E+02	1.68E+03
3.16E+00	1.17E+01	4.61E+02	1.48E+03
3.43E+00	1.27E+01	5.00E+02	1.31E+03
3.98E+00	1.47E+01	5.80E+02	1.12E+03
5.01E+00	1.86E+01	7.31E+02	8.72E+02
6.31E+00	2.34E+01	9.20E+02	6.99E+02
7.94E+00	2.94E+01	1.16E+03	5.46E+02
1.00E+01	3.70E+01	1.46E+03	4.29E+02

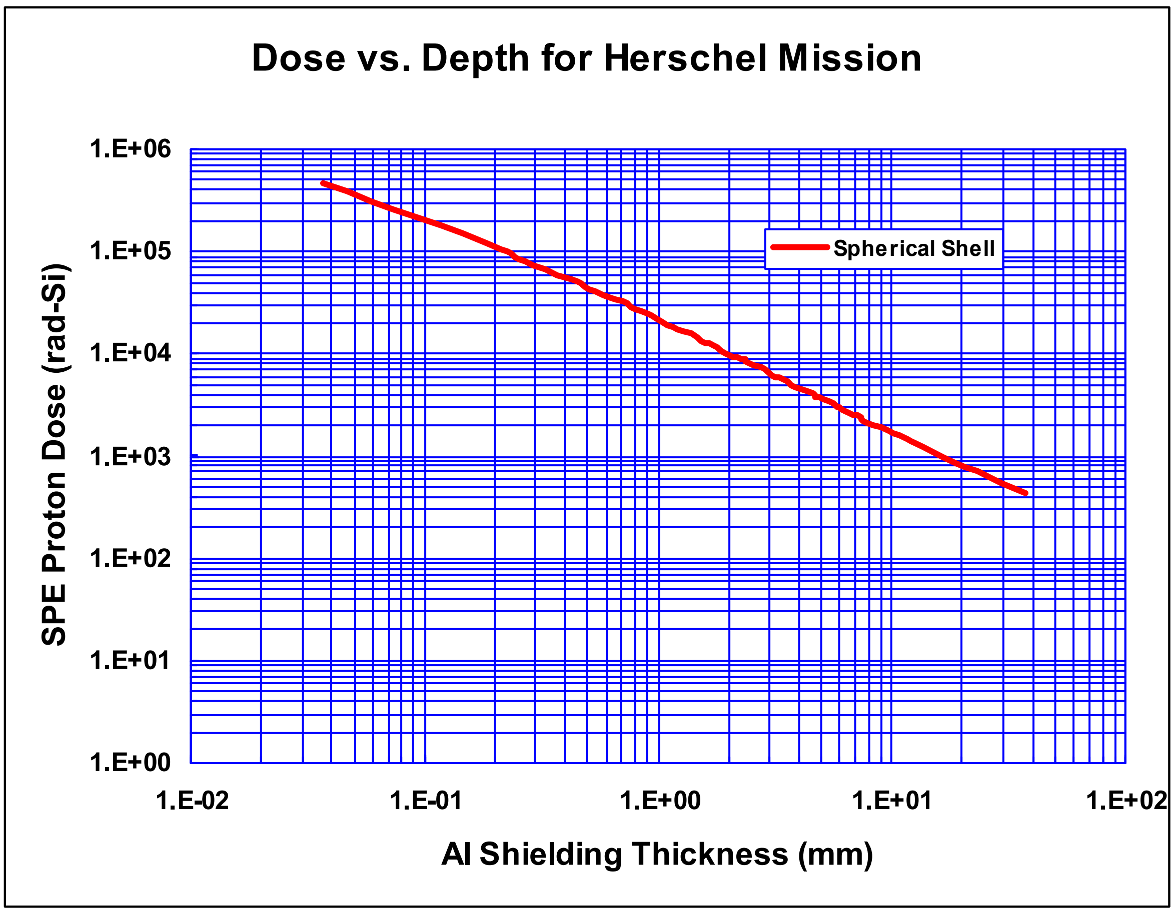


Figure 4-13 Herschel Mission – Dose vs. Depth Curve.
The proton dose (rad-Si) from predicted Solar Proton Events (SPE's) is plotted as a function of Al shielding thickness for a spherical shell.

4.10.1.3. Herschel MISSION (extended)

Mission duration is 5.0 years and an RDF of 1 is assumed for the calculation. Table 4-17 gives the dose for shielding by a spherical Al. The information is plotted in Figure 4-14.

**Table 4-17 Dose/Depth Calculations for the Herschel Mission (Extended).
Dose as a function of shielding thickness is presented. Shielding geometry of a spherical shell is used.
Shielding is Aluminum.**

Ext. Herschel Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
1.00E-02	3.70E-02	1.46E+00	7.78E+05
1.26E-02	4.66E-02	1.84E+00	6.36E+05
1.59E-02	5.87E-02	2.31E+00	5.19E+05
2.00E-02	7.39E-02	2.91E+00	4.32E+05
2.51E-02	9.30E-02	3.66E+00	3.61E+05
3.16E-02	1.17E-01	4.61E+00	3.03E+05
3.98E-02	1.47E-01	5.80E+00	2.54E+05
5.01E-02	1.86E-01	7.31E+00	1.98E+05
6.31E-02	2.34E-01	9.20E+00	1.62E+05
6.86E-02	2.54E-01	1.00E+01	1.43E+05
7.94E-02	2.94E-01	1.16E+01	1.25E+05
1.00E-01	3.70E-01	1.46E+01	9.79E+04
1.26E-01	4.66E-01	1.84E+01	8.03E+04
1.37E-01	5.08E-01	2.00E+01	7.20E+04
1.59E-01	5.87E-01	2.31E+01	6.36E+04
2.00E-01	7.39E-01	2.91E+01	5.19E+04
2.06E-01	7.62E-01	3.00E+01	4.76E+04
2.51E-01	9.30E-01	3.66E+01	3.95E+04
2.74E-01	1.02E+00	4.00E+01	3.52E+04
3.16E-01	1.17E+00	4.61E+01	3.08E+04
3.43E-01	1.27E+00	5.00E+01	2.72E+04
3.98E-01	1.47E+00	5.80E+01	2.41E+04
4.12E-01	1.52E+00	6.00E+01	2.23E+04
4.80E-01	1.78E+00	7.00E+01	1.95E+04
5.01E-01	1.86E+00	7.31E+01	1.78E+04
5.49E-01	2.03E+00	8.00E+01	1.62E+04
6.17E-01	2.29E+00	9.00E+01	1.48E+04
6.31E-01	2.34E+00	9.20E+01	1.39E+04
6.86E-01	2.54E+00	1.00E+02	1.27E+04
7.94E-01	2.94E+00	1.16E+02	1.11E+04
8.23E-01	3.05E+00	1.20E+02	1.02E+04
9.60E-01	3.56E+00	1.40E+02	9.01E+03
1.00E+00	3.70E+00	1.46E+02	8.32E+03
1.10E+00	4.06E+00	1.60E+02	7.54E+03
1.23E+00	4.57E+00	1.80E+02	6.80E+03
1.26E+00	4.66E+00	1.84E+02	6.41E+03
1.37E+00	5.08E+00	2.00E+02	5.92E+03
1.51E+00	5.59E+00	2.20E+02	5.43E+03
1.59E+00	5.87E+00	2.31E+02	5.14E+03
1.65E+00	6.10E+00	2.40E+02	4.82E+03
1.78E+00	6.60E+00	2.60E+02	4.47E+03

Table 4-17 (Cont.) Dose/Depth Calculations for the Herschel Mission (Extended).

