HERSCHEL / PLANCK

ENVIRONMENT AND TESTS REQUIREMENTS

H-P-1-ASPI-SP-0030

Product Code : 000 000

Rédigé par/*Written by*	Responsabilité-Service-Société *Responsibility-Office -Company*	Date	Signature
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Entité Emettrice : Alcatel Space - Cannes
(détentrice de l'original) :

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HERSCHEL/PLANCK	DISTRIBUTION RECORD		
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ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORDS*

Herschel / Planck			**CHANGE RECORD**	
ISSUE	**REV.**	**DATE**	**MODIFICATIONS**	**APPROVAL**
01		03/05/00	Initial issue	
	01	13/09/00	Update Planck axes in accordance with SRS definition (page 6 and 18) Update of ARIANE 5 requirements taking into account Issue 3 of User's Manual (page 8, 9,10)	
02		31/10/00	All pages updated	
	01	15/06/01	Updated taking into account ESA and ALENIA comments	
03		27/07/01	Commentary added in ENVM-030 Updated paragraph 3.4.4.2. Updated random levels. Updated taking into account the changes in issue 2 of the SRS. (see change bars)	

ISSUE	REV.	DATE	MODIFICATIONS	APPROVAL
	01	12/11/01	§ 1: reference to Modules Interface Specifications for definition of detailed module environment § 2.1: addition of H-PLM, P-PLM and SVM Interface Specifications as applicable documents § 2.2,1 Issue of A5UM added §2.2.2 "Other reference documents" added with Design & Development Plan as new reference document § 3.3.2.2: frequency range for low frequency sinusoidal vibrations updated to 5-25. § 3.3.3.2: correction of typo § 3.3.3.3 unit for wavelength in solar spectrum definition changed to microns (RID PLM-015) Table 4.1-1: Test tolerances for Acoustic Vibration updated in accordance with RID AIV-34 New section 4.2 (RID AIV-032) § 4.3.2.5.1: addition of empty fixture vibration test § 4.3.2.5.2: modified paragraph on notching, definition of sweep rate which was missing. Updated values for Fuel tanks sinusoidal vibration levels. § 4.3.2.5.3: new paragraph on notching Table 4.3-1: Updated sinus vibration levels for electronic boxes in accordance with Minutes of Meeting H-P-ASPI-MN-544, dated 07/11/01 Table 4.3-1: updated values for RCS elements qualification temperatures in line with RCS specification.	
3	2	19-Feb-2002	• RD-7: added in answer to AI#3 of MoM H-P-1-ASPI-909. • RD-8 : added as an ESA input from SAWG. • ENVM-060 : updated according to the "MGSE General Specification" H-P-1-ASPI-SP-0044. • §3.3.3.2 Launch phase / saa : updated according to fax H-P-ASPI-LT-819. • §3.3.3.3 : Solar spectrum section updated with RD-8. • Table 3.4-1 : updated. • Table 3.4-2 : updated. • §3.4.3 Thermal environment / saa / HERSCHEL : updated according to fax H-P-ASPI-LT-819. • §3.4.4.3 : updated in answer to AI#3 of MoM H-P-1-ASPI-909. ENVM-080 deleted. • §4.3.2.5.2 : typing error corrected. • §4.3.2.5.3 : First sentence added according to MoM H-P-1-ASPI-909. • Table 4.3-2 : "diplexer" replaced by "RFDN" according to MoM H-P-1-ASPI-909. • Table 4.3-3 : "diplexer" replaced by "RFDN" according to MoM H-P-1-ASPI-909. • Table 4.3-6 : "diplexer" replaced by "RFDN" and minimum temperature of "Thrusters (valves)" updated according to MoM H-P-1-ASPI-909.	I.Bénilan

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS *§ : CHANGE RECORD*	REDACTEUR *AUTHOR*
4.0	25-Jun-2002	GENERAL Issue for the PDR Data Package Requirements are identified and numbered. "Cryo elec" replaced by "CCU". "equipment" replaced by "unit" (except for "test equipment"). Ch.1 : Scope updated. Ch.2 AD-3 : reference corrected. AD-4 to AD-9 : deleted (not mentioned in this document). AD-10 : created and RD-7 deleted according to SRS update for PDR (fax SCI-PT/12693 dated 02-May-2002). Change Requests H-P-ASPI-CR-0120 (ASED), H-P-ASPI-CR-0121 (ALS), H-P-ASPI-CR-0122 (CSAG) have been sent. RD-2 to RD-5 : deleted (not mentioned in this document). RD-7 : deleted (replaced by AD-10). RD-9 to -17 : added. §2.3 Acronyms : created. Ch.3 §3.2.3, Table 3.2-1 : limit load factors "on dollies and trolleys" have been updated with the values given in the "MGSE Specification" (ref. H-P-1-ASPI-SP-044). §3.2.4.1, ENVM-040 : humidity during transport and storage put in line with humidity during ground operations. §3.2.4.1, ENVM-050 : updated according to ENVM-040. §3.3.2.4 (acoustic) : modulation by filling ratio updated §3.3.2.5 Shock : Figure 3-5 updated with shock_spec_05_12_2001.pdf. Creation of Table 3.3-5. §3.3.3.2 (aerothermal fluxes) : updated. §3.3.3.2 (saa) : reworded according to fax H-P-ASPI-LT-1516 dated 27-May-2002. §3.3.3.2 (Eclipse) : updated according to SRS update for PDR (fax SCI-PT/12693 dated 02-May-2002). §3.3.4.1 Pressure : Figure 3-10 updated. Table 3.4-2 (Planck constant accelerations) updated according to fax HP-ASPI-LT-1387 dated 24-Apr-2002. §3.4.3 (saa) reworded according to fax H-P-ASPI-LT-1516 dated 27-	I.Bénilan

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS *§ : CHANGE RECORD*	REDACTEUR *AUTHOR*
		May-2002. §3.4.3, Figure 3-14 Planck attitude constraints : 10° must be understood as the half cone angle. §3.4.3 Angle between spin axis and Earth renamed : also named "Earth aspect angle" and max value updated as a consequence of the Planck orbit size increase from 10° to 15°. §3.4.3 (Eclipse) : updated according to SRS update for PDR (fax SCI-PT/12693 dated 02-May-2002). § 3.4.4.2.1: Duration requirement to survive the space radiation environment deleted. Covered by following data in section 3.4.4.2.1 and by GDIR requirements ENVR-005 and ENVR-030. §3.4.4.3 (Micrometeorites) : updated according to SRS update for PDR (fax SCI-PT/12693 dated 02-May-2002). Change Requests H-P-ASPI-CR-0120 (ASED), H-P-ASPI-CR-0121 (ALS), H-P-ASPI-CR-0122 (CSAG) have already been sent. Ch.4 §4.2.1 Environmental test summary :Table 4.2-1 updated. §4.2.2.2 sine : Table 4.2-2 completed with A5UM data (RD-1). §4.2.3.5.1 (resonance search test) : test parameters are TBC. §4.2.2.4, ENVT-180 : shock test baseline precised. §4.3.2.5.3, Table 4.3-2, -3 : random levels updated §4.3.2.5.3 : "General case by default" updated according to MoM H-P-ASPI-MN-1439 dated 13-May-2002. §4.3.2.5.4, Table 4.3-5 : shock levels updated §4.3.2.5.4 : Table 4.3-6 "unit qualification test temperature" updated with TSU-MAX, SREM, VMC. §4.3.2.5.4, Figure 4-1 "temperature cycling" : typing error corrected (second TO-MAX replaced by TO-MIN). §4.4 : MRB replaced by NRB to be in line with AD-3.	

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1. SCOPE

This specification defines:

- The overall environment to which the satellites, the modules and the units will be subjected from integration until the end of the operational life.
- The test environments to which the satellites, the modules and the units will be submitted to demonstrate their ability to withstand environmental conditions without damage.
- Detailed environment conditions needed for the design of the modules (Herschel and Planck PLM's and Service Module) are given RD-9, RD-10, RD-11 and RD-15.
- Detailed environment conditions for the Instruments are given in the IIDA (see RD-16).

The environmental conditions cover:

- mechanical environment,
- thermal environment,
- other orbit environments (pressure, radiations, micrometeorites ...),
- climatic environment,
- EMC environment,
- cleanliness environment.

Note :

- At the present stage, the SVM unit mechanical environment initially defined by this specification from system analysis results has just been defined by ALS from SVM level model and analysis.
- Convergence between both approaches for mechanical environment requirements specifications is currently running. When achieved, the requirements addressing SVM units will be removed from this document and solely specified in the ALS specification (see RD-17).

2. DOCUMENTS

2.1 Applicable documents

AD- 1 HERSCHEL/PLANCK EMC specification.
H-P-1-ASPI-SP-0037

AD- 2 HERSCHEL/PLANCK General Design and Interface Requirements
H-P-1-ASPI-SP-0027

AD- 3 PA REQUIREMENTS for Subcontractors
Doc. H-P-1-ASPI-SP-0018

AD- 4 Deleted

AD- 5 Deleted

AD- 6 Deleted

AD- 7 Deleted

AD- 8 Deleted

AD- 9 Deleted

AD- 10 Solid Particle Environment for NGST.
Ref. EMA/01-012/GD/NGST, 28-Feb-2001, G.Drolshagen, ESA/TOS-EMA

2.2 Reference documents

2.2.1 ESA and ARIANESPACE Reference Documents

RD- 1: ARIANE 5 User's Manual
Issue 3/Rev 0 Mar 2000

RD- 2 Deleted

RD- 3 Deleted

RD- 4 Deleted

RD- 5 Deleted

RD- 12 FIRST L-2 Radiation Environment
Ref. esa/estec/wma/he/FIRST/3, 04-Mar-1997, H.Evans

2.2.2 Other Reference Documents

RD- 6 Design & Development Plan
H-P-1-ASPI-PL-0009

RD- 7 Deleted.

RD- 8 WM0 Spectrum.
Compilation of the extraterrestial solar spectrum performed by Christoph Wehrli
World Radiation Center Davos Dorf, July 1985

RD- 9 Herschel EPLM Requirements Specification
H-P-2-ASPI-SP-0250

RD- 10 Planck PLM Interface and Applicability Specification
H-P-3-ASPI-IS-0070

RD- 11 Service Module Interface Specification
H-P-4-ASPI-IS-0042

RD- 13 "SHIELDOSE : a computer code for space shielding radiation dose calculations"
S.M. Seltzer, TN-1116 (NBS), 1980.

RD- 14 NOVICE : A Radiation Transport & Shielding Code, Users Guide
1990, Thomas. M. Jordan, Experimental & Mathematical Physics Consultant (EMPC).

RD- 15 Service Module Requirements Specification
H-P-4-ASPI-SP-0019

RD- 16 Instrument Interface Document IID Part A
SCI-PT-IIDA-04624

RD- 17 Mechanical & Environmental Test Requirements
H-P-SP-AI-0030

2.3 Acronyms

ACU	Adaptateur Charge Utile (payload adaptor)
EvTR	Environment and Tests Requirements (acronym of this document)
NCR	Non-Conformance Report
NRB	Non-Conformance Review Board
PSD	Power Spectral Density
RFD	Request for Deviation
RFW	Request for Waiver
SRB	Solid Rocket Booster
SYLDA5	Système Lancement Double Ariane5 (dual launch system for Ariane5)
TRP	Temperature Reference Point
TRR	Test Readiness Review
USF	Under Short Fairing

3. ENVIRONMENTAL DESIGN REQUIREMENTS

3.1 SPACECRAFT AXES

3.1.1 Herschel

The Herschel satellite reference frame (O, X_X, Y_X, Z_x) is defined such that :

- O is located at the centre of the launch vehicle interface ring, on the separation plane.
- X_s coincides with the nominal optical axis of the Herschel telescope. Positive X_S axis is oriented towards the target source. The X_S axis coincides with the launcher longitudinal axis.
- Z_S is in the plane orthogonal to the X_S axis, such that nominally the Sun will lie in the (X_S, Z_S) plane (zero roll angle with respect to Sun). Positive Z_S axis is oriented towards the Sun.
- Y_S completes the right handed orthogonal reference frame.

See Figure 3-1.

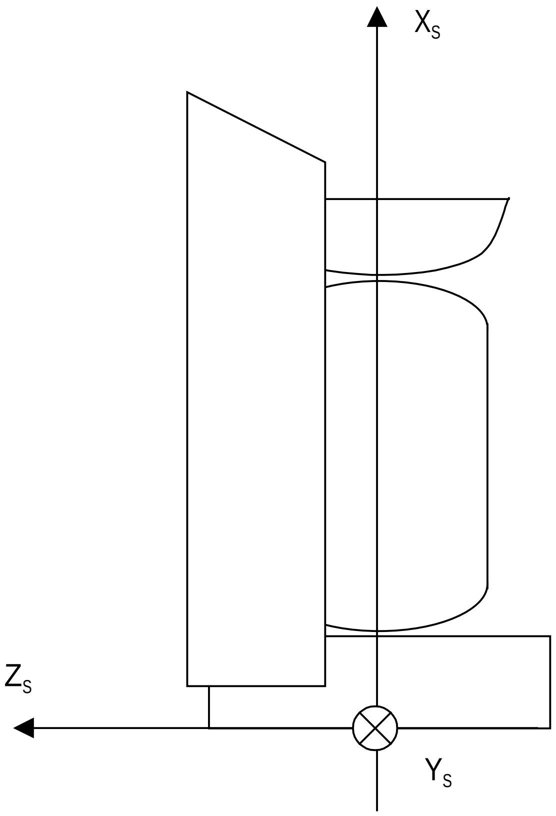


Figure 3-1: Herschel Spacecraft Axes

3.1.2 PLANCK

The PLANCK satellite reference frame (O, X_X, Y_X, Z_x) is defined such that :

- O is located at the center of the launch vehicle interface ring, on the separation plane.
- X_S coincides with the nominal spin axis of PLANCK. Positive X_S axis is oriented opposite to the Sun in nominal operation. The X_S axis coincides with the launcher longitudinal axis.
- Z_S is perpendicular to X_S and contained in the symmetry plane of the telescope, with the positive direction on the concave side of the primary mirror of the telescope.
- Y_S completes the right handed orthogonal reference frame.

See Figure 3-3.

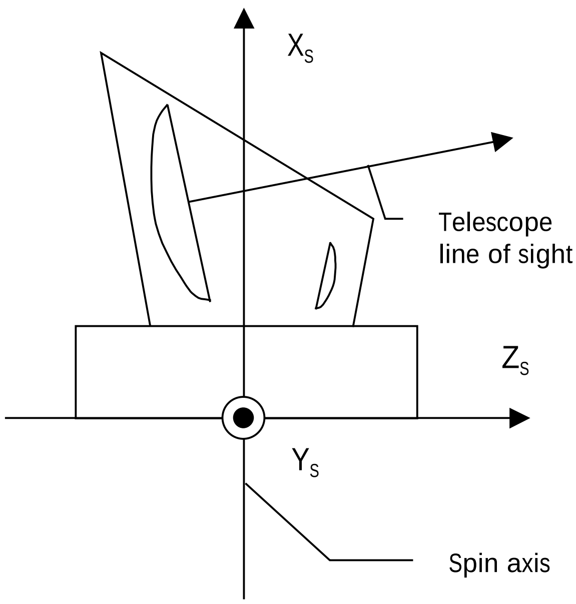


Figure 3-3: PLANCK Spacecraft Axis

3.2 GROUND OPERATION PHASE

3.2.1 Mission phase definition

This phase includes all ground activities conducted during fabrication, handling, transportation and storage phases.

3.2.2 General requirements

ENVM-005

On ground, during integration, handling and transportation, the environment, with the exception of bake-out, shall be such as to be significantly less severe than launch and orbit conditions with the exception of the thermal environment of the Cryostat for Herschel and the Planck sorption cooler radiator. (SENV-005)

*

3.2.3 Mechanical environment

This section describes the mechanical environment to which the spacecraft hardware is subjected during normal ground operations. These environments shall be controlled so as to be significantly less severe than launch and mission conditions.

ENVM-010

Manufacturing, handling and transportation loads (except for the MGSE interface points themselves) as well as test loads shall not be design drivers. (SENV-020)

*

The accelerations defined in this paragraph are criteria for shipping container design and equipment used to handle and transport flight hardware.

ENVM-020

The maximum handling and ground transportation load factors on each point of the satellite when the MGSE is subjected to the external environment shall be as given in Table 3.2-1.

*

ENVM-030

Horizontal and vertical loads shall be considered acting simultaneously for same conditions.

CASES		Applied accelerations (g)
Hoisting	Vertical	-1.3
	Horizontal	±0.2
On integration test fixture with short and slow running	Vertical	-1.1
	Horizontal	±0.2
On dollies and trolleys	Vertical	-1.1
	Horizontal	±0.2
Container Transportation (*)(**)	Vertical	3.0
	Horizontal in main moving directions	±1.5 (TBC)
	Horizontal perpendicular to main moving directions	±1.0

Table 3.2-1: Limit Load Factors for Handling and Transportation

(*) Thermal environments encountered during Hot/Cold transportation (see 3.2.4.2) shall be combined to mechanical loads

(**) First modes of the container fixture are < 10 Hz for any axis.

Note: negative means downward.

*

3.2.4 Thermal and climatic environment

3.2.4.1 Spacecraft hardware

ENVM-035

The environments under integration, transportation and testing shall not be design drivers. (SENV-060)

*

ENVM-040

Unless otherwise specified herein, all system and unit manufacturing, handling and test shall be made at ambient conditions as specified in Table 3.2-2.

	Ground operation	Transportation	Storage
Pressure (mbar)	970 to 1050	200 to 1050	970 to 1050
Humidity (%)	40 to 60	40 to 60	40 to 60
Temperature (°C)	22 ± 3	-10 to 50	20 ± 10
Cleanliness	Class 100 000 or better	Class 100 000 or better	Class 100 000 or better

Table 3.2-2: Ambient environment

*

ENVM-050

The spacecraft shall be designed to withstand a relative humidity (RH) without performance degradation of 40% RH to 65 % RH, non-condensing and for two weeks a relative humidity of 95%, non-condensing. (SENV-065).

*

3.2.4.2 Transportation

ENVM-060

The transport devices shall be capable of maintaining the spacecraft hardware within the ambient environment defined in section 3.2.4.1 when subjected to the following uncontrolled atmospheric conditions as defined below:

- Temperature: transportation and storage ambient temperature extremes to which containers will be exposed, while providing protection for specimen, shall be within –40°C and +60°C.
- Humidity : 1% < RH < 100%
- Pressure : pressure changes during air transportation, from 1050 hPa (sea level) to 15000 m altitude.

*

3.2.4.3 Spacecraft preparation at the launch site

ENVM-70

The constraints applicable to the spacecraft preparation at the launch site shall be derived from RD- 1. (SENV-040)

*

3.2.5 Other environments

3.2.5.1 Pressure

See section 3.2.4.

3.2.5.2 Radiation

No specific radiation environment for this phase

3.2.5.3 Micrometeorites

No specific micrometeorites environment for this phase

3.2.5.4 EMC

The satellites shall be designed to meet the requirements specified in AD- 1.

3.3 LAUNCH

3.3.1 Mission phase definition

The launch phase starts at the umbilical removal and lasts up to the separation of the satellite. The current baseline for HERSCHEL/PLANCK is to use ARIANE 5 - ESV with a delayed ignition of the ESV upper stage. At the lower composite burn-out, the upper stage together with the 2 spacecraft are injected onto a coast arc for a duration of approximately 107 minutes. Before perigee passage, the upper stage is ignited and finally attains the required transfer velocity towards L_2.

Once injection to L_2 is performed, HERSCHEL is separated in 3 axis mode with its Z_S axis oriented towards Sun. Then the ARIANE upper stage re-orients itself and spins up in order to separate PLANCK in spinned mode (1 rpm, TBC) with its X_S axis opposite to Sun.

3.3.2 Mechanical environment

During flight, the Satellites are subjected to static and dynamic loads induced by the launch vehicle.

Such excitation may be of aerodynamic origin (wind gust, buffeting at transonic velocity) or due to the propulsion systems (longitudinal acceleration, thrust build-up of tail off transient, structure-propulsion coupling, attitude control limit cycling, etc…).

3.3.2.1 Quasi-static loads

ENVM-085

The steady state and low frequency dynamic loads are quantified by the combined loads (also called Quasi-Static Loads: QSL). The most critical flight events are the resulting Flight Limit Loads are given in Table 3.3-1 as far as the Satellites complies with the frequency requirements :

- First lateral frequency > 9 Hz
- First longitudinal frequency > 31 Hz

Flight Event	Acceleration (g)		
	Longitudinal		Lateral
	Herschel	Planck	
Lift-off	-1.7 g ± 1.5 g	-1.7 g ± 1.5 g	± 2.0 g
Maximum dynamic pressure	-2.7 g ± 0.5 g	-2.7 g ± 0.5 g	± 2.0 g
SRB end of flight	-4.55 g ± 1.45 g	-4.55 g ± 1.45 g	± 1.0 g
Main Core Thrust Tail-off	-0.2 g ± 1.4 g	-0.2 g ± 1.4 g	± 0.25 g
Max tension case: SRB jettisoning	+2.5 g	+2.5 g	± 0.9 g

Table 3.3-1: Quasi Static Loads (Flight Limit Loads)

*

Notes :

- The minus sign with longitudinal axis values indicates compression.
- The lateral loads may act in any direction simultaneously with longitudinal loads.
- The Quasi-Static-Loads apply on centre of gravity of the satellite.
- The over line loads flux induced by the launcher and which the SVM Primary Structure shall be designed to withstand are specified in IML-060-H for Herschel and IML-070-P for Planck (see RD-11).

3.3.2.2 Low frequency sinusoidal vibrations

The sinusoidal vibration acceptance level at the base of the Satellites is given in Table 3.3-2. These spectra take into account any sinusoidal or transient vibrations inside the given bandwidth.

Axis	Frequency range [Hz]	Acceptance level (0-peak)
Longitudinal	5 - 100	1.0 g
Lateral	5 - 25 25 - 100	0.8 g 0.6 g

Table 3.3-2: Low Frequency Sinusoidal Vibrations

3.3.2.3 Random vibrations

Random vibrations are transmitted by the launcher to the satellite via the launch vehicle/satellite structure interface. They are generated in the launcher by motion of some mechanical parts, combustion phenomena or structural elements excited by the acoustic environment (see below)

3.3.2.4 Acoustic noise

The highest acoustic environment occurs at lift-off and during transonic flight. Outside these periods it is substantially lower. The flight level of acoustic environment are given in Table 3.3-3.

Octave Band Central Frequency [Hz]	Flight Level [dB]
31.5	128
63	130
125	135
250	139
500	134
1000	128
2000	124

Table 3.3-3: Acoustic Environment (Flight Levels)

Acoustic environment will not be modulated taking into account filling ratio (see §4.6.1.3 of the A5-UM [RD-1]) since level incertainty is covered by test tolerance.

3.3.2.5 Shock

ENVM-130

The Satellites are subjected to shocks during interstage separation, fairing and carrying structures jettisoning and on actual spacecraft separation. On ARIANE 5, the fairing and the cryogenic stage/upper stage separation shocks are noticeable at the spacecraft interface. The envelope of actual spacecraft separation environment and shocks generated during the flight has to be considered (see Table 3.3-5 and its graphical representation on the H&P curve of Figure 3-5).

Frequency [Hz]	Shock at launcher interface [g]
100	20
340	430
1 100	2 900
10 000	2 900

Table 3.3-5: Shock Spectrum at launcher interface

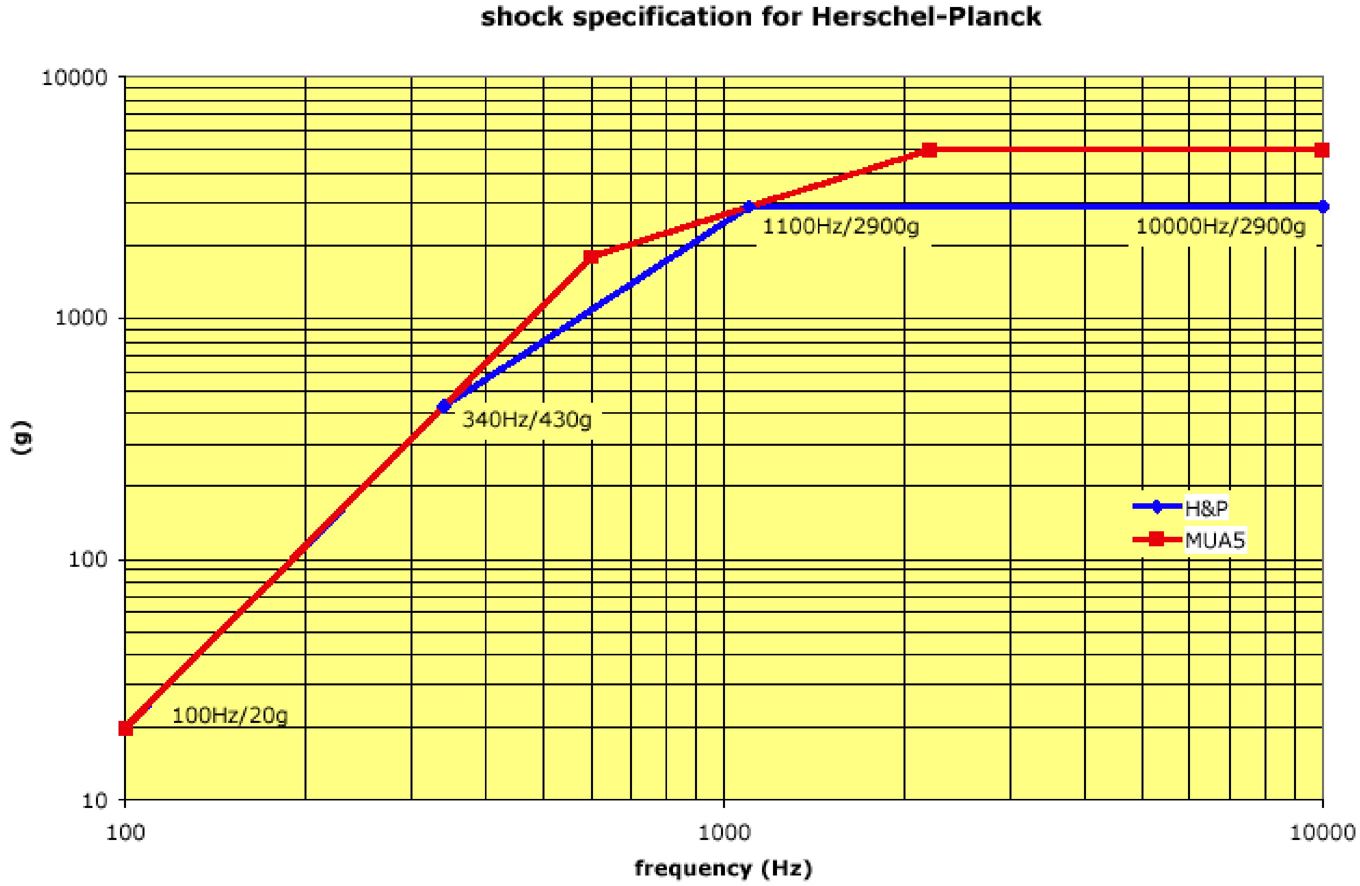


Figure 3-5: Shock Spectrum at launcher interface

*

3.3.3 Thermal environment

3.3.3.1 Pre-launch phase

ENVM-140

The temperature of the air injected inside the fairing on the launch pad is adjustable between 10°C and 25°C. The other characteristics of this class 100 00 cleanliness environment are :

- Relative humidity : ≤ 55%
- Filtration : 0.3 µm
- Main air velocity : ≤ 2 m/s
- Noise : ≤ 94 dB (also inside SYLDA-5)

(RD-1).

*

3.3.3.2 Launch phase

Aerothermal flux

ENVM-150

From launch time to fairing jettison, the Herschel satellite and its modules shall be able to support a net flux density radiated by the fairing $\leq$ 1000 W/m2 at any point [RD-1].

*

ENVM-160

From fairing jettison to the separation of Herschel from the launcher, the Herschel satellite and its modules shall be able to support an aerothermal flux $\leq$ 1135 W/m2 at any point [RD-1].

*

ENVM-165

From launch time to the separation of Planck from the launcher, the Planck satellite and its modules shall be able to support a net flux density radiated by SYLDA5 < 1000 W/m2 at any point [RD-1].

*

Notes :

- The maximum aerothermal flux of 1135 W/m^2 applies to Herschel only and on a plane normal to the trajectory. As shown on Figure 3-7, it occurs at fairing jettison.
- Figure 3-7 shows also that a second (time ≈ 500 s) and a third (time ≈ 7500 s) flux peak below 1135 W/m^2 will occur after fairing jettisonning.
- After fairing jettisoning, Herschel is subjected to solar, albedo and earth fluxes, defined in section 3.3.3.3, whereas Planck remains protected by SYLDA5.

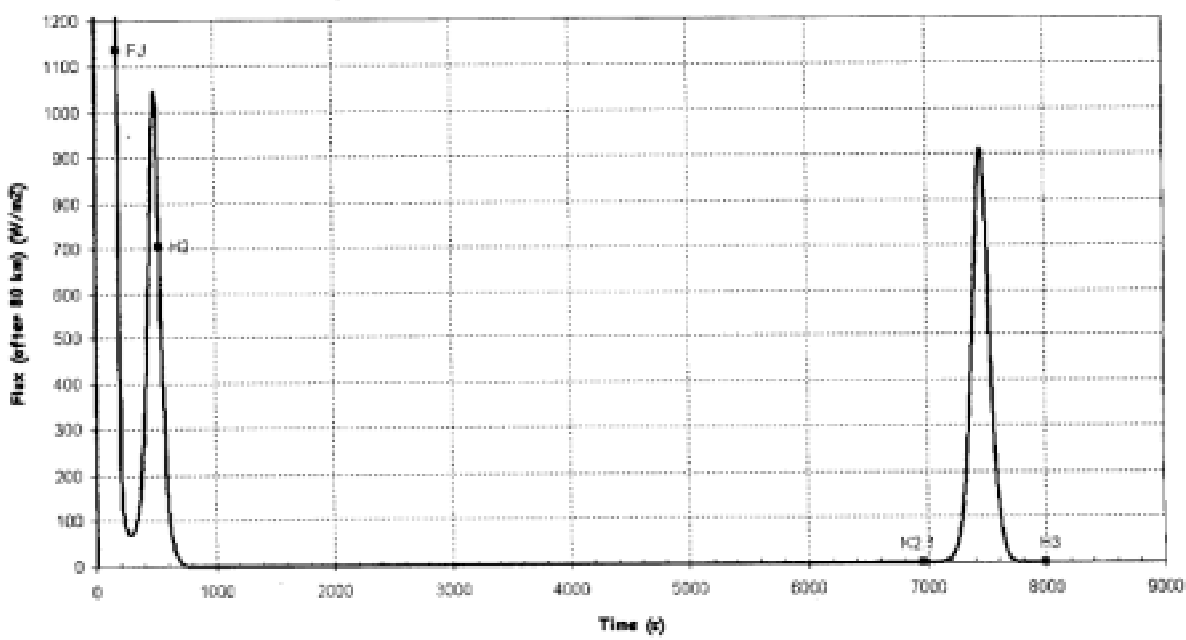


Figure 3-7: Preliminary aerothermal fluxes on ARIANE 5 ESV with delayed ignition

Sun Aspect Angle :

ENVM-170

From fairing jettison to launcher separation, Herschel shall be compatible with a Sun direction :

- between -23° and +23° from the (Xs, Zs) plane and
- between +60° and +140° from the +Xs axis.