Ext. Herschel Mission			
	Thickness		Spherical Shell
g/cm2	mm	mils	Dose (rad-Si)
1.92E+00	7.11E+00	2.80E+02	4.18E+03
2.00E+00	7.39E+00	2.91E+02	3.95E+03
2.06E+00	7.62E+00	3.00E+02	3.74E+03
2.51E+00	9.30E+00	3.66E+02	3.10E+03
2.74E+00	1.02E+01	4.00E+02	2.80E+03
3.16E+00	1.17E+01	4.61E+02	2.47E+03
3.43E+00	1.27E+01	5.00E+02	2.18E+03
3.98E+00	1.47E+01	5.80E+02	1.87E+03
5.01E+00	1.86E+01	7.31E+02	1.45E+03
6.31E+00	2.34E+01	9.20E+02	1.17E+03
7.94E+00	2.94E+01	1.16E+03	9.10E+02
1.00E+01	3.70E+01	1.46E+03	7.15E+02

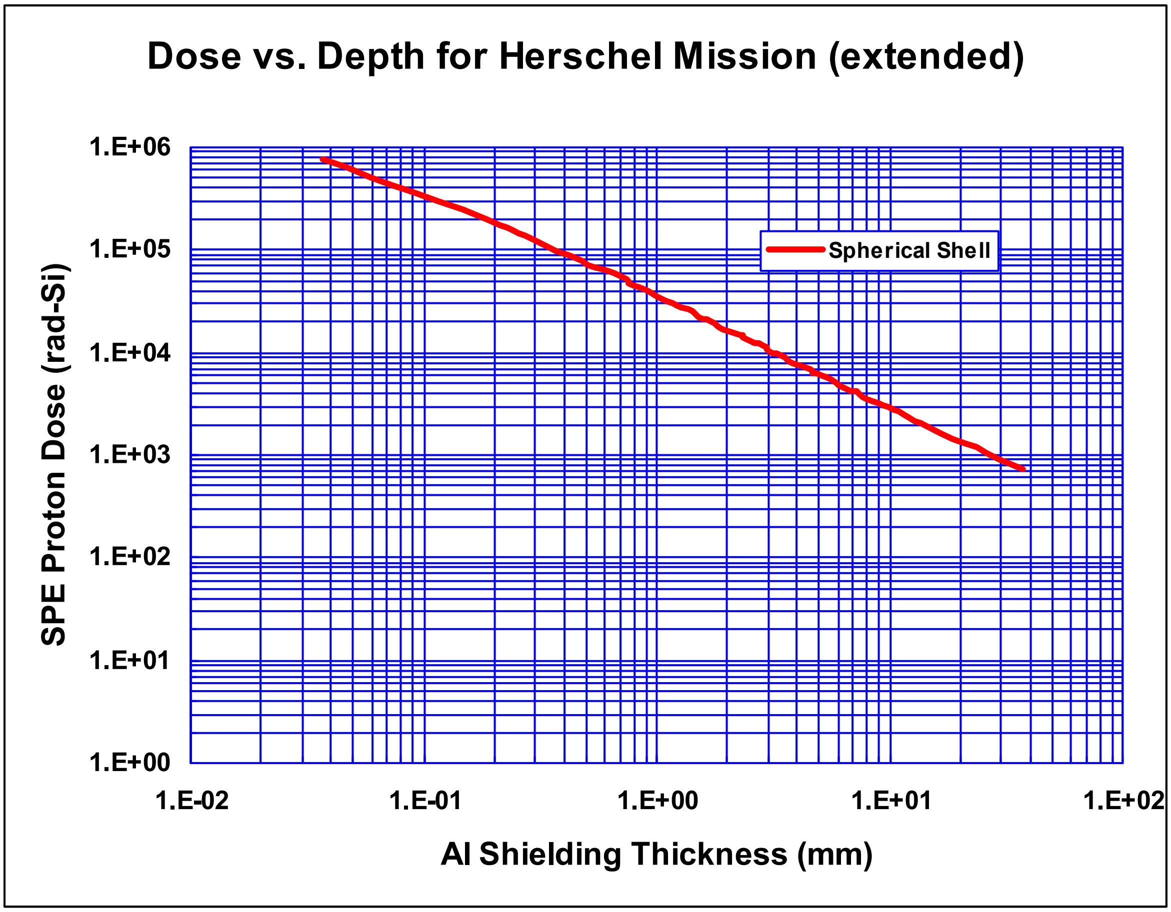


Figure 4-14 Herschel Mission (extended)– Dose vs. Depth Curve.
The proton dose (rad-Si) from predicted Solar Proton Events (SPE's) is plotted as a function of Al shielding thickness for a spherical shell.

4.10.2 SINGLE EVENT EFFECTS (SEE) RADIATION ENVIRONMENT

Electronics may be susceptible to single event effects, or SEE, which include reversible, non-destructive actions (termed 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. These types of high-energy particles are found in galactic cosmic rays and solar particle events. 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-cm2/mg, then high-energy protons can also cause SEE.

A subsystem's electronic devices shall be chosen such that the subsystem operates within performance specification during and after exposure to the charged-particle radiation environments specified in this section.

The subsystem and system-level requirements regarding performance with respect to SEE during operation are as follows:

- 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.

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

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

- Irreversible actions (e.g. latch-up or gate rupture) shall not be permitted.

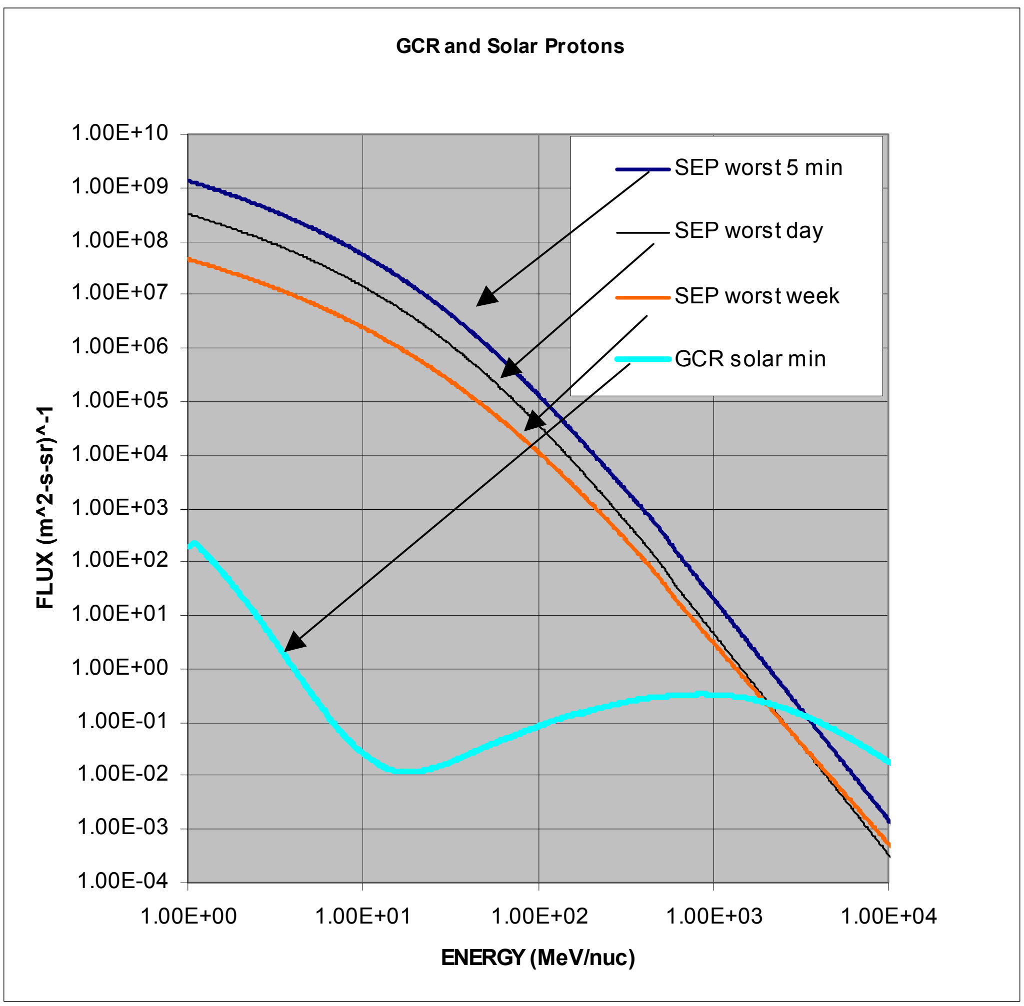
An RDF = 1 shall be applied to the environments specified in this section.

The following solar particle and galactic cosmic ray (GCR) environments shall be used to evaluate the SEE rates of electronic devices:

GCR heavy ions given by the CREME96 solar minimum environment (Figure 4-16)

GCR protons given by the CREME96 solar minimum environment (for proton-induced SEE) (Figure 4-15)

Solar particle event heavy ions given by the CREME96 worst case (5 minute average) solar event model (Figure 4-15)



Solar particle event protons given by the CREME96 worst case (5 minute average) solar event model (for proton-induced) (Figure 4-15)

Figure 4-15 Solar Energetic Proton (SEP) and GCR proton fluxes for determining SEE rates.