*

Notes :

- These allowed Sun directions define a solid angle in the satellite reference frame (see Figure 3-8).
- This solid angle can be scanned by the image of Xs after a combination of 2 rotations :
  - rotation around +Xs with an angle between -23° and +23° ("roll"). +Ys becomes +Ys'.
  - then rotation around +Ys' with an angle between +60° and +140° ("pitch").

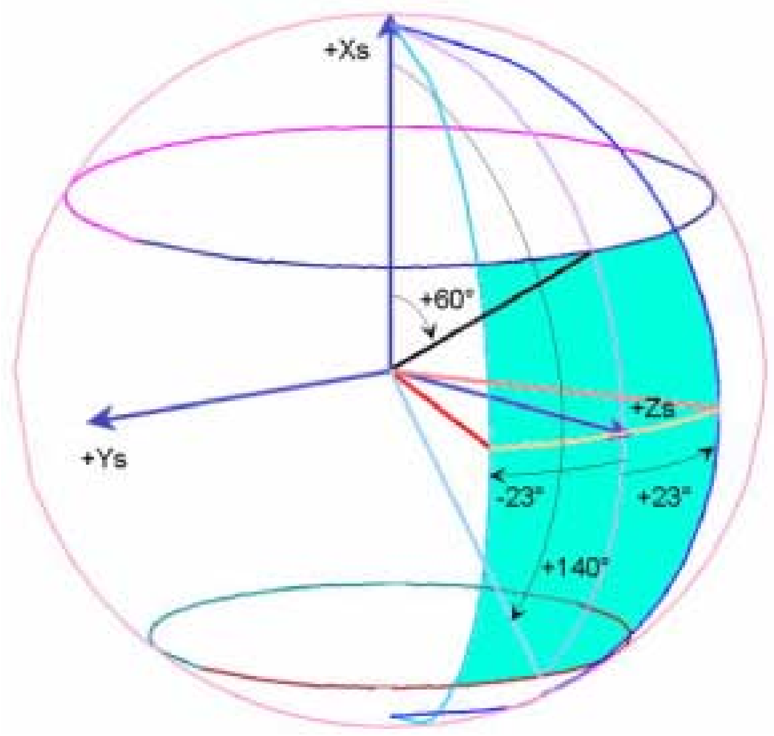


Figure 3-8: Herschel attitude constraints from FJ to launcher separation

ENVM-180

At launcher separation, Herschel spacecraft will be nominally Sun pointed with Zs axis towards Sun. Due to tip-off rates at separation, Herschel shall be compatible with a transient rotation of maximum 2 minutes :

- maximum amplitude of 15° around Xs ; Ys and Zs become Ys' and Zs'.
- then maximum amplitude of 25° around Ys' ; Zs' become Zs".
- and finally maximum amplitude of 25° around Zs".

*

Eclipses :

ENVM-190

The transfer trajectory will be defined such that no eclipse will occur from separation (MISS-035 H/P).

*

3.3.3.3 Definition of solar, albedo and Earth fluxes

Solar constant :

ENVM-200

The value of the solar constant (radiation that falls on a unit area of surface normal to the line from the Sun, per unit time, outside the atmosphere) at 1 AU (1,49598 10^8 km) is 1371 W/m^2. The solar constant has an uncertainty of about ± 10 W/m^2.

*

Variation with distance :

ENVM-210

At heliocentric distances different from 1 AU, the solar irradiance *q* is such that

$$q = \frac{1371}{d^2} W / m^2$$

where *d* is the heliocentric distance in AU.

*

Solar spectrum (source : RD-8) :

ENVM-220

The solar spectral irradiance is defined in Figure 3-9.

A part of the numerical values used to plot this figure is given in Table 3.3-4.

λ : wavelength [µm]

E_λ : solar spectral irradiance averaged over small bandwidth centered at λ [W m^{-2} µm^{-1}]

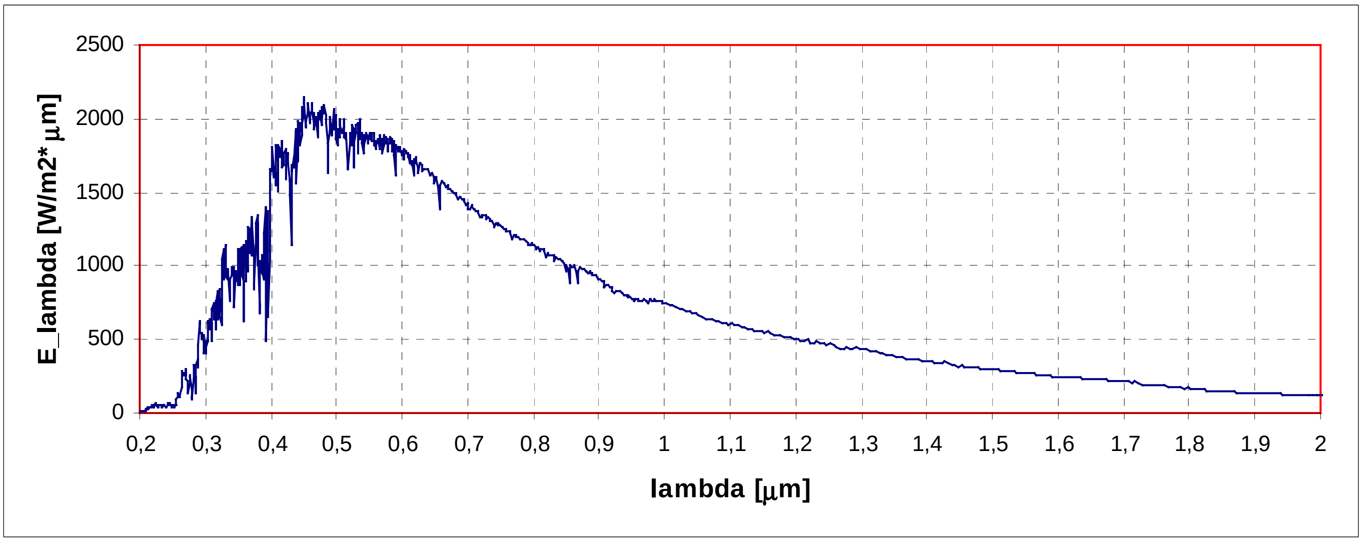


Figure 3-9 :Solar spectral irradiance

λ [µm]	Eλ [W.m-2.µm-1]	λ [µm]	Eλ [W.m-2.µm-1]	λ [µm]	Eλ [W.m-2.µm-1]	λ [µm]	Eλ [W.m-2.µm-1]	λ [µm]	Eλ [W.m-2.µm-1]
0,20	7	0,71	1 387	1,22	481	1,73	190	2,36	65
0,21	28	0,72	1 332	1,23	484	1,74	191	2,38	55
0,22	48	0,73	1 327	1,24	477	1,75	187	2,40	54
0,23	56	0,74	1 259	1,25	474	1,76	184	2,42	57
0,24	43	0,75	1 263	1,26	444	1,77	177	2,44	51
0,25	59	0,76	1 238	1,27	439	1,78	171	2,47	53
0,26	102	0,77	1 205	1,28	435	1,79	169	2,49	54
0,27	293	0,78	1 188	1,29	442	1,80	169	2,52	47
0,28	112	0,79	1 159	1,30	438	1,81	160	2,54	46
0,29	623	0,80	1 143	1,31	419	1,82	159	2,57	44
0,30	403	0,81	1 115	1,32	416	1,83	156	2,59	42
0,31	495	0,82	1 081	1,33	405	1,84	153	2,62	41
0,32	712	0,83	1 069	1,34	398	1,85	148	2,64	39
0,33	1 144	0,84	1 045	1,35	387	1,86	143	2,67	38
0,34	992	0,85	1 003	1,36	378	1,87	135	2,70	36
0,35	1 119	0,86	997	1,37	369	1,88	140	2,73	35
0,36	979	0,87	986	1,38	364	1,89	137	2,76	34
0,37	1 075	0,88	960	1,39	358	1,90	133	2,80	32
0,38	1 289	0,89	944	1,40	353	1,91	138	2,83	31
0,39	1 223	0,90	905	1,41	346	1,92	134	2,87	29
0,40	1 649	0,91	870	1,42	343	1,93	132	2,91	28
0,41	1 502	0,92	830	1,43	337	1,94	129	2,95	26
0,42	1 760	0,93	826	1,44	327	1,95	126	2,99	25
0,43	1 136	0,94	800	1,45	323	1,96	126	3,03	24
0,44	1 715	0,95	778	1,46	317	1,97	125	3,08	23
0,45	2 146	0,96	767	1,47	311	1,98	125	3,13	21
0,46	2 042	0,97	763	1,48	303	1,99	121	3,18	20
0,47	1 879	0,98	762	1,49	303	2,00	116	3,24	19
0,48	2 037	0,99	764	1,50	296	2,01	114	3,30	18
0,49	2 009	1,00	745	1,51	290	2,02	113	3,36	16
0,50	1 859	1,01	734	1,52	286	2,03	110	3,43	15
0,51	1 949	1,02	704	1,53	282	2,04	107	3,50	14
0,52	1 833	1,03	688	1,54	275	2,05	104	3,58	13
0,53	1 954	1,04	681	1,55	273	2,06	100	3,67	12
0,54	1 772	1,05	661	1,56	269	2,08	101	3,76	11
0,55	1 864	1,06	642	1,57	260	2,09	98	3,86	10
0,56	1 845	1,07	638	1,58	255	2,11	93	3,97	9
0,57	1 772	1,08	620	1,59	246	2,12	87	4,09	8
0,58	1 840	1,09	612	1,60	247	2,14	85	4,23	7
0,59	1 815	1,10	608	1,61	244	2,15	81	4,39	6
0,60	1 748	1,11	603	1,62	240	2,17	80	4,58	5
0,61	1 705	1,12	579	1,63	241	2,18	75	4,81	4
0,62	1 736	1,13	566	1,64	234	2,20	73	5,09	3
0,63	1 641	1,14	557	1,65	234	2,21	75	5,45	2
0,64	1 616	1,15	545	1,66	233	2,23	75	5,93	2
0,65	1 608	1,16	540	1,67	228	2,25	72	6,62	1
0,66	1 573	1,17	533	1,68	221	2,26	71	7,79	1
0,67	1 518	1,18	514	1,69	219	2,28	69	10,08	0
0,68	1 494	1,19	511	1,70	217	2,30	66		
0,69	1 450	1,20	496	1,71	203	2,32	53		
0,70	1 388	1,21	489	1,72	205	2,34	58		

Table 3.3-4: Solar Spectral Irradiance

Earth Albedo :

ENVM-230

Albedo is the fraction of incident sunlight which is reflected back into space. The amount of reflected sunlight varies with many factors such as cloud cover, type of terrain, vegetation, presence of water and season. So, it is practical to use and average value for the albedo. A value of 0.3 ± 0.05 shall be used.

*

Earth Infrared Thermal radiation

ENVM-240

The Earth Infrared radiation shall be assumed to be that of a black body with a characteristic temperature of 288 K. The average infrared radiation emitted by Earth is 230 W/m², with variations between 150 W/m² and 350 W/m².

*

3.3.4 Other environments

3.3.4.1 Pressure

ENVM-250

The spacecraft and their modules shall be designed to withstand the depressurisation profile defined in Figure 3-10. The slope of pressure variation is 20 mbar/s during the launch vehicle ascent phase with locally 45 mbars/s during the transonic phase. (SENV-075)

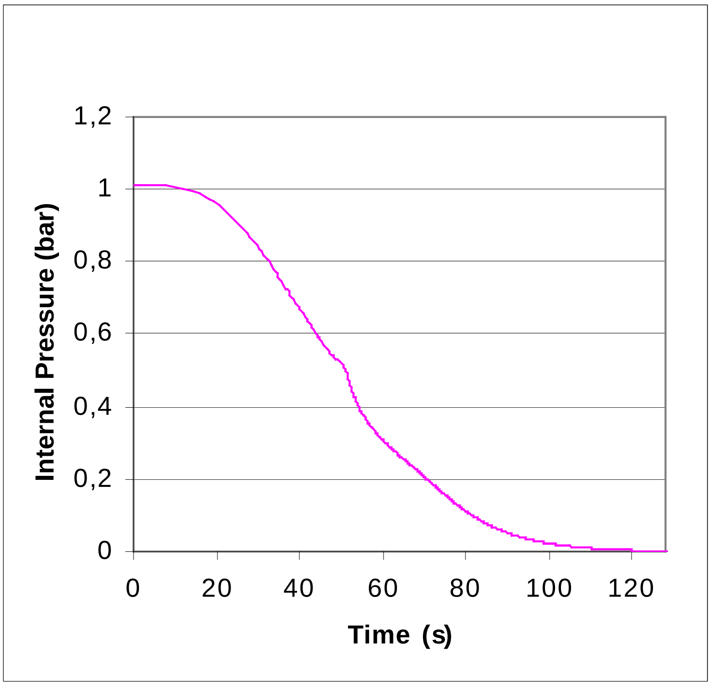


Figure 3-10: Variation of static pressure inside fairing

*

3.3.4.2 Radiation

See section 3.4.4.2.

3.3.4.3 Micrometeorites

See section 3.4.4.3.

3.3.4.4 EMC

The satellites shall be designed to meet the requirements specified in AD- 1.

3.4 ON ORBIT PHASE

3.4.1 Mission phase definition

The on-orbit phase starts at satellite separation from launcher. It can be split into the following subphases :

- transfer from Earth to L_2:
  - initial orbit phase (IOP),
  - commissioning phase,
  - performance verification phase,
- orbit around L_2 (routine observation phase):
  - observation phase (OP),
  - telecommunication phase (TP).

Activities during the on-orbit phase are described in the following sections.

3.4.1.1 Initial orbit phase (IOP)

This phase starts at satellite separation from launcher. This phase is devoted to initial Sun acquisition, establishment of contact with ground stations, post launch satellite health check, performance of first orbit corrections to take place after injection on transfer from Earth to L_2.

3.4.1.2 Commissioning phase

During this phase, functional check-out of the spacecraft is performed as well as performance verification of subsystems (power, data handling, telecommunications, thermal control).

Decontamination heating of HERSCHEL and PLANCK (TBC) telescopes is performed during this phase. When the decontamination heaters are switched OFF, cool down of the Payload Modules can begin. When the payload instruments have reached their operational temperature, they can be switched ON and functional verification can be conducted.

3.4.1.3 Performance verification phase

During this phase Payload calibration in all modes in relation with spacecraft Attitude Control Subsystem will be performed.

3.4.1.4 Routine observation phase

All the phases described in the previous paragraph (Initial orbit phase, commissioning, performance verification) occur during the transfer to the final orbit around L_2. The cumulated duration of these phases is less than 6 months.

To reach the final orbit around L_2, no manoeuvre is required for Herschel. So, it can enter in Routine Observation Phase in order to begin its scientific operation as soon as the Performance verification phase is finished.

On the contrary, PLANCK has to perform an injection manoeuvre to reach its small Lissajous orbit around L_2. Routine observation phase can begin after this manoeuvre.

During Routine observation phase, the day is shared between Observation Phase and Telecommunication phase :

- During Observation Phase (OP), both spacecraft autonomously perform scientific observation according to an observation plan which has been loaded during a previous ground contact. Scientific and housekeeping data are stored in the mass memory.
- During Telecommunication Phase (TP), the spacecraft dumps the mass memory contents to the ground. On PLANCK scientific operations continue during ground contact. On HERSCHEL, scientific activity will be limited by the attitude constraints imposed by the establishment of a link to the ground. In both cases, real time scientific and housekeeping data can be transmitted to ground in parallel to memory dump. During TP, the observation/spacecraft schedule parameters for subsequent days are uplinked, while some housekeeping tasks (e.g. wheel unloading) are performed.

3.4.2 Mechanical environment

Steady state accelerations

ENVM-260

The PLANCK spacecraft is a spinner at 1 rpm along its X_s axis. This will generate a very low steady state acceleration of 0.01 m/s^2 at 1 m from the spin axis.

*

ENVM-270

The maximum in-orbit acceleration applied to the Spacecraft Centre of Mass are defined in Table 3.4-1 for HERSCHEL and Table 3.4-2 for PLANCK

HERSCHEL	Acceleration (m/s^2)	Rotational acceleration (rad/s^2)
X_S	< 0.03	TBD
Y_S	< 0.03	TBD
Z_S	< 0.03	TBD

Table 3.4-1: HERSCHEL constant acceleration

PLANCK	Acceleration (cm/s^2)	Rotational acceleration (rad/s^2)
X_S	-2.0 < X < +4.5	TBD
Y_S	-1.0 < Y < +1.0	TBD
Z_S	-4.0 < Z < 0	TBD

Table 3.4-2: PLANCK constant acceleration

*

3.4.3 Thermal environment

ENVM-280

During on-orbit operation, the satellite is subjected to solar, albedo and earth fluxes, defined in section 3.3.3.3. The maximum S/C to Earth distance is 1.8 10^6 km. S/C to Sun distance is between 147 10^6 km and 154 10^6 km.

*

Sun Aspect Angle :

ENVM-290

During all Herschel mission phases and operational modes, Herschel shall be compatible with a Sun direction :

- between -1° and +1° from the (Xs, Zs) plane and
- between +60° and +120° from the +Xs axis.

*

Notes :

- These allowed Sun directions define a solid angle in the satellite reference frame (see Figure 3-12).
- This solid angle can be scanned by the image of Xs after a combination of 2 rotations :
  - rotation around +Xs with an angle between -1° and +1° ("roll"). +Ys becomes +Ys'.
  - then rotation around +Ys' with an angle between +60° and +120° ("pitch").

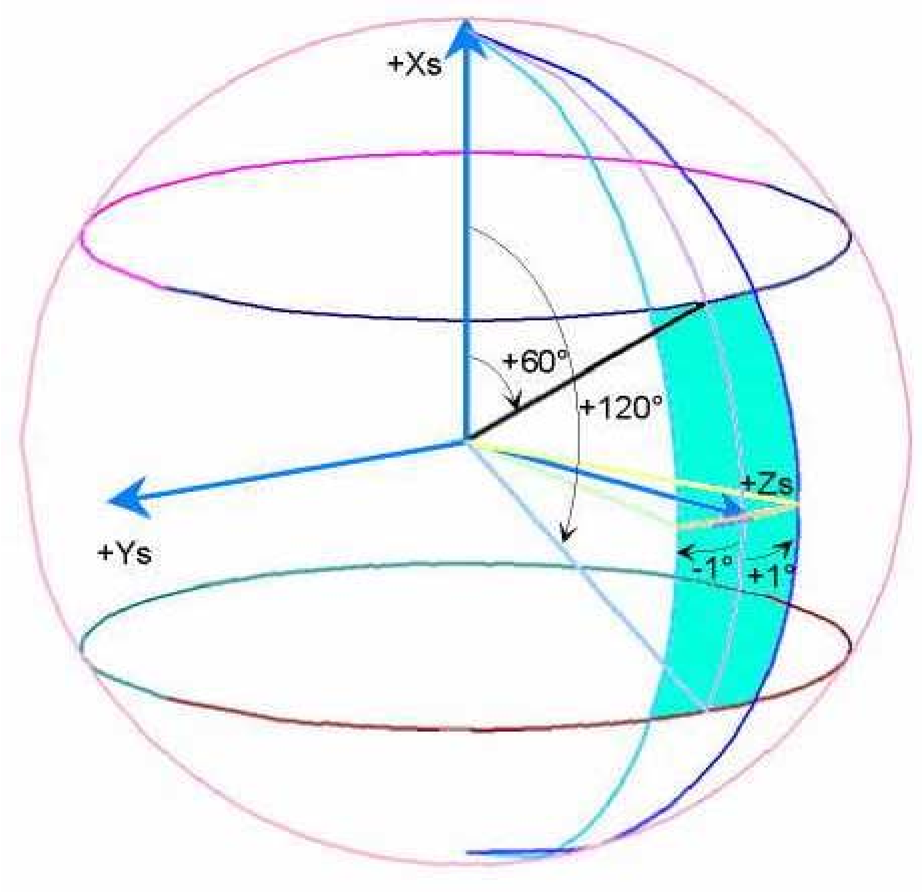


Figure 3-12: Herschel attitude constraints in on-orbit phase

ENVM-300

In contingency cases during Herschel mission phases and operational modes, Herschel shall be compatible with a Sun direction :

- between -10° and +10° from the (Xs, Zs) plane and
- between +55° and +125° from the +Xs axis.

Maximum duration of transient is 1 minute.

*

Notes :

- These allowed Sun directions define a solid angle in the satellite reference frame.
- This solid angle can be scanned by the image of Xs after a combination of 2 rotations :
  - rotation around +Xs with an angle between -10° and +10° ("roll"). +Ys becomes +Ys'.
  - then rotation around +Ys' with an angle between +55° and +125° ("pitch").

ENVM-310

PLANCK : during all PLANCK mission phases and operational modes, the Sun will be maintained at 10 deg from the spin axis (see Figure 3-14).

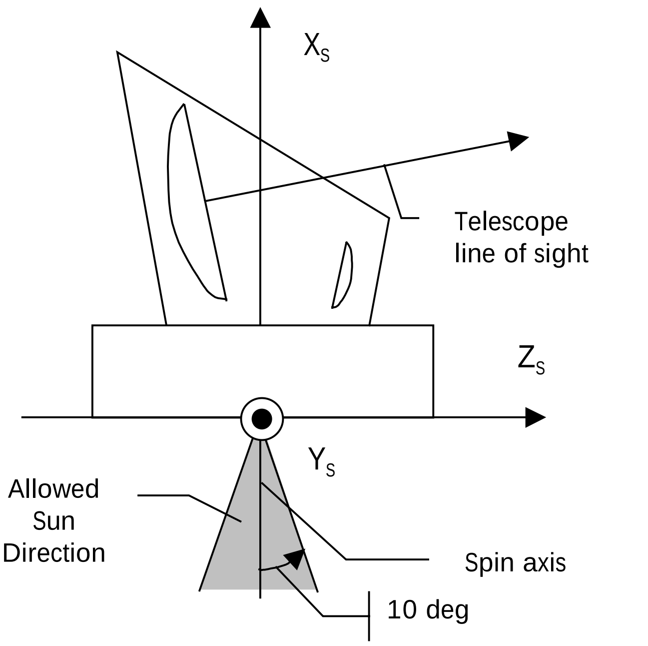


Figure 3-14: Planck attitude constraints

*

Angle between spin axis and Earth

ENVM-320

During PLANCK mission, the spin axis (Xs) can be depointed by 10° off Sun. This however will be done such that the Earth aspect angle (angle between the -Xs and the Earth direction) remain below15°.

*

Eclipses :

ENVM-330

On their Lissajous orbits, the HERSCHEL and PLANCK spacecraft will be well outside the Earth's shadow so that no eclipse will occur during their lifetimes.

*

3.4.4 Other environments

3.4.4.1 Pressure

ENVM-340

The spacecraft and their modules shall be designed to withstand any external air pressure between ambiant (0.105 MPa) and free space vacuum (<10^{-4} Pa). (SENV-070)

*

3.4.4.2 Radiation

The HERSCHEL and PLANCK spacecraft, which will conduct their mission around the L2 Lagrange point of the Earth/Sun system, will be submited to a relatively benign radiation environment. This is due, in particular, to the fact that the spacecraft will only be exposed to trapped particles during the launch phase. They will be however exposed to energetic protons and heavy ions from solar flares and galactic cosmic rays.

Similarly, as L2 is outside the Earth magnetosphere, plasma is basically the one contained in solar wind. So surface charging potential is expected to be low.

The principal anticipated radiation effects are :

- Degradation of electronic components, detectors and materials (dose effect).
- Interference with detector operation (background).
- Latch-up.
- Electrostatic charging.

3.4.4.2.1 Space Radiation Environment description

ENVM-370

The minimum allowable radiation level for active parts shall be :

Minimum Total Dose Behavior	10 krad (Si)
Minimum Displacement Damage Equivalent Fluence (Si)	6.10^9 10 MeV p/cm²
Minimum Displacement Damage Equivalent Fluence (GaAs)	5.10^9 10 MeV p/cm²

*

3.4.4.2.1.1 Trapped Electrons

ENVM-380

Trapped Electrons flux on Transfert orbit (0.22 day) is calculated using the AE8 NASA GSFC model [RD-12]. Trapped Electrons fluxes are given in Figure 3-16 and Table 3.4-3.

*

3.4.4.2.1.2 Trapped Protons

ENVM-390

Trapped Protons flux on Transfert orbit (0.22 day) is calculated using the AP8 NASA GSFC model [RD-12]. Trapped Protons flux is given in Figure 3-18 and Table 3.4-4.

*

3.4.4.2.1.3 Solar Protons

ENVM-400

The mission Solar Protons fluence is calculated using the JPL Feynman Model considering a BOM in 2007 and a 4 years mission (0.5 years in Solar Max) combined with a prediction Confidence Level of 95% [RD-12]. Solar Protons fluence is given in Figure 3-20 and Table 3.4-5.

*

ENVM-410

The Solar Protons Peak Flux (October 89 worst 5 minutes) to be considered for SEP rates calculations is given in Figure 3-22 and Table 3.4-6.

*

3.4.4.2.1.4 Cosmic Rays

ENVM-420

Predictions of cosmic ray fluxes on orbit are obtained using the Cosmic Ray Effects on Micro Electronics (CREME96) suite of programs (from Naval Research Laboratory). Qualitatively, solar cycle variations have opposite effects on solar and galactic cosmic rays populations. To calculate worst case SEP rates, the cosmic rays environment will be calculated in terms of integral Linear Energy Transfer (LET) spectrum.

- Ion species : $1 \leq Z \leq 92$
- Environment Model : Solar Quiet (no "flare") Conditions / Solar Minimum (Cosmic-Ray Maximum)
- Spacecraft Location : Near-Earth Interplanetary/Geosynchronous Orbit
- Shielding : 1 g/cm2

LET flux is given in Figure 3-24 and Table 3.4-7.

*

3.4.4.2.2 Space Radiation Effects

If the Sub-Contractor don't use advanced particle/matter interaction simulation tools, the following 'between in' curves shall be used, instead of using directly particle fluxes and fluences as an input.

3.4.4.2.2.1 Dose depth curve

ENVM-430

The particle fluxes specified in the previous sections are converted into Dose Depth Curve [RD-12], using SHIELDOSE software [RD-13]. This curve is calculated for an Aluminum Solid Sphere Shielding, with a Silicon Detector located in the center of the sphere. It shall be used to perform Ray Tracing Analysis to calculate Deposited Dose.

The mission Dose Depth Curve takes into account particle fluxes. This curve is given in Table 3.4-8 and Figure 3-26.

*

3.4.4.2.2.2 Single Event Phenomena

ENVM-440

Heavy Ions Induced SEU : For Single Event Upset calculations, the SEU rate, normalized to a device cross section of 1 cm², is calculated for various LET threshold. This SEU Rate versus LET_{th} curve is given in Figure 3-28 and Table 3.4-9.

This curve shall be convoluted with the experimental Device Cross Sections versus LET curve, in order to get the Galactic Cosmic Rays SEU rate for the device.

*

ENVM-450

Protons Induced SEU : : For Single Event Upset calculations, the SEU rate, normalized to a device cross section of 10^{-8} cm², is calculated for various LET threshold. This SEU Rate versus LET_{th} curve is given in Table 3.4-10 and Figure 3-30.

*

ENVM-460

For other effects (Latchup, Burnout, Gate Rupture, Hard Error, Transient, ...), the particle fluxes and fluences shall be directly used.

*

3.4.4.2.2.3 Displacement Damage

Both protons and electrons can induce displacement damage in semiconductor devices. The part of deposited energy involved in displacement defects creation is called NonIonizing Energy Loss (NIEL). The particles fluxes spectra are converted into a fluence of monoenergetic particles producing the same amount of defects (10 MeV protons).

ENVM-470

The Displacement Damage Equivalent Fluence (10 MeV protons) is calculated using the NOVICE code [RD-14]. This curve is calculated for an Aluminum Solid Sphere Shielding. The mission Displacement Damage Equivalent Fluence Depth Curves are given in Figure 3-32 and Table 3.4-11 for Silicon and GaAs detectors.

*

3.4.4.2.2.4 SOLAR CELLS DEGRADATION EQUIVALENT FLUENCE

ENVM-480

The Solar Cells degradation equivalent fluences of 1 MeV electrons as a function of cover glass thickness are calculated with the EQFRUX code (JPL) for the mission (5 years) [RD-12]. Infinite cell back shielding is assumed and a 10 MeV proton to 1 MeV electron equivalence ration of 3000 is used for maximum power degradation.

The results are provided in :

- Figure 3-34 and Table 3.4-12 for Pmax-Voc in Silicon
- Figure 3-36 and Table 3.4-13 for Isc in Silicon
- Figure 3-38and Table 3.4-14 for Voc in GaAs
- Figure 3-40and Table 3.4-15 for Pmax in GaAs