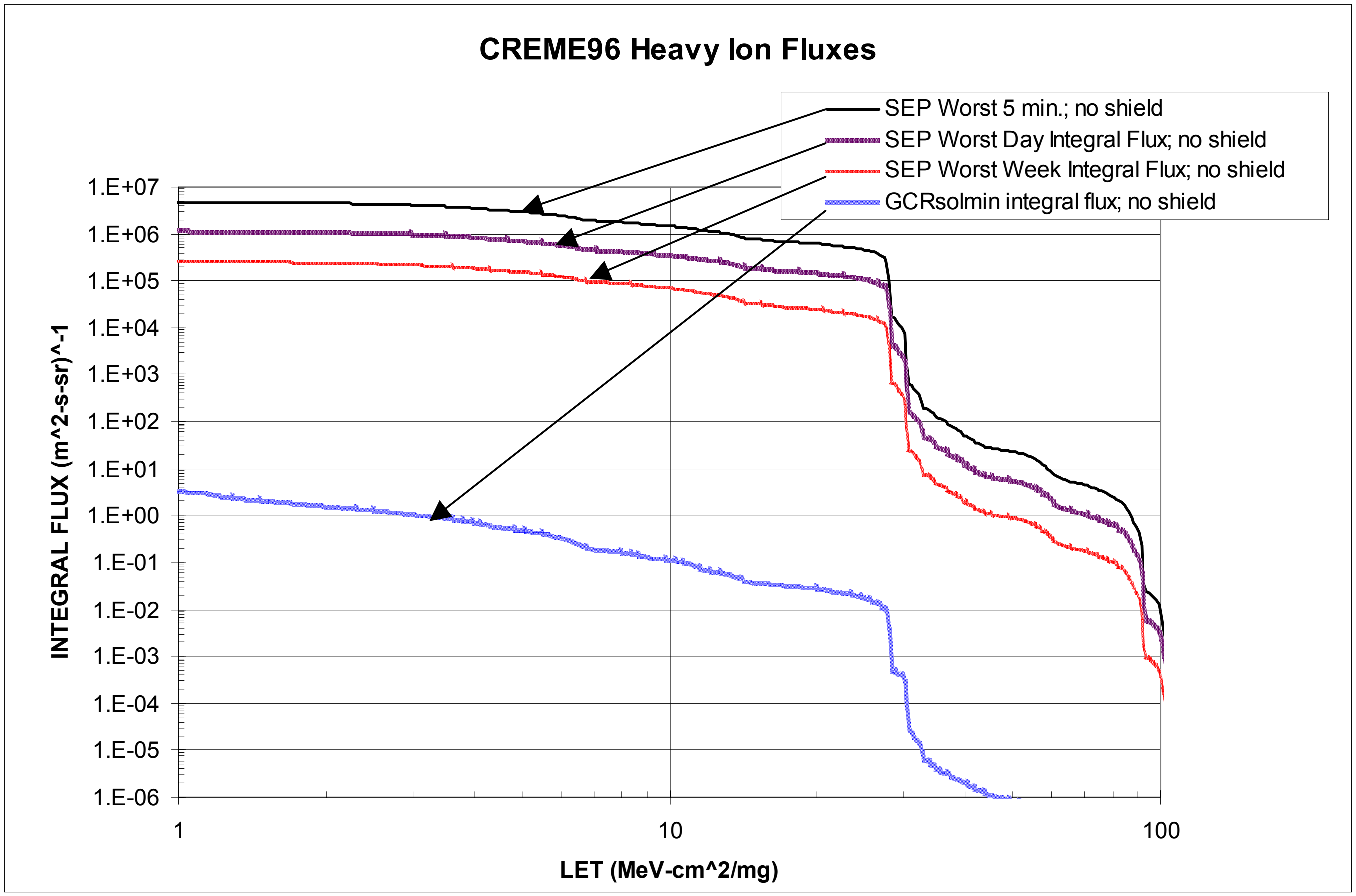


Figure 4-16 Creme96 Heavy Ion Fluxes

4.11. SOLID PARTICLE ENVIRONMENTS.

The spacecraft shall have a greater than 95% probability of meeting performance requirements after exposure to the meteoroid and orbital debris environments specified in this section.
The environments in this section represent the nominal environments external to the spacecraft. No design factor needs to be applied to these environments.

4.11.1 Meteoroid Environment

The spacecraft shall have a greater than 95% probability of meeting performance requirements after exposure to the meteoroid environment specified in Figure 4-17 and Tables 4-18, 4-19 and 4-20.

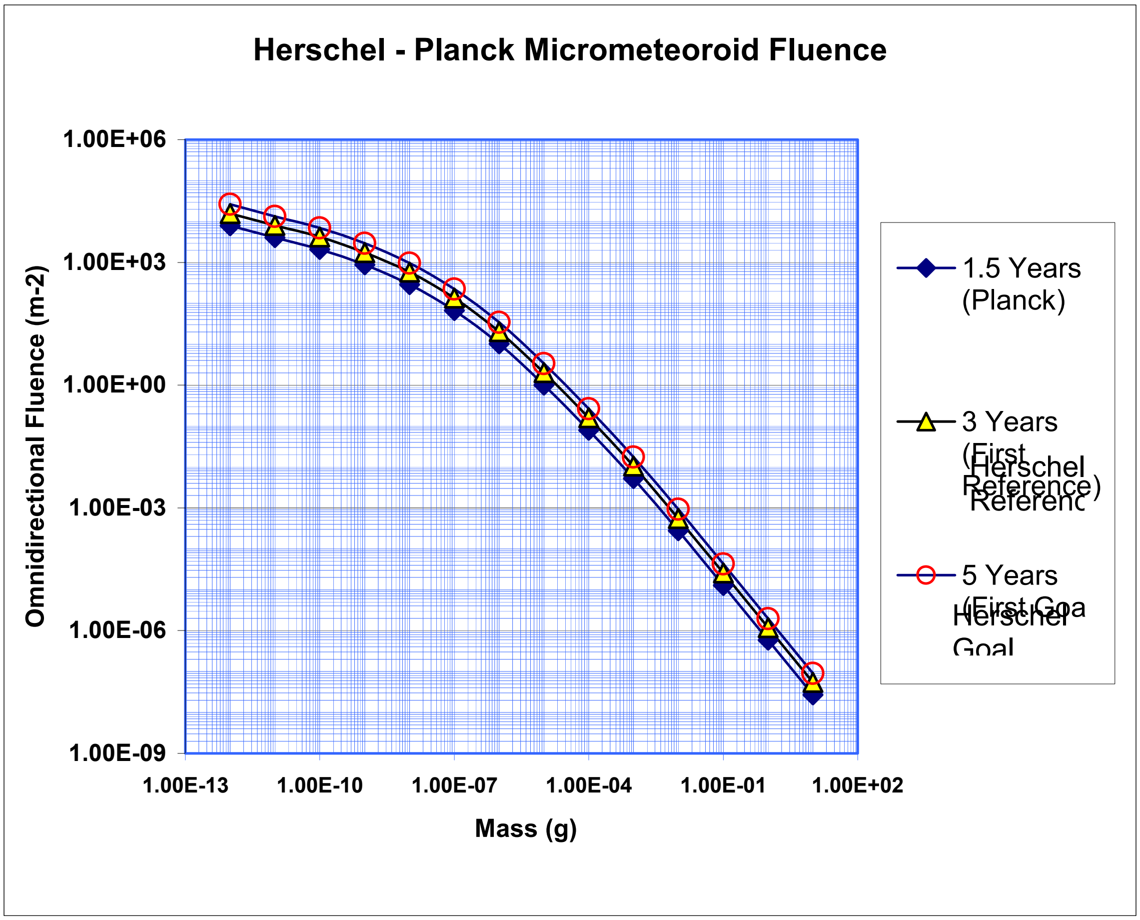


Figure 4-17 Omnidirectional Meteoroid Fluence as a function of Mass.

Table 4-18 Planck Omnidirectional micrometeoroid fluence for 1.5 years at 1 AU.

Underlined is minimum mass of micrometeoroids in grams. First column is impact velocity in m/s. The listings are for fluence in m^{-2}.

Period in Days = 548

FLUENCE (m-2)

	1.00E-12	1.00E-11	1.00E-10	1.00E-09	1.00E-08	1.00E-07	1.00E-06
all	7.88E+03	4.01E+03	2.10E+03	8.76E+02	2.89E+02	6.69E+01	1.02E+01
0.00E+00	2.01E+03	9.71E+02	4.63E+02	2.06E+02	7.68E+01	1.90E+01	2.97E+00
1.00E+04	2.20E+03	1.08E+03	5.22E+02	2.30E+02	8.38E+01	2.05E+01	3.16E+00
1.50E+04	1.53E+03	7.75E+02	4.02E+02	1.69E+02	5.65E+01	1.34E+01	2.04E+00
2.00E+04	1.19E+03	6.34E+02	3.54E+02	1.42E+02	4.25E+01	9.56E+00	1.44E+00
2.50E+04	5.02E+02	3.11E+02	2.08E+02	7.45E+01	1.57E+01	2.84E+00	4.11E-01
3.00E+04	2.48E+02	1.56E+02	1.07E+02	3.74E+01	7.30E+00	1.08E+00	1.41E-01
4.00E+04	1.98E+02	8.80E+01	3.91E+01	1.57E+01	6.31E+00	6.36E-01	2.61E-02

	1.00E-05	1.00E-04	1.00E-03	1.00E-02	1.00E-01	1.00E+00	1.00E+01
all	1.01E+00	7.97E-02	5.26E-03	2.77E-04	1.28E-05	5.88E-07	2.72E-08
0.00E+00	3.20E-01	3.01E-02	2.18E-03	1.18E-04	5.51E-06	2.55E-07	1.18E-08
1.00E+04	3.16E-01	2.49E-02	1.65E-03	8.66E-05	4.01E-06	1.84E-07	8.52E-09
1.50E+04	1.96E-01	1.39E-02	8.56E-04	4.40E-05	2.02E-06	9.21E-08	4.25E-09
2.00E+04	1.31E-01	7.79E-03	4.14E-04	2.01E-05	8.98E-07	4.04E-08	1.85E-09
2.50E+04	3.82E-02	2.46E-03	1.41E-04	7.07E-06	3.20E-07	1.45E-08	6.67E-10
3.00E+04	1.20E-02	6.02E-04	2.62E-05	1.15E-06	4.87E-08	2.12E-09	9.56E-11
4.00E+04	7.22E-04	1.94E-05	4.87E-07	1.23E-08	3.09E-10	7.77E-12	1.96E-13

Note: The fluence numbers are for all micrometeoroids of mass greater than or equal to the minimum mass underlined at the top of the column.