- Figure 3-42and Table 3.4-16 for Isc in GaAs

*

3.4.4.2.3 *Figures and tables*

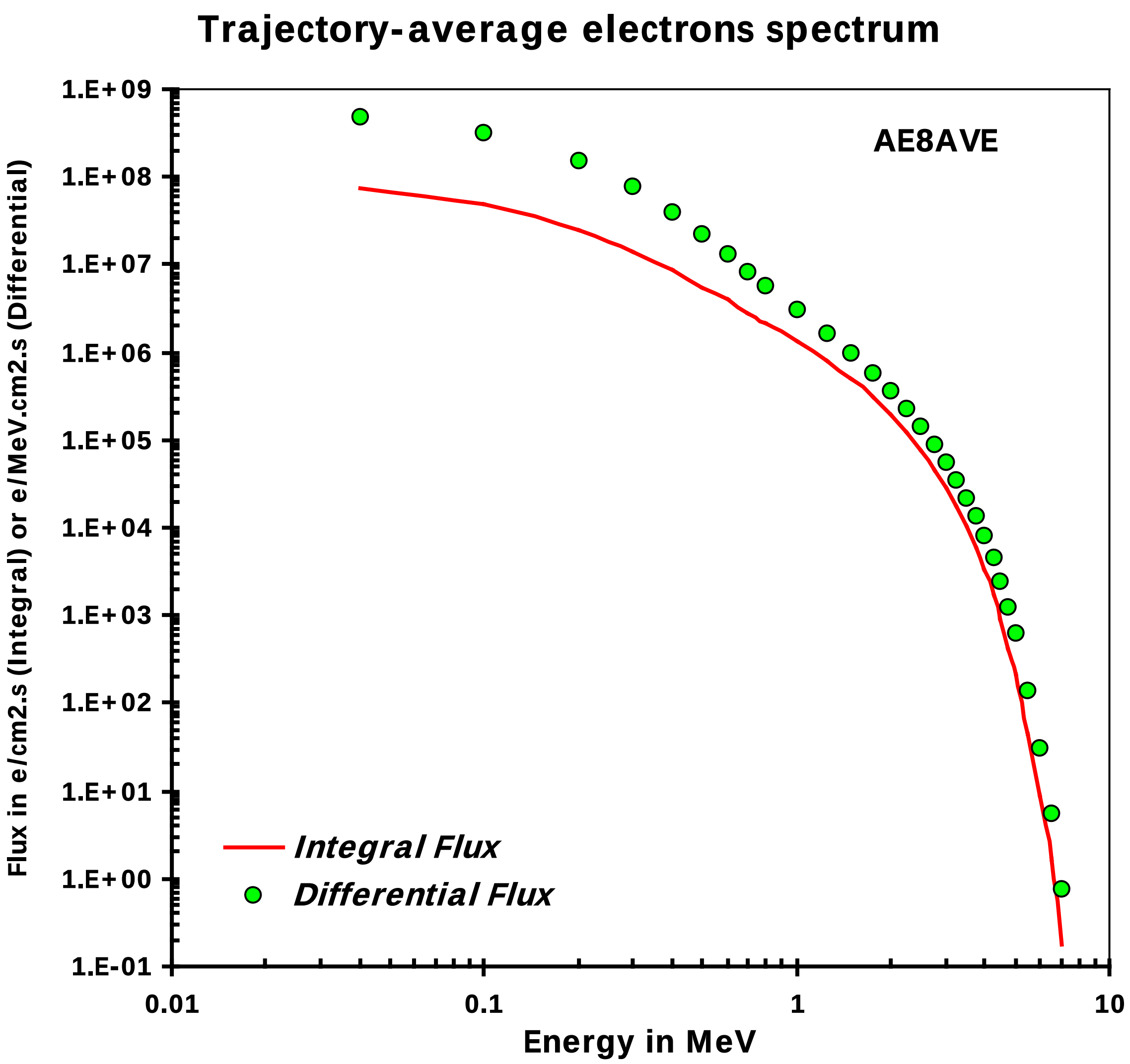


Figure 3-16: GTO Trapped Electrons Flux

Energy MeV	Int. Flux e/cm2.sec	Diff. Flux e/MeV.cm2.s	Energy MeV	Int. Flux e/cm2.sec	Diff. Flux e/MeV.cm2.s	Energy MeV	Int. Flux e/cm2.sec	Diff. Flux e/MeV.cm2.s
0.04	7.31E+07	4.92E+08	1.25	8.06E+05	1.65E+06	3.75	5.90E+03	1.36E+04
0.10	4.88E+07	3.25E+08	1.50	4.87E+05	9.61E+05	4.00	3.32E+03	7.97E+03
0.20	2.47E+07	1.55E+08	1.75	3.04E+05	5.77E+05	4.25	1.74E+03	4.55E+03
0.30	1.38E+07	7.61E+07	2.00	1.90E+05	3.56E+05	4.50	9.21E+02	2.48E+03
0.40	8.56E+06	3.97E+07	2.25	1.19E+05	2.23E+05	4.75	4.24E+02	1.26E+03
0.50	5.48E+06	2.22E+07	2.50	7.54E+04	1.42E+05	5.00	2.10E+02	6.21E+02
0.60	3.90E+06	1.33E+07	2.75	4.63E+04	8.96E+04	5.50	4.44E+01	1.39E+02
0.70	2.83E+06	8.49E+06	3.00	2.86E+04	5.61E+04	6.00	9.00E+00	3.04E+01
0.80	2.14E+06	5.64E+06	3.25	1.73E+04	3.53E+04	6.50	1.63E+00	5.58E+00
1.00	1.35E+06	3.03E+06	3.50	1.05E+04	2.23E+04	7.00	1.74E-01	7.53E-01

Table 3.4-3: GTO Trapped Electrons Flux

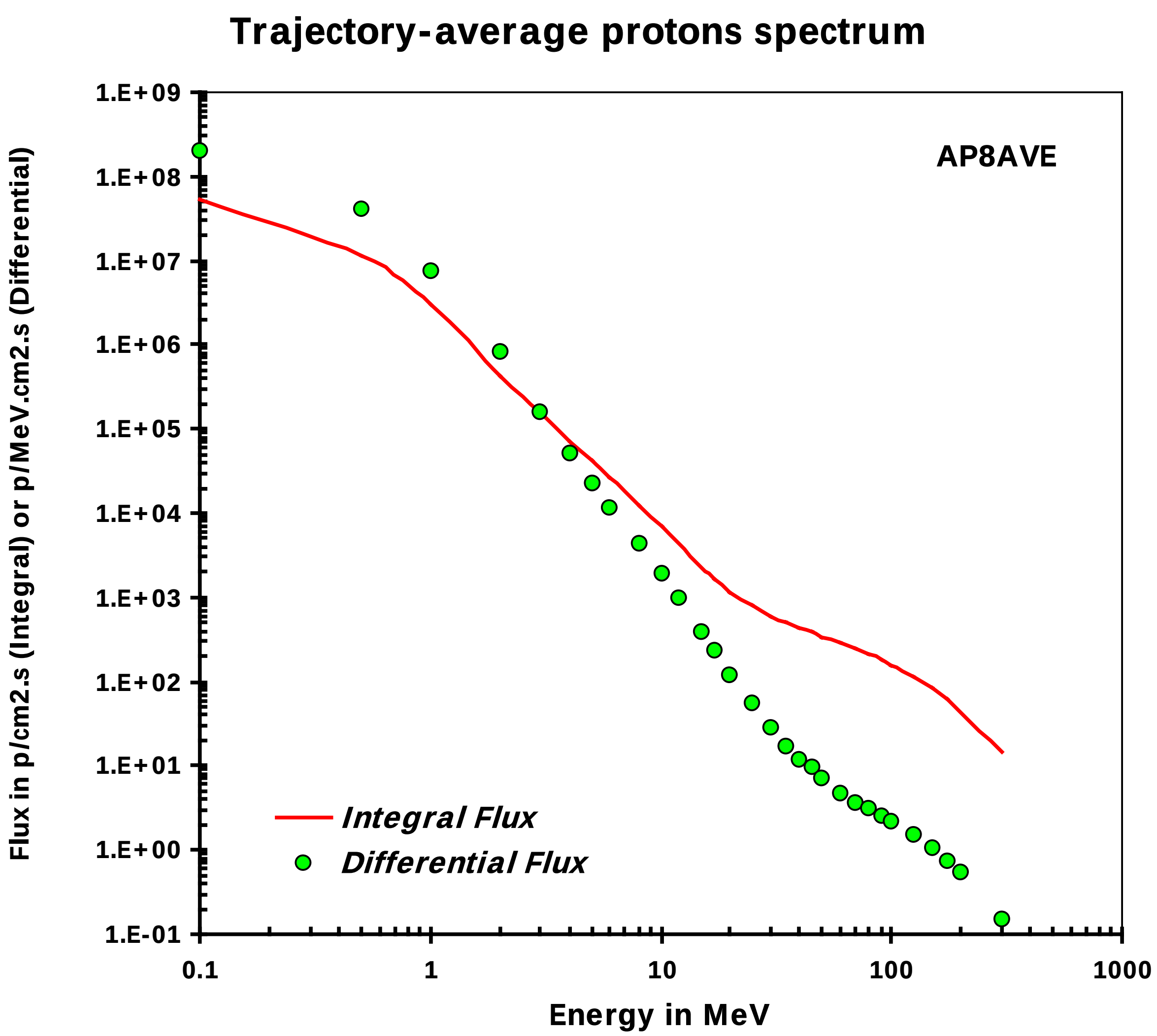


Figure 3-18: GTO Trapped Protons Flux

Energy MeV	Int. Flux p/cm2.s	Diff. Flux p/MeV.cm2.s	Energy MeV	Int. Flux p/cm2.s	Diff. Flux p/MeV.cm2.s	Energy MeV	Int. Flux p/cm2.s	Diff. Flux p/MeV.cm2.s
0.1	5.44E+07	2.07E+08	12.0	4.30E+03	1.01E+03	60.0	2.86E+02	4.82E+00
0.5	1.14E+07	4.08E+07	15.0	2.22E+03	4.02E+02	70.0	2.45E+02	3.72E+00
1.0	2.99E+06	7.51E+06	17.0	1.68E+03	2.35E+02	80.0	2.11E+02	3.09E+00
2.0	4.31E+05	8.15E+05	20.0	1.14E+03	1.19E+02	90.0	1.83E+02	2.58E+00
3.0	1.58E+05	1.64E+05	25.0	7.98E+02	5.46E+01	100.0	1.59E+02	2.17E+00
4.0	7.17E+04	5.28E+04	30.0	5.82E+02	2.83E+01	125.0	1.15E+02	1.50E+00
5.0	4.22E+04	2.25E+04	35.0	5.02E+02	1.69E+01	150.0	8.30E+01	1.07E+00
6.0	2.61E+04	1.14E+04	40.0	4.37E+02	1.20E+01	175.0	6.03E+01	7.61E-01
8.0	1.25E+04	4.31E+03	45.0	3.83E+02	9.48E+00	200.0	4.40E+01	5.36E-01
10.0	6.85E+03	1.94E+03	50.0	3.38E+02	7.22E+00	300.0	1.48E+01	1.53E-01

Table 3.4-4: GTO Trapped Protons Flux

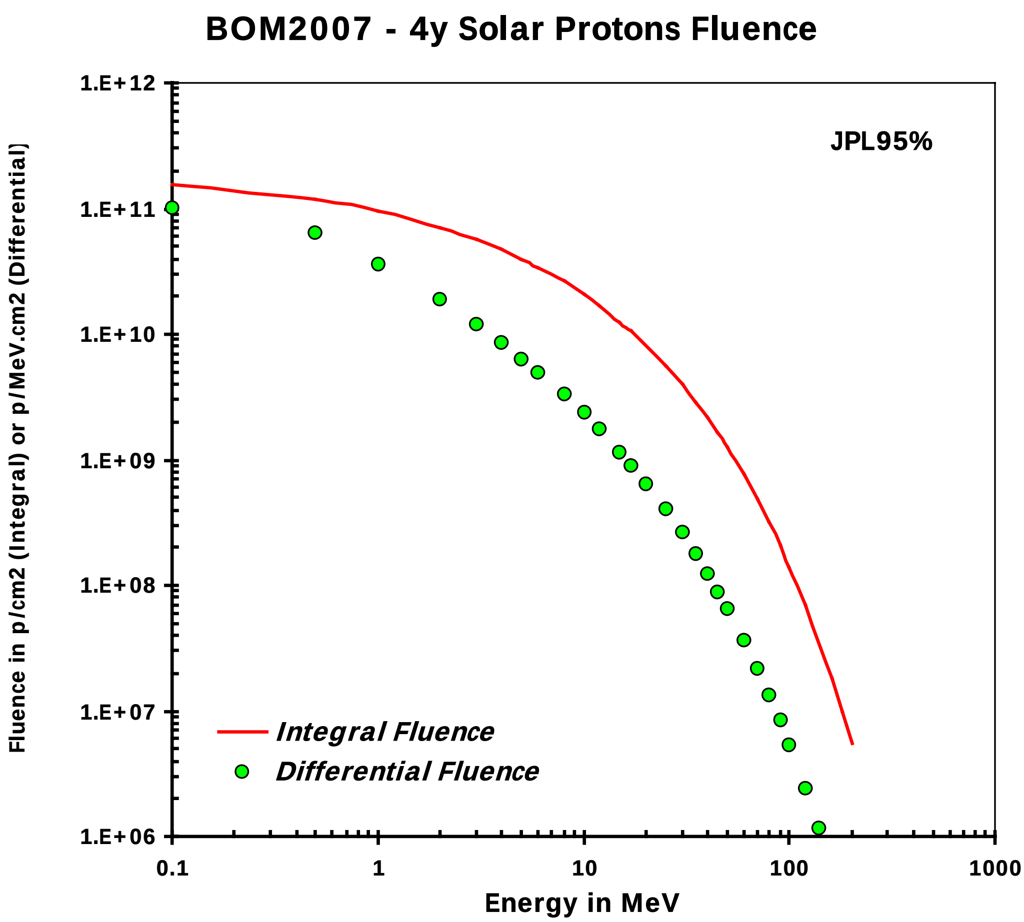


Figure 3-20: Solar Protons Fluence for the 4 years mission BOM 2007

Energy MeV	Int. Fluence p/cm2	Diff. Fluence p/MeV.cm2	Energy MeV	Int. Fluence p/cm2	Diff. Fluence p/MeV.cm2
1.00E-01	1.54E+11	1.02E+11	3.00E+01	3.98E+09	2.65E+08
5.00E-01	1.17E+11	6.42E+10	3.50E+01	2.90E+09	1.79E+08
1.00E+00	9.52E+10	3.60E+10	4.00E+01	2.16E+09	1.25E+08
2.00E+00	7.11E+10	1.90E+10	4.50E+01	1.63E+09	8.91E+07
3.00E+00	5.69E+10	1.21E+10	5.00E+01	1.26E+09	6.47E+07
4.00E+00	4.71E+10	8.56E+09	6.00E+01	7.65E+08	3.67E+07
5.00E+00	3.99E+10	6.38E+09	7.00E+01	4.84E+08	2.17E+07
6.00E+00	3.43E+10	4.94E+09	8.00E+01	3.15E+08	1.33E+07
8.00E+00	2.63E+10	3.33E+09	9.00E+01	2.10E+08	8.37E+06
1.00E+01	2.07E+10	2.36E+09	1.00E+02	1.42E+08	5.39E+06
1.20E+01	1.67E+10	1.73E+09	1.20E+02	6.88E+07	2.44E+06
1.50E+01	1.25E+10	1.16E+09	1.40E+02	3.49E+07	1.16E+06
1.70E+01	1.05E+10	9.07E+08	1.60E+02	1.84E+07	5.81E+05
2.00E+01	8.18E+09	6.49E+08	1.80E+02	9.99E+06	3.03E+05
2.50E+01	5.61E+09	4.06E+08	2.00E+02	5.57E+06	1.63E+05

Table 3.4-5: Solar Protons Fluence for the 4 years mission BOM 2007

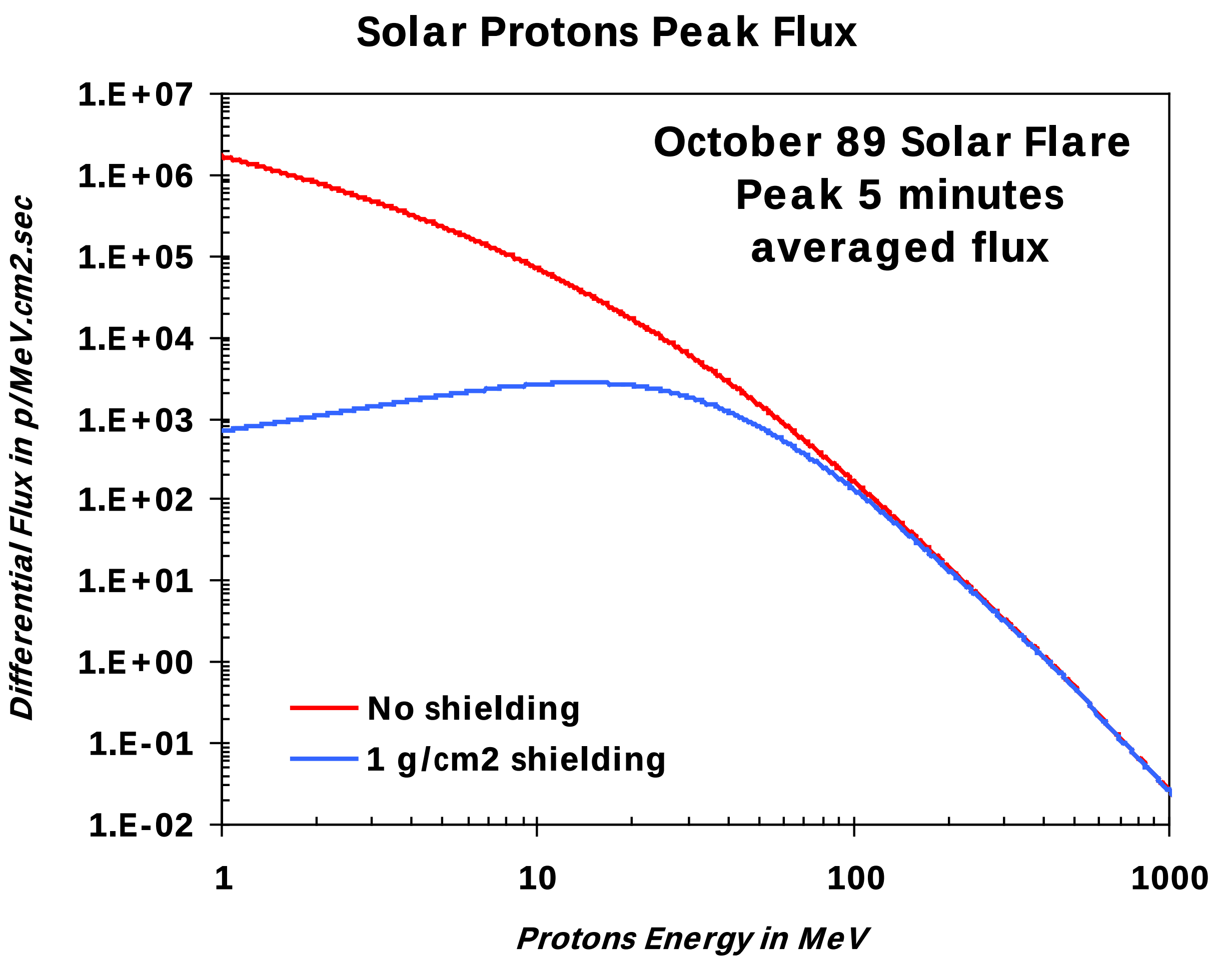


Figure 3-22: Solar Protons Peak Fluxes

	No Shielding	1g/cm2 shd		No Shielding	1g/cm2 shd
Energy MeV	Differential Flux p/MeV.cm2.sec	Differential Flux p/MeV.cm2.sec	Energy MeV	Differential Flux p/MeV.cm2.sec	Differential Flux p/MeV.cm2.sec
1.00E+00	1.70E+06	6.95E+02	5.05E+01	1.46E+03	7.88E+02
2.00E+00	8.00E+05	1.07E+03	6.04E+01	8.55E+02	5.28E+02
3.02E+00	4.74E+05	1.40E+03	7.03E+01	5.33E+02	3.62E+02
3.98E+00	3.23E+05	1.67E+03	8.07E+01	3.43E+02	2.50E+02
5.04E+00	2.28E+05	1.93E+03	9.02E+01	2.39E+02	1.83E+02
7.02E+00	1.33E+05	2.30E+03	1.01E+02	1.65E+02	1.32E+02
1.00E+01	6.99E+04	2.65E+03	1.20E+02	8.97E+01	7.54E+01
1.20E+01	4.94E+04	2.76E+03	1.50E+02	4.14E+01	3.65E+01
1.50E+01	3.13E+04	2.77E+03	2.01E+02	1.46E+01	1.35E+01
1.79E+01	2.12E+04	2.67E+03	3.00E+02	3.41E+00	3.26E+00
2.00E+01	1.65E+04	2.56E+03	5.06E+02	4.78E-01	4.65E-01
3.03E+01	5.99E+03	1.82E+03	8.09E+02	6.31E-02	6.19E-02
4.05E+01	2.75E+03	1.20E+03	1.01E+03	2.53E-02	2.49E-02

Table 3.4-6: Solar Protons Peak Fluxes

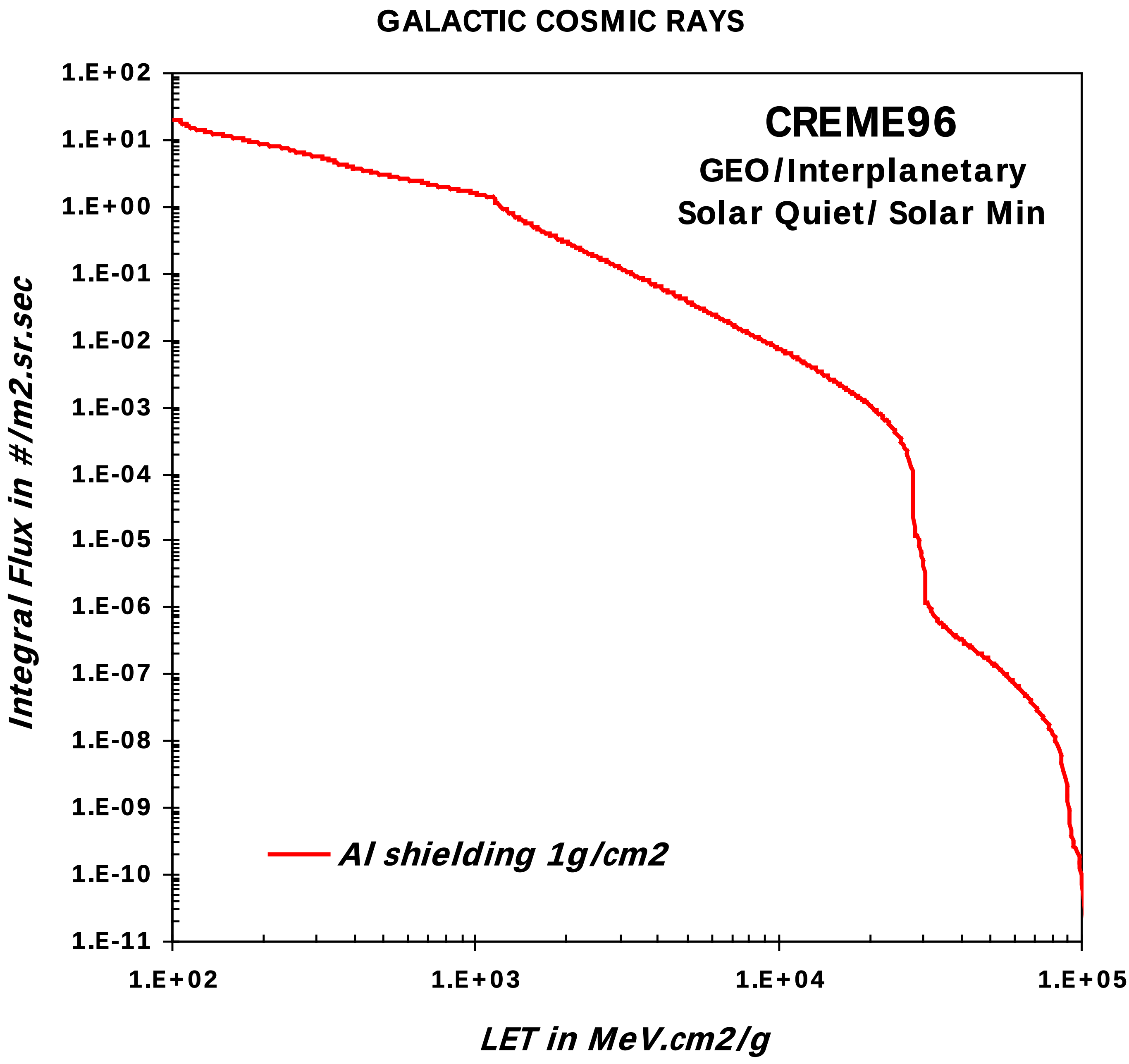


Figure 3-24: Galactic Cosmic Rays LET spectrum

LET MeV-cm2/g	Integral Flux #/m2.sr.sec	LET MeV-cm2/g	Integral Flux #/m2.sr.sec	LET MeV-cm2/g	Integral Flux #/m2.sr.sec	LET MeV-cm2/g	Integral Flux #/m2.sr.sec	LET MeV-cm2/g	Integral Flux #/m2.sr.sec
1.01E+02	1.97E+01	4.06E+02	3.77E+00	1.63E+03	4.54E-01	6.57E+03	2.04E-02	2.64E+04	2.17E-04
1.03E+02	1.95E+01	4.16E+02	3.68E+00	1.67E+03	4.31E-01	6.72E+03	1.93E-02	2.70E+04	1.57E-04
1.06E+02	1.93E+01	4.26E+02	3.60E+00	1.71E+03	4.09E-01	6.88E+03	1.83E-02	2.77E+04	9.81E-05
1.08E+02	1.76E+01	4.36E+02	3.49E+00	1.75E+03	3.89E-01	7.04E+03	1.73E-02	2.83E+04	1.28E-05
1.11E+02	1.66E+01	4.46E+02	3.39E+00	1.79E+03	3.70E-01	7.21E+03	1.63E-02	2.90E+04	1.00E-05
1.13E+02	1.59E+01	4.56E+02	3.30E+00	1.83E+03	3.52E-01	7.38E+03	1.54E-02	2.97E+04	6.96E-06
1.16E+02	1.53E+01	4.67E+02	3.23E+00	1.88E+03	3.34E-01	7.55E+03	1.46E-02	3.04E+04	2.03E-06
1.19E+02	1.48E+01	4.78E+02	3.16E+00	1.92E+03	3.18E-01	7.73E+03	1.38E-02	3.11E+04	1.14E-06
1.22E+02	1.43E+01	4.89E+02	3.08E+00	1.97E+03	3.02E-01	7.91E+03	1.31E-02	3.18E+04	9.43E-07
1.24E+02	1.39E+01	5.01E+02	3.01E+00	2.01E+03	2.87E-01	8.09E+03	1.25E-02	3.26E+04	7.71E-07
1.27E+02	1.35E+01	5.12E+02	2.95E+00	2.06E+03	2.73E-01	8.28E+03	1.18E-02	3.33E+04	6.70E-07
1.30E+02	1.32E+01	5.24E+02	2.89E+00	2.11E+03	2.60E-01	8.48E+03	1.12E-02	3.41E+04	6.03E-07
1.33E+02	1.29E+01	5.37E+02	2.84E+00	2.16E+03	2.47E-01	8.68E+03	1.06E-02	3.49E+04	5.38E-07
1.37E+02	1.25E+01	5.49E+02	2.77E+00	2.21E+03	2.35E-01	8.88E+03	1.01E-02	3.57E+04	4.93E-07
1.40E+02	1.23E+01	5.62E+02	2.70E+00	2.26E+03	2.24E-01	9.09E+03	9.54E-03	3.66E+04	4.53E-07
1.43E+02	1.20E+01	5.75E+02	2.65E+00	2.31E+03	2.13E-01	9.30E+03	9.02E-03	3.74E+04	4.14E-07
1.46E+02	1.17E+01	5.89E+02	2.60E+00	2.37E+03	2.02E-01	9.52E+03	8.53E-03	3.83E+04	3.83E-07
1.50E+02	1.15E+01	6.03E+02	2.55E+00	2.42E+03	1.92E-01	9.75E+03	8.07E-03	3.92E+04	3.54E-07
1.53E+02	1.13E+01	6.17E+02	2.49E+00	2.48E+03	1.83E-01	9.97E+03	7.63E-03	4.01E+04	3.26E-07
1.57E+02	1.11E+01	6.31E+02	2.44E+00	2.54E+03	1.74E-01	1.02E+04	7.23E-03	4.10E+04	3.01E-07
1.61E+02	1.09E+01	6.46E+02	2.39E+00	2.60E+03	1.65E-01	1.04E+04	6.82E-03	4.20E+04	2.77E-07
1.64E+02	1.07E+01	6.61E+02	2.35E+00	2.66E+03	1.57E-01	1.07E+04	6.45E-03	4.30E+04	2.57E-07
1.68E+02	1.03E+01	6.77E+02	2.30E+00	2.72E+03	1.50E-01	1.09E+04	6.08E-03	4.40E+04	2.37E-07
1.72E+02	1.00E+01	6.93E+02	2.22E+00	2.79E+03	1.42E-01	1.12E+04	5.73E-03	4.50E+04	2.20E-07
1.76E+02	9.75E+00	7.09E+02	2.17E+00	2.85E+03	1.35E-01	1.15E+04	5.41E-03	4.61E+04	2.04E-07
1.80E+02	9.52E+00	7.26E+02	2.13E+00	2.92E+03	1.28E-01	1.17E+04	5.07E-03	4.72E+04	1.89E-07
1.85E+02	9.31E+00	7.43E+02	2.08E+00	2.99E+03	1.22E-01	1.20E+04	4.74E-03	4.83E+04	1.75E-07
1.89E+02	9.12E+00	7.60E+02	2.04E+00	3.06E+03	1.16E-01	1.23E+04	4.48E-03	4.94E+04	1.61E-07
1.93E+02	8.94E+00	7.78E+02	2.00E+00	3.13E+03	1.10E-01	1.26E+04	4.21E-03	5.06E+04	1.49E-07
1.98E+02	8.78E+00	7.96E+02	1.96E+00	3.20E+03	1.05E-01	1.29E+04	3.96E-03	5.18E+04	1.36E-07
2.03E+02	8.61E+00	8.15E+02	1.93E+00	3.28E+03	9.98E-02	1.32E+04	3.71E-03	5.30E+04	1.25E-07
2.07E+02	8.42E+00	8.34E+02	1.87E+00	3.35E+03	9.47E-02	1.35E+04	3.49E-03	5.42E+04	1.14E-07
2.12E+02	8.25E+00	8.53E+02	1.83E+00	3.43E+03	9.01E-02	1.38E+04	3.27E-03	5.55E+04	1.04E-07
2.17E+02	8.10E+00	8.73E+02	1.80E+00	3.51E+03	8.55E-02	1.41E+04	3.06E-03	5.68E+04	9.43E-08
2.22E+02	7.97E+00	8.94E+02	1.76E+00	3.59E+03	8.13E-02	1.45E+04	2.85E-03	5.81E+04	8.48E-08
2.28E+02	7.84E+00	9.15E+02	1.72E+00	3.68E+03	7.71E-02	1.48E+04	2.68E-03	5.95E+04	7.68E-08
2.33E+02	7.72E+00	9.36E+02	1.69E+00	3.77E+03	7.33E-02	1.51E+04	2.52E-03	6.09E+04	6.89E-08
2.38E+02	7.60E+00	9.58E+02	1.66E+00	3.85E+03	6.95E-02	1.55E+04	2.36E-03	6.23E+04	6.08E-08
2.44E+02	7.21E+00	9.81E+02	1.62E+00	3.94E+03	6.61E-02	1.59E+04	2.21E-03	6.38E+04	5.46E-08
2.50E+02	6.92E+00	1.00E+03	1.57E+00	4.04E+03	6.27E-02	1.62E+04	2.07E-03	6.53E+04	4.90E-08
2.55E+02	6.70E+00	1.03E+03	1.54E+00	4.13E+03	5.95E-02	1.66E+04	1.93E-03	6.68E+04	4.37E-08
2.61E+02	6.52E+00	1.05E+03	1.51E+00	4.23E+03	5.66E-02	1.70E+04	1.81E-03	6.84E+04	3.89E-08
2.68E+02	6.35E+00	1.08E+03	1.46E+00	4.33E+03	5.36E-02	1.74E+04	1.69E-03	7.00E+04	3.41E-08
2.74E+02	6.20E+00	1.10E+03	1.43E+00	4.43E+03	5.09E-02	1.78E+04	1.57E-03	7.16E+04	2.98E-08
2.80E+02	6.07E+00	1.13E+03	1.40E+00	4.53E+03	4.82E-02	1.82E+04	1.46E-03	7.33E+04	2.58E-08
2.87E+02	5.89E+00	1.15E+03	1.27E+00	4.64E+03	4.58E-02	1.87E+04	1.36E-03	7.50E+04	2.21E-08
2.94E+02	5.74E+00	1.18E+03	1.11E+00	4.75E+03	4.34E-02	1.91E+04	1.26E-03	7.68E+04	1.88E-08
3.01E+02	5.61E+00	1.21E+03	1.01E+00	4.86E+03	4.12E-02	1.95E+04	1.16E-03	7.86E+04	1.57E-08
3.08E+02	5.49E+00	1.24E+03	9.38E-01	4.97E+03	3.90E-02	2.00E+04	1.07E-03	8.04E+04	1.29E-08
3.15E+02	5.38E+00	1.27E+03	8.74E-01	5.09E+03	3.69E-02	2.05E+04	9.78E-04	8.23E+04	1.02E-08
3.22E+02	5.28E+00	1.30E+03	8.19E-01	5.21E+03	3.50E-02	2.10E+04	8.91E-04	8.42E+04	7.53E-09
3.30E+02	5.07E+00	1.33E+03	7.69E-01	5.33E+03	3.32E-02	2.14E+04	8.04E-04	8.62E+04	4.84E-09
3.37E+02	4.79E+00	1.36E+03	7.16E-01	5.46E+03	3.15E-02	2.19E+04	7.32E-04	8.82E+04	2.80E-09
3.45E+02	4.60E+00	1.39E+03	6.71E-01	5.59E+03	2.98E-02	2.25E+04	6.59E-04	9.03E+04	1.57E-09
3.54E+02	4.45E+00	1.42E+03	6.32E-01	5.72E+03	2.83E-02	2.30E+04	5.90E-04	9.24E+04	3.69E-10
3.62E+02	4.31E+00	1.45E+03	5.96E-01	5.85E+03	2.68E-02	2.35E+04	5.17E-04	9.46E+04	2.76E-10
3.70E+02	4.19E+00	1.49E+03	5.63E-01	5.99E+03	2.54E-02	2.41E+04	4.56E-04	9.68E+04	2.18E-10
3.79E+02	4.07E+00	1.52E+03	5.33E-01	6.13E+03	2.40E-02	2.46E+04	3.92E-04	9.91E+04	1.50E-10
3.88E+02	3.96E+00	1.56E+03	5.05E-01	6.27E+03	2.28E-02	2.52E+04	3.34E-04	1.01E+05	4.59E-11