Table 4-19 Herschel Requirement Omnidirectional micrometeoroid fluence for 3 years at 1 AU.

Underlined is minimum mass of micrometeoroids in grams. First column is impact velocity in m/s. The listings are for fluence in m^{-2}.

Period in Days = 1095

FLUENCE (m-2)

	1.00E-12	1.00E-11	1.00E-10	1.00E-09	1.00E-08	1.00E-07	1.00E-06
all	1.57E+04	8.02E+03	4.19E+03	1.75E+03	5.77E+02	1.34E+02	2.04E+01
0.00E+00	4.01E+03	1.94E+03	9.25E+02	4.12E+02	1.53E+02	3.79E+01	5.93E+00
1.00E+04	4.40E+03	2.15E+03	1.04E+03	4.59E+02	1.67E+02	4.09E+01	6.32E+00
1.50E+04	3.05E+03	1.55E+03	8.03E+02	3.38E+02	1.13E+02	2.67E+01	4.08E+00
2.00E+04	2.38E+03	1.27E+03	7.08E+02	2.84E+02	8.49E+01	1.91E+01	2.88E+00
2.50E+04	1.00E+03	6.22E+02	4.16E+02	1.49E+02	3.13E+01	5.67E+00	8.22E-01
3.00E+04	4.95E+02	3.12E+02	2.14E+02	7.46E+01	1.46E+01	2.17E+00	2.82E-01
4.00E+04	3.95E+02	1.76E+02	7.81E+01	3.14E+01	1.26E+01	1.27E+00	5.22E-02

	1.00E-05	1.00E-04	1.00E-03	1.00E-02	1.00E-01	1.00E+00	1.00E+01
all	2.02E+00	1.59E-01	1.05E-02	5.53E-04	2.56E-05	1.17E-06	5.43E-08
0.00E+00	6.40E-01	6.01E-02	4.35E-03	2.35E-04	1.10E-05	5.09E-07	2.37E-08
1.00E+04	6.31E-01	4.98E-02	3.29E-03	1.73E-04	8.02E-06	3.67E-07	1.70E-08
1.50E+04	3.92E-01	2.77E-02	1.71E-03	8.79E-05	4.03E-06	1.84E-07	8.49E-09
2.00E+04	2.62E-01	1.56E-02	8.28E-04	4.02E-05	1.79E-06	8.07E-08	3.70E-09
2.50E+04	7.64E-02	4.92E-03	2.82E-04	1.41E-05	6.40E-07	2.90E-08	1.33E-09
3.00E+04	2.40E-02	1.20E-03	5.24E-05	2.30E-06	9.73E-08	4.25E-09	1.91E-10
4.00E+04	1.44E-03	3.87E-05	9.73E-07	2.45E-08	6.16E-10	1.55E-11	3.93E-13

Note: The fluence numbers are for all micrometeoroids of mass greater than or equal to the minimum mass underlined at the top of the column.

Table 4-20 Herschel (Extended) Omnidirectional micrometeoroid fluence for 5 years at 1 AU.

Underlined is minimum mass of micrometeoroids in grams. First column is impact velocity in m/s. The listings are for fluence in m^{-2}.

Period in Days = 1825

FLUENCE (m-2)

	1.00E-12	1.00E-11	1.00E-10	1.00E-09	1.00E-08	1.00E-07	1.00E-06
all	2.62E+04	1.34E+04	6.98E+03	2.92E+03	9.61E+02	2.23E+02	3.39E+01
0.00E+00	6.68E+03	3.23E+03	1.54E+03	6.87E+02	2.56E+02	6.32E+01	9.88E+00
1.00E+04	7.34E+03	3.59E+03	1.74E+03	7.65E+02	2.79E+02	6.82E+01	1.05E+01
1.50E+04	5.08E+03	2.58E+03	1.34E+03	5.63E+02	1.88E+02	4.45E+01	6.80E+00
2.00E+04	3.96E+03	2.11E+03	1.18E+03	4.73E+02	1.42E+02	3.18E+01	4.79E+00
2.50E+04	1.67E+03	1.04E+03	6.93E+02	2.48E+02	5.22E+01	9.46E+00	1.37E+00
3.00E+04	8.26E+02	5.20E+02	3.57E+02	1.24E+02	2.43E+01	3.61E+00	4.71E-01
4.00E+04	6.59E+02	2.93E+02	1.30E+02	5.23E+01	2.10E+01	2.12E+00	8.71E-02

	1.00E-05	1.00E-04	1.00E-03	1.00E-02	1.00E-01	1.00E+00	1.00E+01
all	3.37E+00	2.65E-01	1.75E-02	9.22E-04	4.26E-05	1.96E-06	9.05E-08
0.00E+00	1.07E+00	1.00E-01	7.26E-03	3.92E-04	1.84E-05	8.49E-07	3.94E-08
1.00E+04	1.05E+00	8.29E-02	5.48E-03	2.88E-04	1.34E-05	6.12E-07	2.84E-08
1.50E+04	6.53E-01	4.62E-02	2.85E-03	1.46E-04	6.71E-06	3.07E-07	1.42E-08
2.00E+04	4.36E-01	2.59E-02	1.38E-03	6.70E-05	2.99E-06	1.35E-07	6.16E-09
2.50E+04	1.27E-01	8.20E-03	4.71E-04	2.35E-05	1.07E-06	4.83E-08	2.22E-09
3.00E+04	4.01E-02	2.00E-03	8.73E-05	3.83E-06	1.62E-07	7.08E-09	3.18E-10
4.00E+04	2.40E-03	6.45E-05	1.62E-06	4.08E-08	1.03E-09	2.59E-11	6.54E-13

Note: The fluence numbers are for all micrometeoroids of mass greater than or equal to the minimum mass underlined at the top of the column.

4.12. ORBITAL DEBRIS

The orbital debris assessment will be performed at the spacecraft level.

4.13. ATOMIC OXYGEN

No Requirements.

4.14. SOLAR ELECTROMAGNETIC RADIATION

Exposed materials and surfaces on the spacecraft shall meet all performance requirements after exposure to 5 Sun-years of solar electromagnetic radiation, as derived from a solar power flux of 1371 W/m^2 and the solar irradiance spectrum of Table 4-21.