Table 3.4-7: Galactic Cosmic Rays LET spectrum

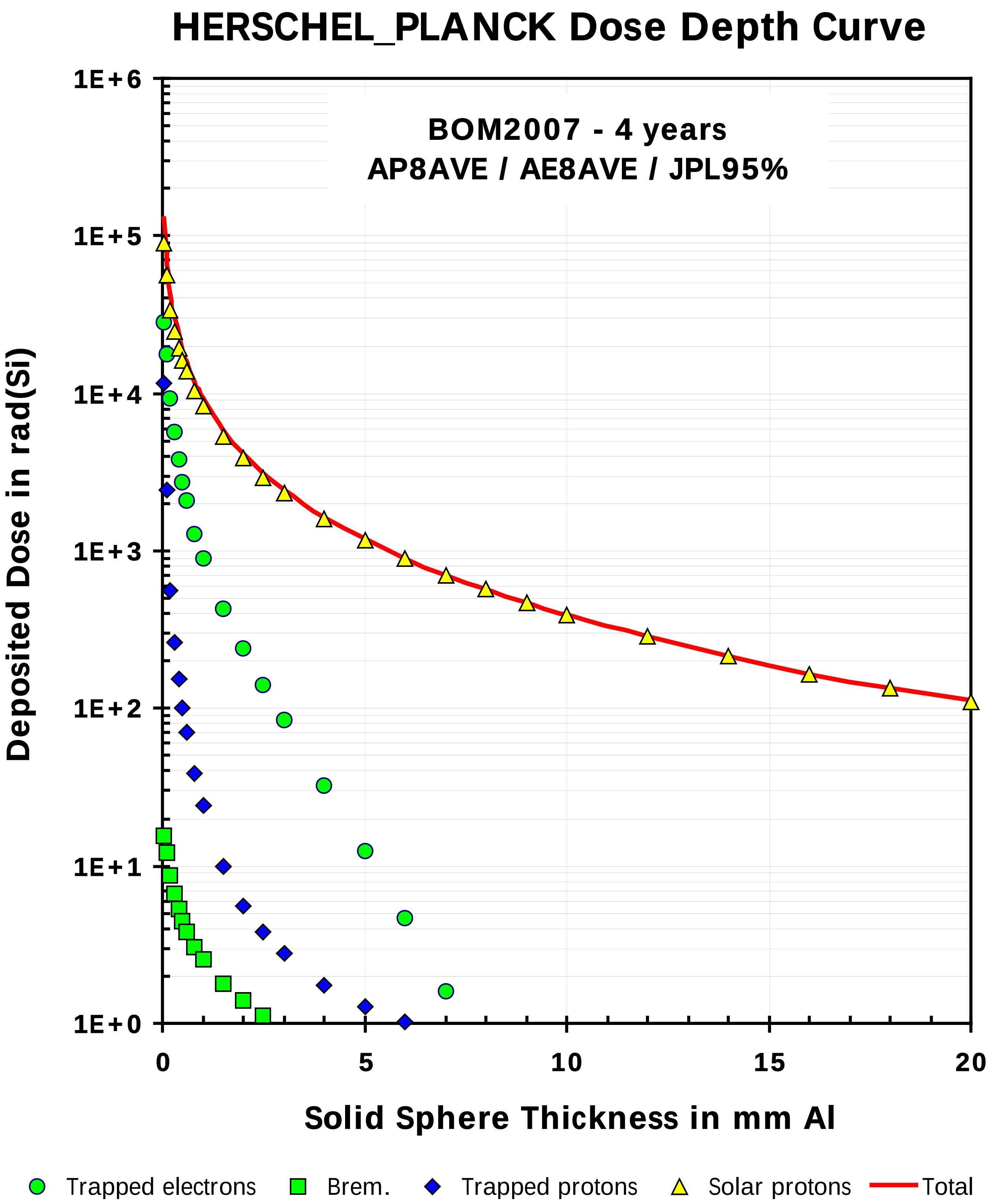


Figure 3-26: Mission Dose Depth Curve

			Detector : Si				
Z mils	**Z** mm	**Z** g/cm2	**Electrons** rad	**Brem.** rad	**TR. Protons** rad	**Sol. Protons** rad	**TOTAL** rad
1.97E+00	5.00E-02	1.40E-02	28420	16	11580	89210	1.29E+05
3.94E+00	1.00E-01	2.70E-02	17790	12	2421	56370	7.66E+04
7.87E+00	2.00E-01	5.40E-02	9185	9	564	33540	4.33E+04
1.18E+01	3.00E-01	8.10E-02	5651	7	263	24580	3.05E+04
1.57E+01	4.00E-01	1.08E-01	3815	5	155	19580	2.36E+04
1.97E+01	5.00E-01	1.35E-01	2742	4	101	16200	1.90E+04
2.36E+01	6.00E-01	1.62E-01	2064	4	70	13740	1.59E+04
3.15E+01	8.00E-01	2.16E-01	1291	3	39	10410	1.17E+04
3.94E+01	1.00E+00	2.70E-01	885	3	24	8312	9.22E+03
5.91E+01	1.50E+00	4.05E-01	431	2	10	5344	5.79E+03
7.87E+01	2.00E+00	5.40E-01	239	1	6	3905	4.15E+03
9.84E+01	2.50E+00	6.75E-01	140	1	4	2945	3.09E+03
1.18E+02	3.00E+00	8.10E-01	84	1	3	2343	2.43E+03
1.57E+02	4.00E+00	1.08E+00	32	1	2	1597	1.63E+03
1.97E+02	5.00E+00	1.35E+00	12	1	1	1169	1.18E+03
2.36E+02	6.00E+00	1.62E+00	5	1	1	893	8.99E+02
2.76E+02	7.00E+00	1.89E+00	2	0	1	702	7.05E+02
3.15E+02	8.00E+00	2.16E+00		0	1	574	5.75E+02
3.54E+02	9.00E+00	2.43E+00		0	1	465	4.66E+02
3.94E+02	1.00E+01	2.70E+00		0	1	389	3.90E+02
4.72E+02	1.20E+01	3.24E+00		0	0	287	2.88E+02
5.51E+02	1.40E+01	3.78E+00		0	0	215	2.16E+02
6.30E+02	1.60E+01	4.32E+00		0	0	166	1.66E+02
7.09E+02	1.80E+01	4.86E+00		0	0	134	1.34E+02
7.87E+02	2.00E+01	5.40E+00		0	0	111	1.12E+02

Table 3.4-8: Mission Dose Depth Curve

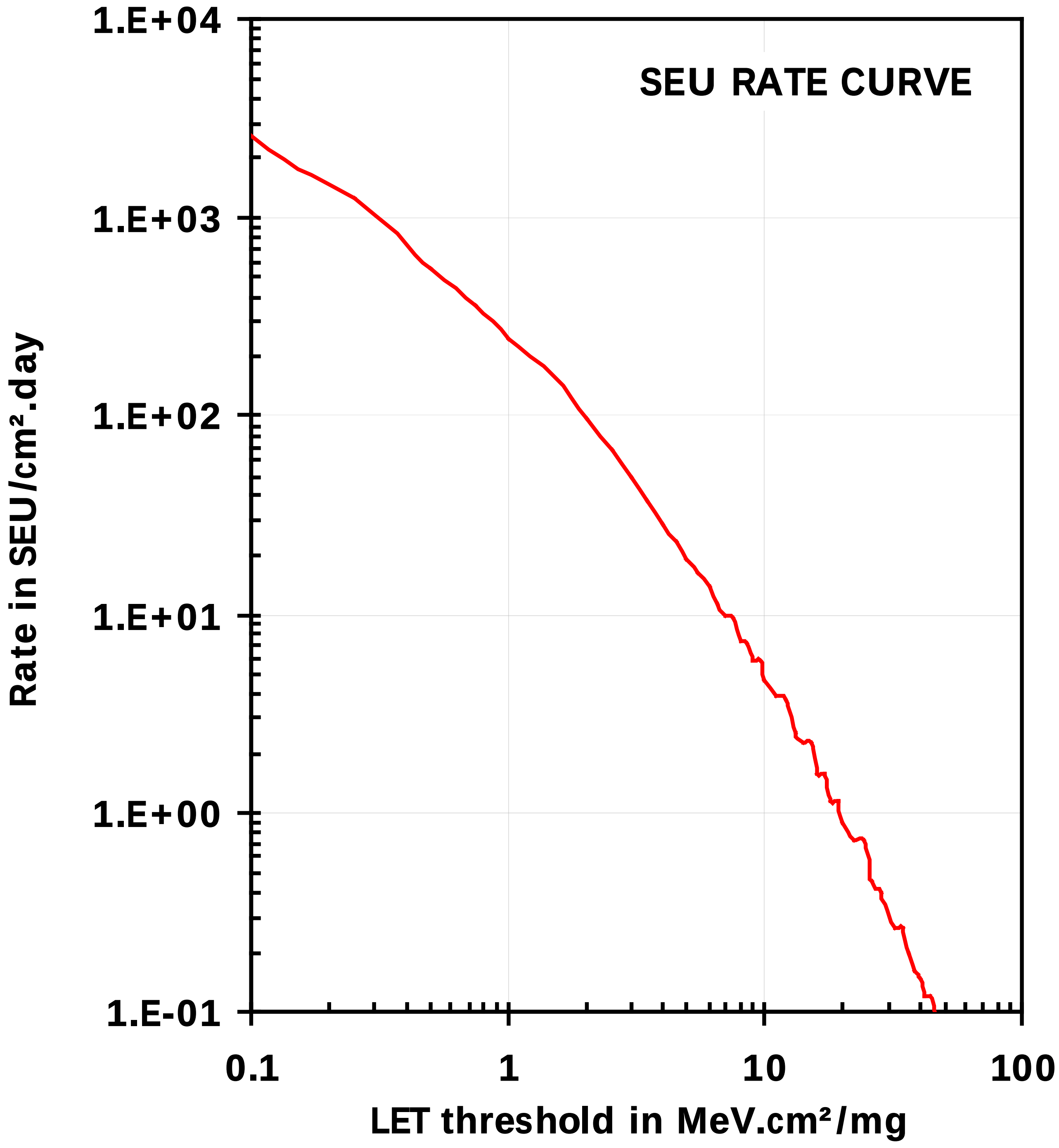


Figure 3-28: Heavy Ions Induced SEU rate

LET MeV.cm²/mg	RATE seu/cm2.day	LET MeV.cm²/mg	RATE seu/cm2.day	LET MeV.cm²/mg	RATE seu/cm2.day
0.005	7.81E+04	16	1.57E+00	72	2.75E-02
0.01	3.51E+04	17	1.57E+00	74	2.40E-02
0.1	2.57E+03	18	1.17E+00	76	2.16E-02
0.25	1.27E+03	19	1.17E+00	78	2.16E-02
0.5	5.54E+02	20	9.10E-01	80	2.08E-02
0.75	3.67E+02	22	7.40E-01	82	1.80E-02
1	2.47E+02	24	7.40E-01	84	1.61E-02
1.5	1.59E+02	26	4.51E-01	86	1.47E-02
2	9.72E+01	28	3.95E-01	88	1.47E-02
2.5	6.76E+01	30	3.05E-01	90	1.44E-02
3	4.95E+01	32	2.68E-01	92	1.26E-02
3.5	3.77E+01	34	2.68E-01	94	1.13E-02
4	2.92E+01	36	1.94E-01	96	1.04E-02
4.5	2.33E+01	38	1.60E-01	98	1.04E-02
5	1.92E+01	40	1.48E-01	100	1.10E-02
5.5	1.63E+01	42	1.22E-01	102	9.41E-03
6	1.40E+01	44	1.22E-01	104	8.39E-03
6.5	1.13E+01	46	9.69E-02	106	7.63E-03
7	1.00E+01	48	8.31E-02	108	7.02E-03
7.5	9.69E+00	50	8.21E-02	110	7.02E-03
8	7.51E+00	52	6.79E-02	112	7.84E-03
8.5	7.16E+00	54	5.93E-02	114	6.67E-03
9	5.87E+00	56	5.93E-02	116	5.93E-03
9.5	5.87E+00	58	5.01E-02	118	5.39E-03
10	4.74E+00	60	4.39E-02	120	4.96E-03
11	3.98E+00	62	4.39E-02	130	4.03E-03
12	3.71E+00	64	3.90E-02	140	4.03E-03
13	2.56E+00	66	3.38E-02	150	2.24E-03
14	2.27E+00	68	3.02E-02	200	1.02E-03
15	2.27E+00	70	3.02E-02	250	4.74E-04