Table 4-21 Solar Electromagnetic Radiation Environment

	0 Solar Spectral Irradiance Data 0.0850 to 7.0 Microns				
lambda l	p (%)	lambda	P (%)	lambda	p(%)
(micro m)		(micro m)		(micro M)	
---------	----------------	------------------	----------------	-----	
		0.360	5.317	0.670	43.745
		0.365	5.732	0.680	44.816
		0.370	6.151	0.690	45.856
		0.375	6.583	0.700	46.880
		0.380	7.003	0.710	47.882
		0.385	7.413	0.720	48.865
		0.390	7.819	0.730	49.827
0.120	0.0004	0.395	8.242	0.740	50.769
0.125	0.0005	0.400	8.725	0.750	51.691
0.130	0.0005	0.405	9.293	0.800	56.019
0.135	0.0005	0.410	9.920	0.850	59.890
0.140	0.0005	0.415	10.572	0.900	63.358
0.145	0.0009	0.420	11.222	0.950	66.544
0.150	0.0009	0.425	11.858	1.000	69.465
0.155	0.0006	0.430	12.474	1.100	74.409
0.160	0.0007	0.435	13.084	1.200	78.836
0.165	0.0008	0.440	13.726	1.300	81.638
0.170	0.0010	0.445	14.415	1.400	84.343
0.175	0.0013	0.450	15.141	1.500	86.645
0.180	0.0017	0.455	15.892	1.600	88.607
0.185	0.0023	0.460	16.653	1.700	90.256
0.190	0.0032	0.465	17.414	1.800	91.590
0.195	0.0082	0.470	18.168	1.900	92.643
0.200	0.0081	0.475	18.921	2.000	93.489
0.205	0.013	0.480	19.682	2.100	94.202
0.210	0.021	0.485	20.430	2.200	94.827
0.215	0.035	0.490	21.156	2.300	95.370
0.220	0.050	0.495	21.878	2.400	95.858
0.225	0.073	0.500	22.599	2.500	96.294
0.230	0.097	0.505	23.313	2.600	96.671
0.235	0.121	0.510	24.015	2.700	97.007
0.240	0.143	0.515	24.702	2.800	97.310
0.245	0.168	0.520	25.379	2.900	97.584
0.250	0.194	0.525	26.060	3.000	97.828
0.255	0.227	0.530	26.743	3.100	98.038
0.260	0.270	0.535	27.419	3.200	98.218
0.265	0.328	0.540	28.084	3.300	98.372
0.270	0.405	0.545	28.738	3.400	98.505
0.275	0.486	0.550	29.381	3.500	98.620
0.280	0.564	0.555	30.017	3.600	98.724
0.285	0.644	0.560	30.648	3.700	98.819
0.290	0.811	0.565	31.276	3.800	98.906
0.295	1.008	0.570	31.908	3.900	98.985
0.300	1.211	0.575	32.542	4.000	99.058
0.305	1.417	0.580	33.176	4.100	99.125
0.310	1.656	0.585	33.908	4.200	99.186
0.315	1.924	0.590	34.440	4.300	99.241
0.320	2.219	0.595	35.065	4.400	99.291
0.325	2.552	0.600	35.683	4.500	99.337
0.330	2.928	0.610	36.902	4.600	99.379
0.335	3.324	0.620	38.098	4.700	99.416
0.340	3.722	0.630	39.270	4.800	99.450
0.345	4.118	0.640	40.421	4.900	99.482
0.350	4.517	0.650	41.550	5.000	99.511
0.355	4.919	0.660	42.655	6.000	99.718
lambda is wavelength; and P is the percentage of the solar constant associated with wavelengths shorter than lambda					

5.0 ASSEMBLY AND SUBSYSTEM ENVIRONMENTAL TEST IMPLEMENTATION

5.1. GENERAL

This section provides detail requirements for environmental testing of Herschel/Planck assemblies and subsystems delivered by JPL. Additional test implementation requirements are presented in Appendix B.

5.2. TEST CONFIGURATIONS

5.2.1 ASSEMBLY

In all tests, the electrical cabling, connectors, and other hardware associated with the assembly shall be used and considered part of the assembly. Each test article will be comprised of the serial numbered subassemblies that are intended to remain with the assembly or subsystem through delivery.

5.3. ENVIRONMENTAL TEST

Test parameters shall not exceed the following tolerances, unless otherwise specified.

5.3.1 DYNAMICS TEST TOLERANCES

The dynamics test tolerances shall be as follows:

Sinusoidal vibration level: Measured sine amplitude will be within ±10 % of the specified value.

Random vibration spectral shape: Measured in frequency bands no more than 25 Hz band-wide, the Power Spectral Density (PSD) test spectra will be within ±3 dB above 500 Hz and ±1.5 dB below 500 Hz.

Random vibration overall (RMS) level: Within ±1 dB of that specified.

Acoustic spectral shape: Tolerances for Sound Pressure Levels (SPLs), measured in fixed 1/3-octave bands, are given in Table 4-12. Acoustic overall level: Within +3,-1 dB of the specified level.

Frequency: Within ± 5% or ±1 Hz, which ever is greater.

Time: +5 %, -0 %

Pyroshock SRS level: Within ±3 dB of the specified shock spectrum level.

5.3.2 THERMAL/VACUUM AND TEMPERATURE/ATMOSPHERE TEST TOLERANCES

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

3. <u>Pressure</u>: +2 to -5 percent from atmospheric to 10 percent of atmospheric. At vacuum conditions, tolerances will be such that a pressure of $1x10^{-5}$ Torr or less is assured.
4. <u>Time</u>: +10, -0 minutes
5. Temperature: Tmax: -0°c, +3°c,
   Tmin +0°c, -3°c
6. Thermal Stability: dTdt < 1°C/hr.

5.3.3 EMC/MAGNETICS TEST TOLERANCES

The EMC/Magnetics test values will be measured within the following tolerances:

1. Voltage: +10 percent of the peak value
2. Current: +10 percent of the peak value
3. RF Amplitudes: +5 dB
4. Frequency: +2 percent
5. Resistance: +10 percent
6. Distance: +5 percent of specified distance or +5.0 cm, whichever is less.

6.0 ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AFT	Allowable Flight Temperature
AM	Amplitude Modulation
ASD	Acceleration Spectral Density
ATLO	Assembly, Test, and Launch Operations
BEU	Block-End Unit
BOLA	Bolometer Amplifier
Cog/E	Cognizant Engineer
CVV	Cryostat Vacuum Vessel
DC	Direct Current
EACS	Environmental Analysis Completion Statement
ECR	Engineering Change Requirement
ELDR	Enhanced Low Dose Rate
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ERD	Environmental Requirements Document
ERE	Environmental Requirements Engineer
ESA	European Space Agency
ESD	Electrostatic Discharge
ETAS	Environmental Test Authorization and Summary
EUV	Solar Electromagnetic Radiation
FA	Flight Acceptance
FM	Flight Model
FPU	Focal Plane Unit, Planck Sorption Cooler
FS	Flight Spare
Herschel	Far InfraRed and Submillimetre Telescope
HW	Hardware
GCR	Gelactic Cosmic Rays
GSE	Ground Support Equipment
HEB	Hot Electronic Bolometer
HFI	High Frequency Instrument
HIFI	Heterodyne Instrument for Herschel
HRCR	Hardware Review/Certification Requirement
I&T	Integration and Test
ICD	Interface Control Document
JFET	Junction Field Effect Transistor
JPL	Jet Propulsion Laboratory
LET	Linear Energy Transfer
LFI	Low Frequency Instrument
LOU	Local Oscillator Unit
MAM	Mission Assurance Manager
MIL-STD	Military Standard
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NIEL	Non-Ionizing Energy Loss
PEM	Project Element Manager
PF	Protoflight
PFR	Problem/Failure Report
QA	Quality Assurance
QUAL	Qualification (Model)
RDF	Radiation Design Factor
RF	Radio Frequency
SA	Safety Assurance
SCC	Sorption Cooler Compressor
SEE	Single Event Effects
SEGR	Single Event Gate Rupture
SER	Solar Electromagnetic Radiation
SEU	Single Event Upset
SM	Section Manager
SPIRE	Spectral and Photometric Imaging Receiver
SPL	Sound Pressure Level
SRS	Shock Response Spectrum
SVM	Service Module, Planck Spacecraft
TBD	To Be Determined
TBS	To Be Specified
TID	Total Ionizing Dose
URL	Uniform Resource Locator
VTFMT	Voltage/Temperature /Frequency Margin Testing

7.0 APPENDIX A: SAMPLE ETAS FORM

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

AUTHORIZATION SECTION

PROJECT		LOG NO.	
SUBSYSTEM / ASSEMBLY TITLE			DATE ISSUED
REFERENCE DESIGNATION NO.	PART NO. (IF MULTIPLE, ATTACH LIST)	REV.	SERIAL NO.
HARDWARE TYPE ☐ EM QUAL ☐ FLIGHT ☐ FLIGHT SPARE ☐ OTHER ____	PRE-ENVIRONMENTAL INSPECTION REPORT NUMBER (ATTACH IR)		
WIRING HARNESS ☐ FLIGHT ☐ FLIGHT SPARE ☐ EM ☐ S.E.	PART NO.	REV.	SERIAL NO.

TEST DESCRIPTION (CHECK ALL APPLICABLE)
☐ SINE VIBRATION ☐ PYROSHOCK ☐ ACOUSTIC ☐ EMC ☐ OTHER ____
☐ RANDOM VIBRATION ☐ THERMAL VAC ☐ THERMAL ATMOSPHERE

TYPE OF TEST
☐ QUALIFICATION ☐ FLIGHT ACCEPTANCE
☐ PROTO FLIGHT ☐ RETEST

WILL ALL TESTS/LEVELS/DURATIONS REQUIRED BY THE PROJECT DOCUMENTS BE PERFORMED ON THIS UNIT?
☐ YES ☐ NO (IF NO, ATTACH EXCEPTIONS LIST) ENTER PROJ. DOC. NO. AND REV. ____

HAS THE UNIT PASSED ALL PRE-ENVIRONMENTAL FUNCTIONAL TESTS?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

HAVE ALL DESIGN ANALYSES BEEN COMPLETED AND REQUIRED CHANGES BEEN IMPLEMENTED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

IS THE TEST ARTICLE IDENTICAL TO OTHER FLIGHT UNITS?
☐ YES ☐ NO (IF NO, LIST DIFFERENCES AND ATTACH)
BRIEF EXPLANATION

ARE ALL PFRs AGAINST THIS UNIT CLOSED?
☐ YES ☐ NO (IF NO, WILL ANY OPEN PFRs AFFECT ENVIRONMENTAL TESTING? HOW?)
BRIEF EXPLANATION

HAVE ALL WAIVERS AND ECRs BEEN APPROVED AND ARE THEY INCORPORATED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION) ☐ N/A
BRIEF EXPLANATION

TEST AUTHORIZED BY

COGNIZANT ENG.	DATE	TECHNICAL MGR./INSTR MGR./PI REP.	DATE	ENVIRONMENTAL REQUIREMENTS ENG.	DATE

SUMMARY SECTION

TEST AGENCY (IF MULTIPLE, ATTACH SUMMARY AND TEST DATES)	TEST INITIATION DATE	ACCUMULATED OPERATING HOURS PRIOR TO FIRST ENVIRONMENTAL TEST
SERIAL NUMBERS ACTUALLY TESTED	TEST TERMINATION DATE	OPERATING HOURS DURING ENVIRONMENTAL EXPOSURE

TEST DESCRIPTION

VIBRATION — AXES: X Y Z
SINE VIBRATION ☐ ☐ ☐
RANDOM VIBRATION ☐ ☐ ☐

ACOUSTIC ☐

PYROTECHNIC SHOCK — AXES: X Y Z ☐ ☐ ☐
SHOCKS/AXIS:

☐ THERMAL VACUUM
PRESSURE:
NO. OF CYCLES:

☐ TEMPERATURE ATMOSPHERE
NO. OF CYCLES:

☐ OTHER ____

EMC ☐ COND. SUSC. ☐ COND. EMIS. ☐ ISOLATION
☐ ESD ☐ RAD. SUSC. ☐ RAD. EMIS. ☐ MAGNETICS

TEMP. LEVEL (°C) AND ACCUMULATED DURATION (HRS.)
HOT: ____°C, ____h COLD: ____°C, ____h
HOT: ____°C, ____h COLD: ____°C, ____h

WERE THERE ANY PFRs GENERATED DURING ENVIRONMENTAL TESTS?
☐ YES ☐ NO (IF YES, ATTACH A COPY OF THE PFRs)
LIST PFR NOS. / BRIEF EXPLANATION

ARE THE POST ENVIRONMENTAL DAMAGE INSPECTIONS COMPLETE?
☐ YES ☐ NO (IF YES, ATTACH A COPY OF THE INSPECTION REPORTS. IF NO, ATTACH EXPLANATION.)
BRIEF EXPLANATION

WERE ALL PLANNED TESTS/LEVELS/DURATIONS ACHIEVED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

☐ TESTS HAVE NOT BEEN SUCCESSFULLY COMPLETED. SEE THE ATTACHED SUMMARY FOR ACTIONS THAT NEED TO BE TAKEN.

COGNIZANT ENG.	DATE	TECHNICAL MGR./INSTR MGR./PI REP.	DATE	ENVIRONMENTAL REQUIREMENTS ENG.	DATE

☐ HARDWARE HAS SUCCESSFULLY COMPLETED THE ENVIRONMENTAL TESTS LISTED ON THIS FORM OR REMAINING ACTIONS HAVE BEEN TAKEN, INCLUDING RETEST.

COGNIZANT ENG.	DATE	TECHNICAL MGR./INSTR MGR./PI REP.	DATE	ENVIRONMENTAL REQUIREMENTS ENG.	DATE

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

OTHER AUTHORIZATION PROVISIONS AND EXPLANATIONS

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)
ENVIRONMENTAL TEST SUMMARY

HARDWARE	S/N	ETAS	TEST ENVIRONMENT LEVELS & DURATION	DATE TEST PERFORMED	TEST AGENCY	PASS/ FAIL	COMMENTS

8.0 APPENDIX B: TEST IMPLEMENTATION

8.1. ASSEMBLY LEVEL TESTS

Each assembly shall be subjected to prescribed functional modes before, during, and after each environmental test. Functional modes that verify all functional and electrical interface requirements in every phase of the flight shall be identified by the hardware Cognizant Engineer and specified in the functional test procedure.

Each assembly will be functionally tested as part of the test activity. Each assembly shall perform within the functional tolerances and limits of the Herschel/Planck Integrated First Delivery Project Functional Requirements Document, JPL D-XXXX. Any difficulties shall be worked through the ERE to ensure test objectives are adequately met.

The individual environmental tests are described in the following paragraphs.

8.2. DYNAMICS TESTS

Assemblies in the appropriate configuration and operating mode shall be subjected to dynamic environments, which relate to launch dynamics. Assemblies shall be unpowered during the random vibration test.

Random Vibration Test

The random vibration test conditions above will be applied in each of three orthogonal axes, and have a Gaussian Probability Distribution of the instantaneous acceleration amplitude. Both the Power Spectral Density (PSD) and wideband acceleration (Overall Grms) are test parameters and shall be within specified tolerances.

Tolerances for random vibration tests are stated in paragraph 5.3.1, Dynamics Test Tolerances. The power spectral density amplitudes and overall RMS level shall each be maintained within their respective tolerances. To compensate for the mismatch between the vibration fixture impedance and the impedance of the hardware mounting structure on the spacecraft, force limiting, which limits the force to the test item at resonance, may be implemented for Herschel/Planck hardware. To accommodate force-limiting procedures, force transducers must be incorporated into the original design of the vibration adapter fixture for the hardware. Also, to measure the response limits an accelerometer shall be mounted near the board or assembly attachment point.

Test Configuration

Each assembly or subsystem shall be in the appropriate configuration as specified above. The assembly or subsystem shall be attached to the vibration test fixture at its normal flight structural interfaces.

Test Control

A minimum of two input control accelerometer(s) shall be located at the fixture-test article interface(s). The test shall be controlled by average control of the accelerometer signals. A third accelerometer will be connected to an independent safety shut down system. Force limiting or response limiting will employ the extremal control strategy. Automatic, closed-loop servo control shall be used. . The control accelerometers shall have flat frequency response characteristics within +0.5 dB from 5 Hz to 2kHz.

Vibration Instrumentation and Data

Each assembly or subsystem shall be instrumented with accelerometers (including control accelerometers) and strain gages (as required). Locations shall be specified in the applicable ETAS or in the Cognizant Engineers Detailed Test Plan, as appropriate. The accelerometers, strain gages, and data acquisition system shall have flat frequency response characteristics within +1 dB from 5 Hz to 2 kHz. Visual data available on site during actual execution of the test will include quick-look analysis data in the form of Acceleration PSD. Magnetic tape recordings of the time histories of the control and selected response channels shall be available after the test.

8.3. THERMAL TESTS

8.3.1 Flight and Non-Flight Hardware

When an "Engineering Model" is being used as a "Qual Model" for qual testing, it must not have major differences in design and parts from the Flight Model. Otherwise, the forthcoming "Flight Model" must be tested at the Protoflight/Qual level.

The test article should be as flight-like as possible. When non-flight hardware substitutes the flight hardware in this test, the simulator must be flight-like in all interface heat transfer.

Inherited hardware, i.e., flight hardware which has been thermally qualified by test in a previous project or application, must be at least flight acceptance tested without exception.

8.3.2 Location of the Reference or Baseplate Temperature

Temperatures at the radiator for the assembly, at an assembly wall, at its chassis, at its boards, at the case of a part, and at the junction of a transistor are all quite different. A common reference must be established for the test temperature. This is accomplished by defining the physical location of the test temperature sensor. This is commonly referred to as the thermocouple location, or flight temperature sensor location when it is being used for testing purposes. The thermocouple locations should be formally documented in drawings and form a integral part of a test plan or test procedure.

Internal electronic boxes have the baseplate, box wall, or the chassis as the logical reference temperature location. Motors have the motor housing as the logical reference temperature location.

When the location of this reference temperature sensor is not clear, the Cog E, the thermal engineer, and ERE should be contacted and agreement reached before implementation of thermal testing.

8.3.3 Test Objectives

1. This assembly shall, therefore, demonstrate that its functional and performance specifications are met by actual measurements in this test. This is in addition to showing that all parts of the assembly can withstand the extreme high and low temperatures of the mission plus margins in a flight like environment.

2. The qual/PF or FA test margins are demonstrated in this test. This includes the operating and non-operating condition, hot and cold. The amount of margin to be demonstrated are specified in temperature requirement table of the ERD or test spec.

3. This test shall show reliability, robustness, quality workmanship by the assembly undergoing a thermal cycling testing phase. This is in addition to the thermal cycling experienced in the parts and packaging verification processes. This is also in addition to the power on/off cycling testing, life testing, and fatigue cycling testing this assembly may have experienced.

4. This test normally includes a thermal balance testing case. This is typically done since the cost impact of a thermal balance test as part of the thermal qual/PF or FA test is minimal. Assembly thermal design is verified by this thermal balance testing. Thermal control aspects such as radiator sizing, MLI insulation, thermal model validation, heat sink to heat source conductances are all verified in this test. Heater operations are also an important part of this test.

5. Where applicable, the flight temperature sensing devices are calibrated in this test. This is accomplished by placing temporary temperature sensing devices alongside or nearby the flight sensors in this test.

8.3.4 Test Setup Basics and Test Methods

Test setup includes:

- Simulation of external and internal heat sources and sinks.
- Actual or simulated mechanical and electrical interfaces between the test article and its surroundings.

It is required to specify in the test plan and/or test procedure the approach being implemented:

1. The test setup will be flight-like. In this case, there is no question about the measurements, verification of the allowable flight temperatures, or the demonstration of the temperature margins.

2. The test setup forgoes the simulation of the external thermal environment but the demonstration of temperature margins is emphasized. For instance, instead of simulating the solar flux and the spectrum precisely, IR lamps or Calrod heaters can be used for the test. In place of flux level of 1400 w/m2, flux level of 2000 w/m2 is actually applied to the test article and the assembly meets the spec performance. In this case, the thermal balance test data will be for a non-flight condition but yet remains valid for thermal model correlation. The temperature margins, on the other hand, has been demonstrated in a much preferred condition.

As a general rule, the first approach is preferred.

In terms of heat dissipation to the mission environment, radiative or conductive test method can be used.

Radiative test method is used where large temperature ramp rate is not required and where conduction heat transfer is not present in flight. The basic setup is shown in Figure 8-1, along with key heat transfer considerations.

Conductive test method is used where: (i) Flight condition simulation is not important; (ii) Demonstration of thermal margin is critical; and (iii) Large temperature ramp rate is important.

The conductive setup is shown in Figure 8-2, along with the test article, the adapter plate, the heat exchanger, and related plumbing.

8.3.5 Environmental Simulations

(i) Simulation of External Heat Fluxes

Spectral simulation of the solar heat fluxes is generally not required except where performance of the assembly is strongly affected by the wavelengths of the flux. Quartz lamps, calrods, and other heating arrangements are all acceptable heat supplying devices.

Total heat input i.e., the time and wave-length integrated amount of heat energy applied to the test article, however, must be simulated adequately in the test. In demonstrating the temperature margins, the total heat input can exceed the level which the assembly will experience in flight.

Local heating devices can be used as necessary.

(ii) Deep Space Simulation

Chamber shrouds can be used to simulate the deep space. LN_2 temperature is acceptable for the simulation of the deep space.

(iii) Vacuum Simulation

Unless expressly specified, chamber pressure level of 1.0E-5 torr or lower is normally adequate for the simulation of space vacuum.

(iv) Internal Environmental Simulation

For thermal environmental testing, power input to all parts of the assembly which have corresponding nodal points in the thermal engineer's thermal math model should be measured. As a minimum, power input to the assembly as a whole should be measured continuously.

A thermal test without internal power measurements is not a valid thermal test since the thermal math model correlation and the predicted temperatures from the model will be in error leading to erroneous flight predictions.

(v) Interface Heat Transfer

Mechanical interfaces must be physically flight-like or adequately simulated where conduction heat transfer is significant. Large mounting surface, large wire bundles, and large temperature differentials across the interface must be simulated in test or special heat transfer provisions made. Mere temperature measurements on both sides of the interface will provide information on the amount of heat transfer across the interface but will violate the flight-like condition.

(vi) Launch Pressure Profile

This is a test for the adequacy of the venting configuration, the strength of the containing walls of the assembly, and, sometimes, for the escape routes of contaminates. MLI and all assemblies with enclosed spaces should be considered for this test.

This test is carried out at the beginning of the test, i.e., during the pumpdown phase of the test profile. The rate of pumpdown should be as fast as the test facility will permit. The venting analysis, is considered adequate for the environmental program.

8.3.6 Test Cases and Test Profiles

Assembly PF (or qual) and FA test should have at least six test cases:

1. Operating test case, cold and hot
2. Non-Operating test case, cold and hot
3. Thermal balance test case, cold and hot

8.3.7 Test Temperature Levels, Temperature Margins, and Test Durations

Test temperature is measured at the reference point or at the baseplate. The required test temperature levels and temperature margins are shown in Tables 4-4, -5, -6, -7.

Test durations are "accumulative". For example, the durations the assembly experiences in the thermal cycling test phase can be added to that of the PF/Qual and FA test phases to fulfill the requirements of the test durations.

8.3.8 Number of Startups

The number of startups are as follows:

	Hot	Cold
Operating	6	4
Non-Operating	6	4

Hot and cold startups are intended as a verification of operability of the assembly at temperatures but not as testing for fatigue life, power on-off life cycle, or planetary diurnal cycles.

8.3.9 Rate of Change of Temperatures

The ramp rate should be limited to 5° C/minute in order for the detection of creep-induced defects to be effective. Actual flight experiences have shown that only under very special conditions will any assembly experience ramp rate as high as 5° C/minute.

A ramp rate based on the thermal math model prediction plus a 50% margin is recommended for the PF/Qual and FA assembly thermal testing, provided 5° C/minute is not exceeded.

Fast ramp rate is usually only achievable by the conductive method of testing.

8.3.10 Flight Hardware Protection

Warnings and alarms must be used for this test. It is recommended that both visual (on monitors) and audible warnings be directed to at least the thermal engineer on duty and the test conductor.

Warnings : When approaching 2° C of AFTs

Yellow Alarm Limits: At 2° C of AFTs

Red Alarm Limits: At and above AFTs

8.3.11 Test Monitoring by Environmental Personnel

Environmental personnel are involved in the test monitoring at several levels:

1. Preparation and/or review of test plan, test spec, test procedures, test results, test reports, and environmental assessment report
2. In addition to 1 above, drop-in during the test
3. In addition to 1 above, Coverage of 1 shift, usually the day shift
4. In addition to 1 above, Full coverage (i.e., 3 full shifts)

Level of involvement for the environmental personnel is determined by the Cog. E, thermal engineer, and the ERE.

8.3.12 Test Documentation

The assembly level thermal PF/qual and FA tests requires the following listed documentation:

(i) Test Plans, Test Specs, and Test Procedures, as appropriate
(ii) ETAS Forms
(iii) Test Data
(iv) Post-Test Reports
(v) Thermal Model Correlation Results
(vi) Anomaly Lists and PFRs

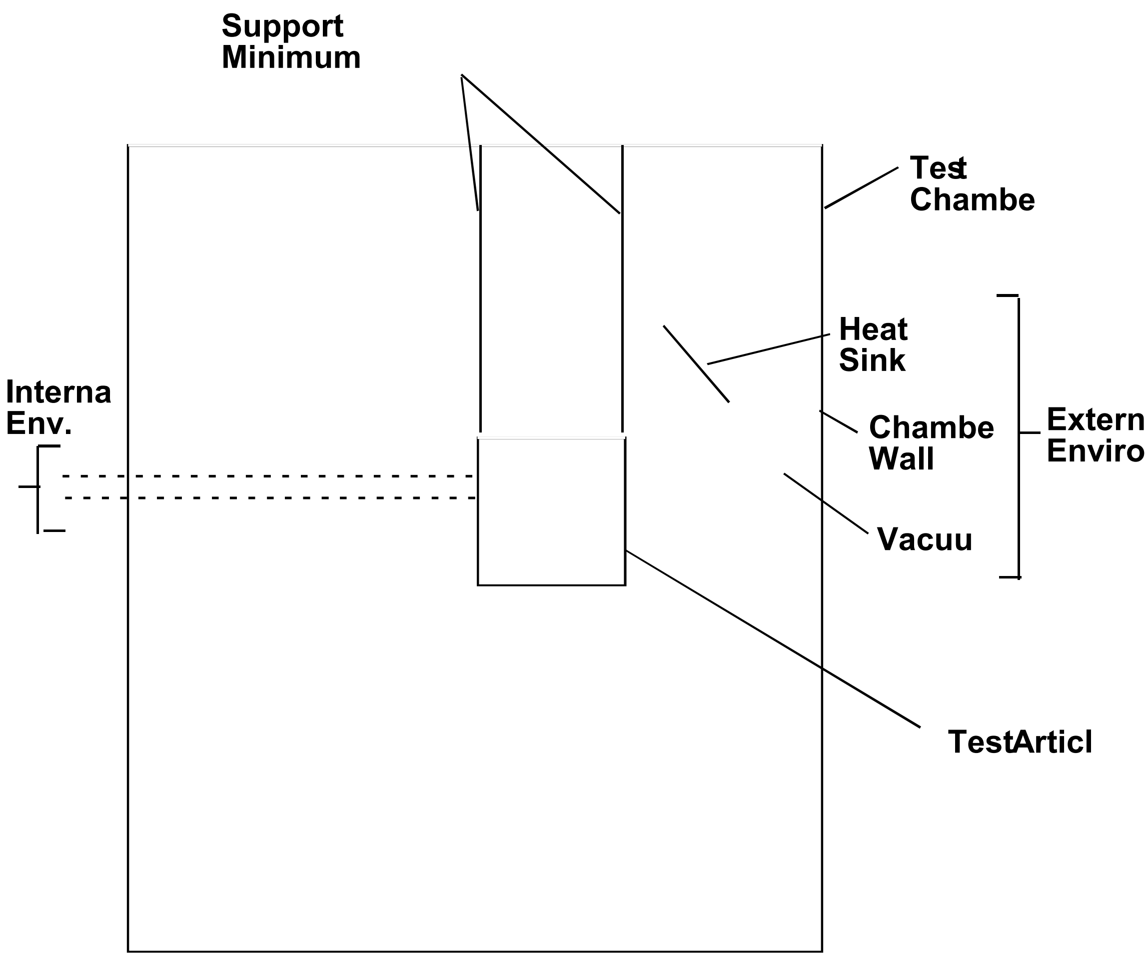


Figure 8-1 Radiative Test Method

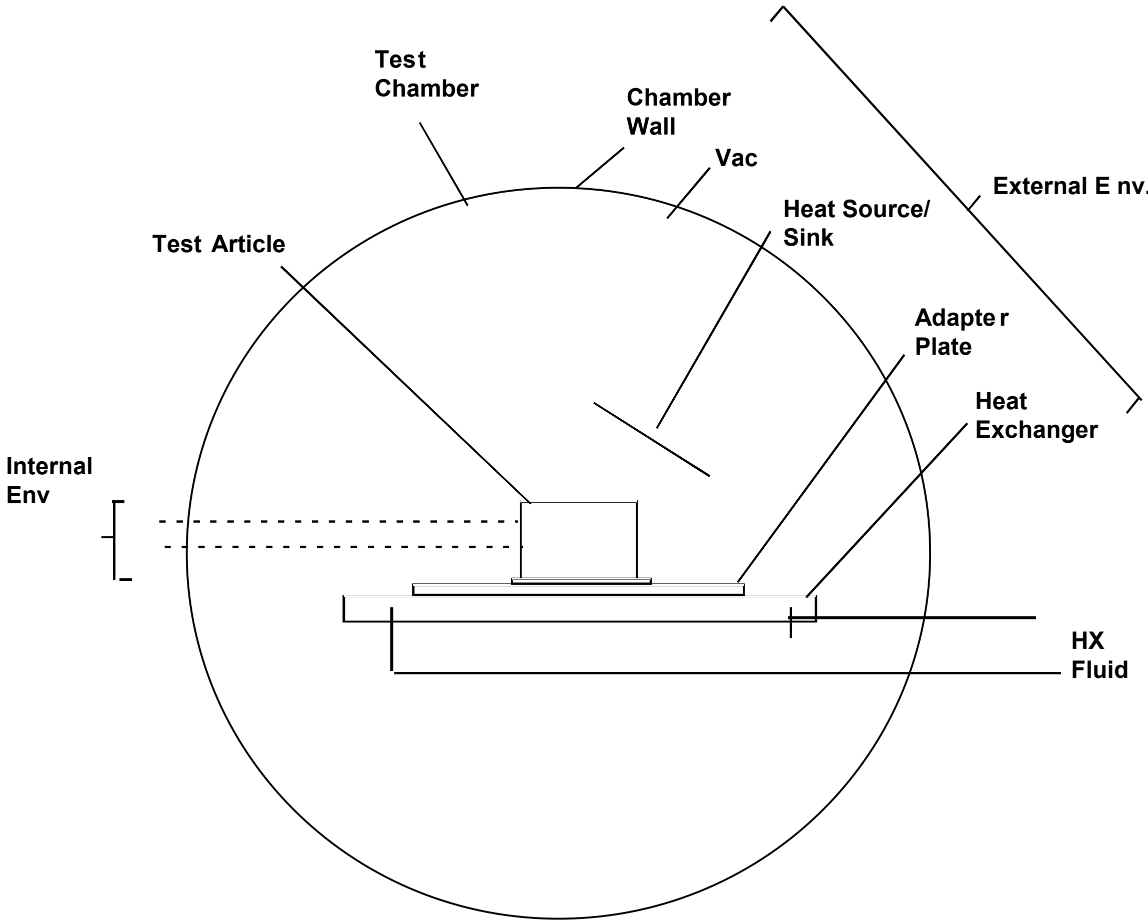


Figure 8-2 Conductive Test Method

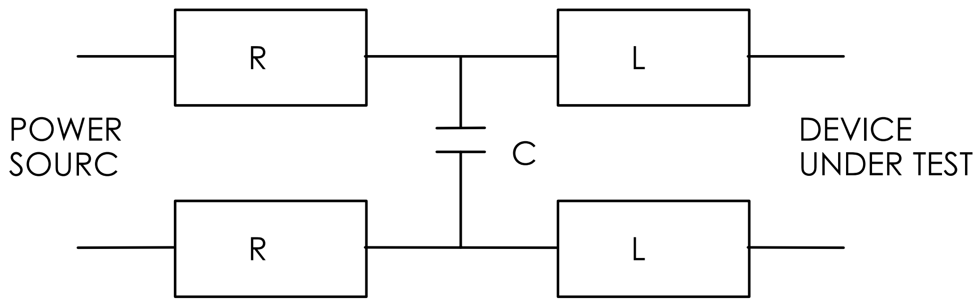
8.4. ELECTROMAGNETIC COMPATIBILITY (EMC) TESTS.

Conducted Emissions Tests

Testing shall be performed per MIL-STD-462 and the particular assembly detailed test procedure.

Conducted Emissions, Power Line Transients

Assembly transients shall not exceed the envelope of allowable transients with the spacecraft power impedance simulation of Figure 8-3, during turn-on, turn-off, and switching through all operational modes.



R ≤ 0.05 ohms,
L ~
C selectable, but 5,000 uF as

Figure 8-3 Impedance Simulation Network.

Test Configuration

Grounding and cabling (shielding and twisting) shall, wherever practical, be similar to flight configuration. Testing involves monitoring DC power lines for ripple and transients. To accomplish this, access to test article power cables shall be provided for the EMC current and voltage probes. Standard procedures also specify that the test sample power lines shall pass through 10 uF feedthrough capacitors. This should be considered in the design of test cables.

Test Control

Not applicable to emission measurements.

Instrumentation and Data

A spectrum analyzer, computer, and an oscilloscope with appropriate probes and data recording capability will be used in performing the measurements. Data shall include measurements of current in frequency domain and voltage in time domain. The current data shall be analyzed and presented in the test report in a format comparable to that used in specifying the requirements.

Conducted Susceptibility Tests

Testing shall be performed per MIL-STD-462 and the particular assembly detailed test procedure.

Conducted Susceptibility, Ripple

No assembly or subsystem shall be susceptible to the AC ripple defined by paragraph 4.8.4.1.8, injected onto DC power lines.

Test Configuration

Grounding and cabling (shielding and twisting) shall, wherever practical, be similar to flight configuration. Testing involves superimposing voltage ripple and transients on the nominal DC voltage of the power lines. To accomplish this, access to test article power cables shall be provided for EMC coupling and control mechanisms.

Test Control

If considered necessary, special protective devices may be incorporated, per the detailed test procedure, to limit voltage/current excursions. Injected voltages shall be increased from zero to requirement level by setting voltage control initially at zero for each test. The test operator will be monitored by a second EMC Group member during this test.

Instrumentation and Data

A spectrum analyzer, oscilloscope, camera and various signal generators, amplifiers, meters, capacitors and transformers may be used to generate and monitor the injected voltages and currents. Recorded data will include handwritten notes periodically recording frequency, injected voltage and current levels, wave shape, and test article response. Any interference noted shall be fully documented including threshold levels of susceptibility.

Isolation Test

Isolation tests will be performed on all circuits required to be isolated from circuit common or chassis ground. Testing shall be performed per the particular assembly or subsystem detailed test procedure.

Test Configuration

The test article Cognizant Engineer shall provide access to the necessary pins and connectors either through a non-flight connector or cable, or through a break-out box.

Test Control

Potential hazards arising from attachment of the ohm meter shall be identified and addressed in the detail test procedure. The usual solution is to use a 'low power' ohm meter.

Instrumentation and Data

Measurements shall be taken with an ohmmeter. Data shall consist of resistance measurements and shall be manually recorded.