Table 3.4-9: Heavy Ions Induced SEU rates

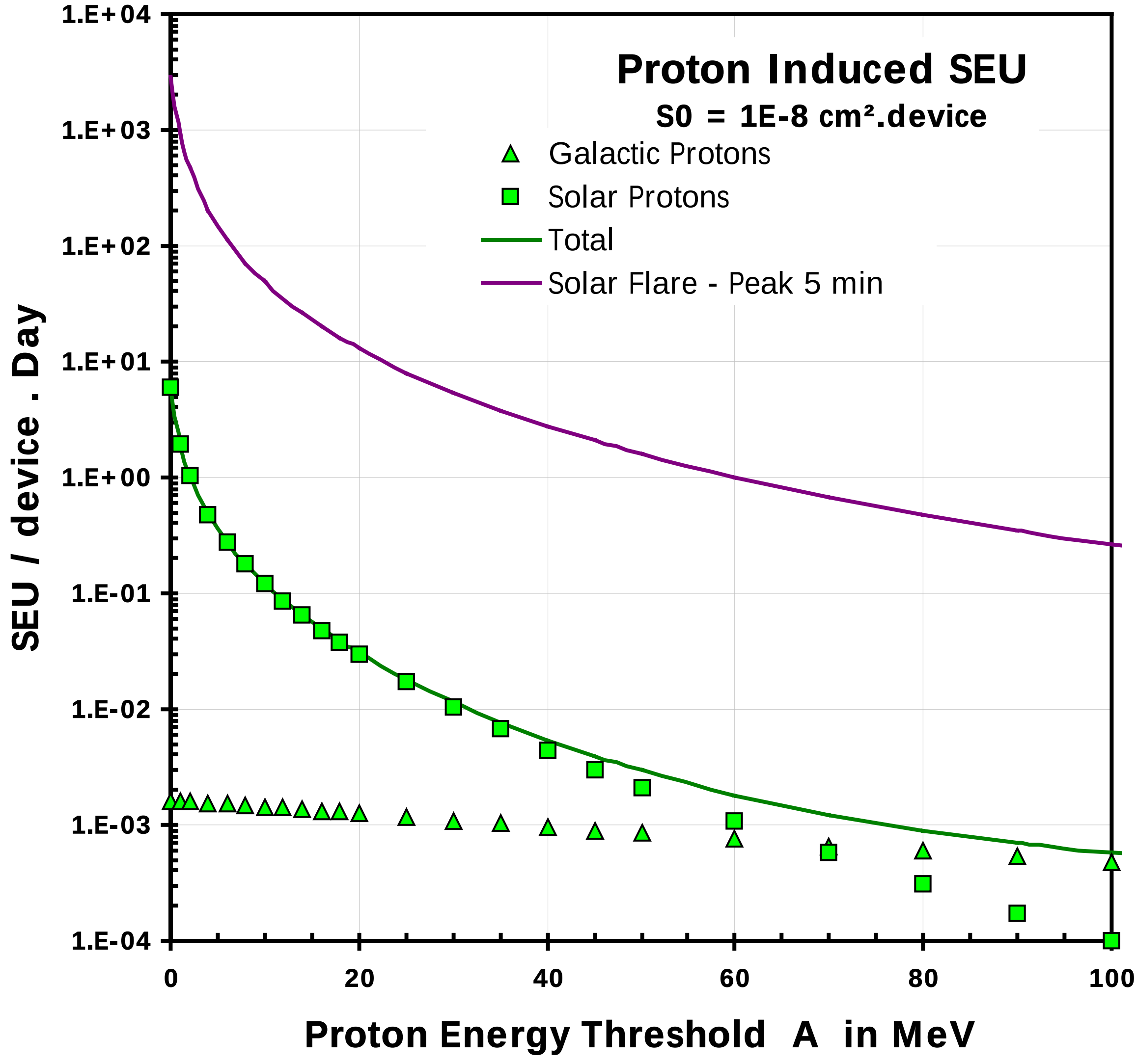


Figure 3-30: Protons Induced SEU rates

S_0 cm² 1.0E-08	Galactic Protons	Solar Protons	Total	Solar Flare - Peak 5 min
E Threshold MeV	Rate seu/device.day	Rate seu/device.day	Rate seu/device.day	Rate seu/device.day
0.1	1.58E-03	5.93E+00	5.93E+00	2.83E+03
1	1.58E-03	1.91E+00	1.91E+00	9.28E+02
2	1.57E-03	1.05E+00	1.05E+00	4.71E+02
4	1.55E-03	4.84E-01	4.86E-01	2.02E+02
6	1.52E-03	2.79E-01	2.81E-01	1.13E+02
8	1.48E-03	1.78E-01	1.80E-01	7.16E+01
10	1.45E-03	1.22E-01	1.23E-01	4.90E+01
12	1.41E-03	8.70E-02	8.84E-02	3.53E+01
14	1.37E-03	6.42E-02	6.55E-02	2.64E+01
16	1.34E-03	4.86E-02	4.99E-02	2.04E+01
18	1.30E-03	3.76E-02	3.89E-02	1.61E+01
20	1.26E-03	2.95E-02	3.08E-02	1.30E+01
25	1.18E-03	1.71E-02	1.83E-02	8.05E+00
30	1.10E-03	1.05E-02	1.16E-02	5.36E+00
35	1.03E-03	6.71E-03	7.74E-03	3.76E+00
40	9.62E-04	4.45E-03	5.41E-03	2.74E+00
45	9.02E-04	3.03E-03	3.93E-03	2.06E+00
50	8.46E-04	2.12E-03	2.96E-03	1.59E+00
60	7.47E-04	1.07E-03	1.82E-03	1.00E+00
70	6.63E-04	5.69E-04	1.23E-03	6.75E-01
80	5.91E-04	3.10E-04	9.02E-04	4.75E-01
90	5.29E-04	1.73E-04	7.02E-04	3.47E-01
100	4.75E-04	9.87E-05	5.74E-04	2.62E-01
200	1.82E-04	8.76E-22	1.82E-04	3.70E-02
400	3.23E-05	8.76E-22	3.23E-05	4.34E-03

Table 3.4-10: Protons Induced SEU rates

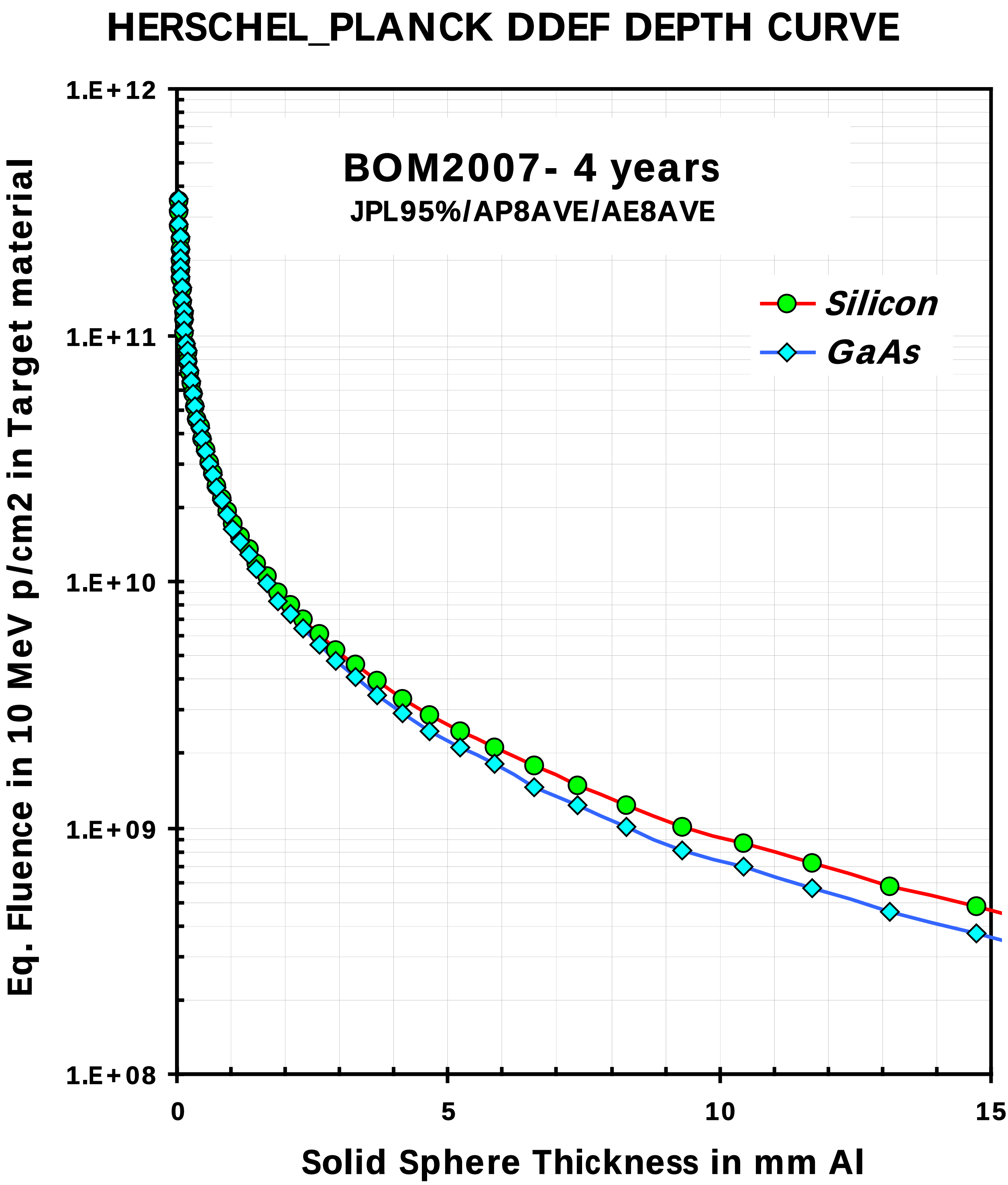


Figure 3-32: Mission DDEF Depth Curves for Si and GaAs detectors

Al thick. mm	10MeV p/cm2 Silicon	10MeV p/cm2 GaAs		Al thick. mm	10MeV p/cm2 Silicon	10MeV p/cm2 GaAs
3.70E-02	3.51E+11	3.56E+11		1.31E+00	1.35E+10	1.28E+10
4.20E-02	3.17E+11	3.20E+11		1.47E+00	1.19E+10	1.12E+10
4.70E-02	2.80E+11	2.83E+11		1.65E+00	1.06E+10	9.90E+09
5.20E-02	2.45E+11	2.49E+11		1.86E+00	9.03E+09	8.37E+09
5.90E-02	2.21E+11	2.25E+11		2.08E+00	8.07E+09	7.44E+09
6.60E-02	2.01E+11	2.04E+11		2.34E+00	7.07E+09	6.46E+09
7.40E-02	1.85E+11	1.89E+11		2.62E+00	6.14E+09	5.57E+09
8.30E-02	1.71E+11	1.73E+11		2.94E+00	5.29E+09	4.74E+09
9.30E-02	1.54E+11	1.56E+11		3.30E+00	4.63E+09	4.12E+09
1.04E-01	1.37E+11	1.40E+11		3.70E+00	3.94E+09	3.47E+09
1.17E-01	1.24E+11	1.26E+11		4.16E+00	3.36E+09	2.91E+09
1.31E-01	1.14E+11	1.16E+11		4.66E+00	2.87E+09	2.47E+09
1.47E-01	1.02E+11	1.04E+11		5.23E+00	2.48E+09	2.12E+09
1.65E-01	9.14E+10	9.26E+10		5.87E+00	2.14E+09	1.81E+09
1.86E-01	8.56E+10	8.66E+10		6.59E+00	1.77E+09	1.47E+09
2.08E-01	7.80E+10	7.86E+10		7.39E+00	1.49E+09	1.24E+09
2.34E-01	7.08E+10	7.14E+10		8.29E+00	1.23E+09	1.00E+09
2.62E-01	6.43E+10	6.47E+10		9.30E+00	1.01E+09	8.09E+08
2.94E-01	5.75E+10	5.76E+10		1.04E+01	8.64E+08	6.92E+08
3.30E-01	5.12E+10	5.12E+10		1.17E+01	7.18E+08	5.71E+08
3.70E-01	4.55E+10	4.54E+10		1.31E+01	5.79E+08	4.54E+08
4.16E-01	4.25E+10	4.22E+10		1.47E+01	4.76E+08	3.71E+08
4.66E-01	3.81E+10	3.78E+10		1.65E+01	3.79E+08	2.90E+08
5.23E-01	3.41E+10	3.37E+10		1.86E+01	3.02E+08	2.28E+08
5.87E-01	3.06E+10	3.01E+10		2.08E+01	2.47E+08	1.86E+08
6.59E-01	2.76E+10	2.71E+10		2.34E+01	1.97E+08	1.47E+08
7.39E-01	2.44E+10	2.39E+10		2.62E+01	1.55E+08	1.16E+08
8.29E-01	2.18E+10	2.12E+10		2.94E+01	1.19E+08	8.77E+07
9.30E-01	1.92E+10	1.85E+10		3.30E+01	9.13E+07	6.59E+07
1.04E+00	1.70E+10	1.63E+10		3.70E+01	6.78E+07	4.88E+07
1.17E+00	1.52E+10	1.46E+10				

Table 3.4-11: Mission DDEF Depth Curves for Si and GaAs detectors

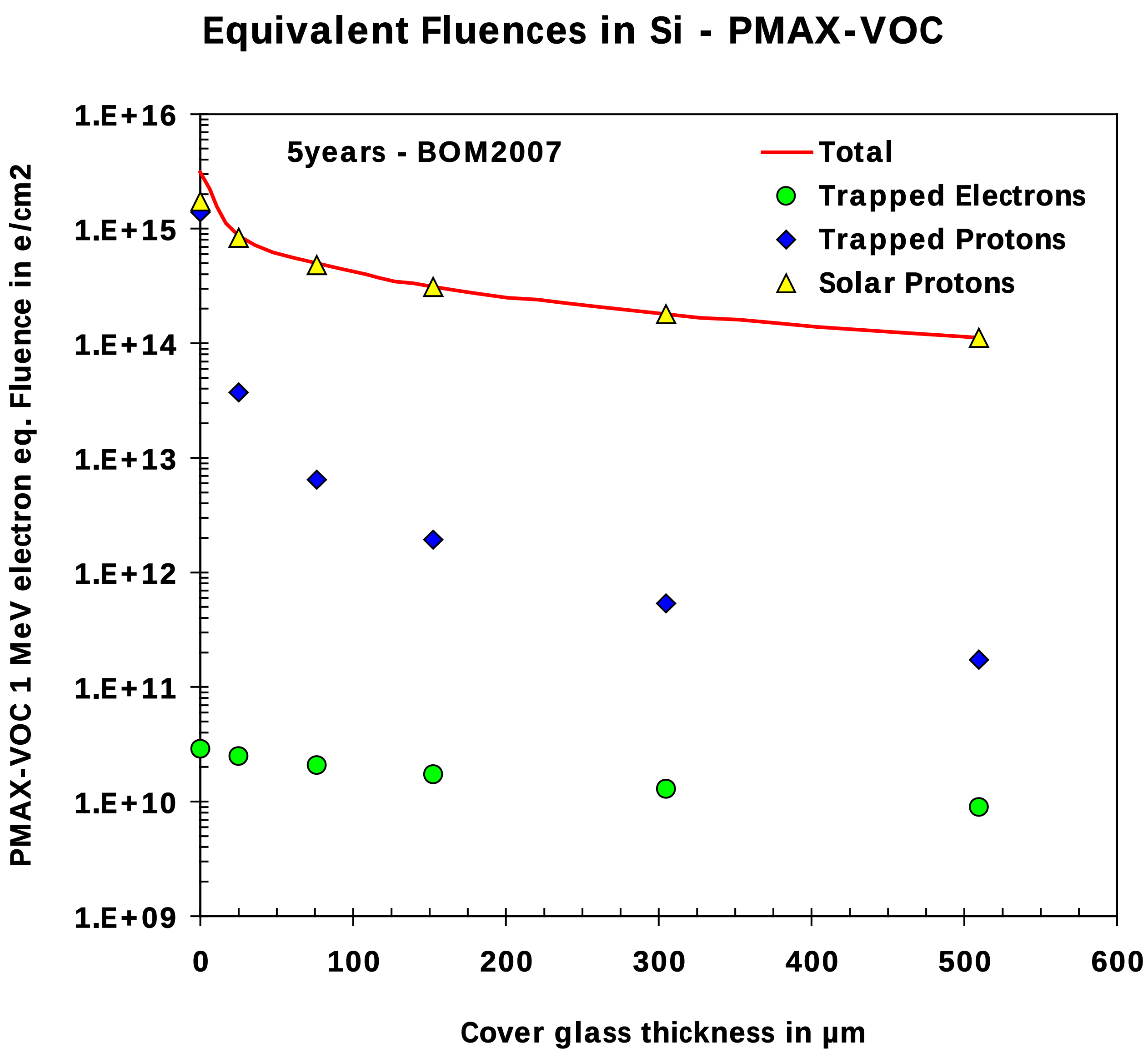


Figure 3-34: Mission 1 MeV electron Equivalent Fluence for PMAX-VOC in Si

PMAX-VOC	1 MeV e/cm2 in Si			
Coverglass microns	Total	Trapped Electrons	Trapped Protons	Solar Protons
0.00	3.10E+15	2.90E+10	1.40E+15	1.70E+15
25.41	8.57E+14	2.50E+10	3.70E+13	8.20E+14
76.36	4.97E+14	2.10E+10	6.50E+12	4.90E+14
152.27	3.12E+14	1.70E+10	1.90E+12	3.10E+14
305.00	1.81E+14	1.30E+10	5.40E+11	1.80E+14
509.09	1.10E+14	9.00E+09	1.70E+11	1.10E+14

Table 3.4-12: Mission 1 MeV electron Equivalent Fluence for PMAX-VOC in Si

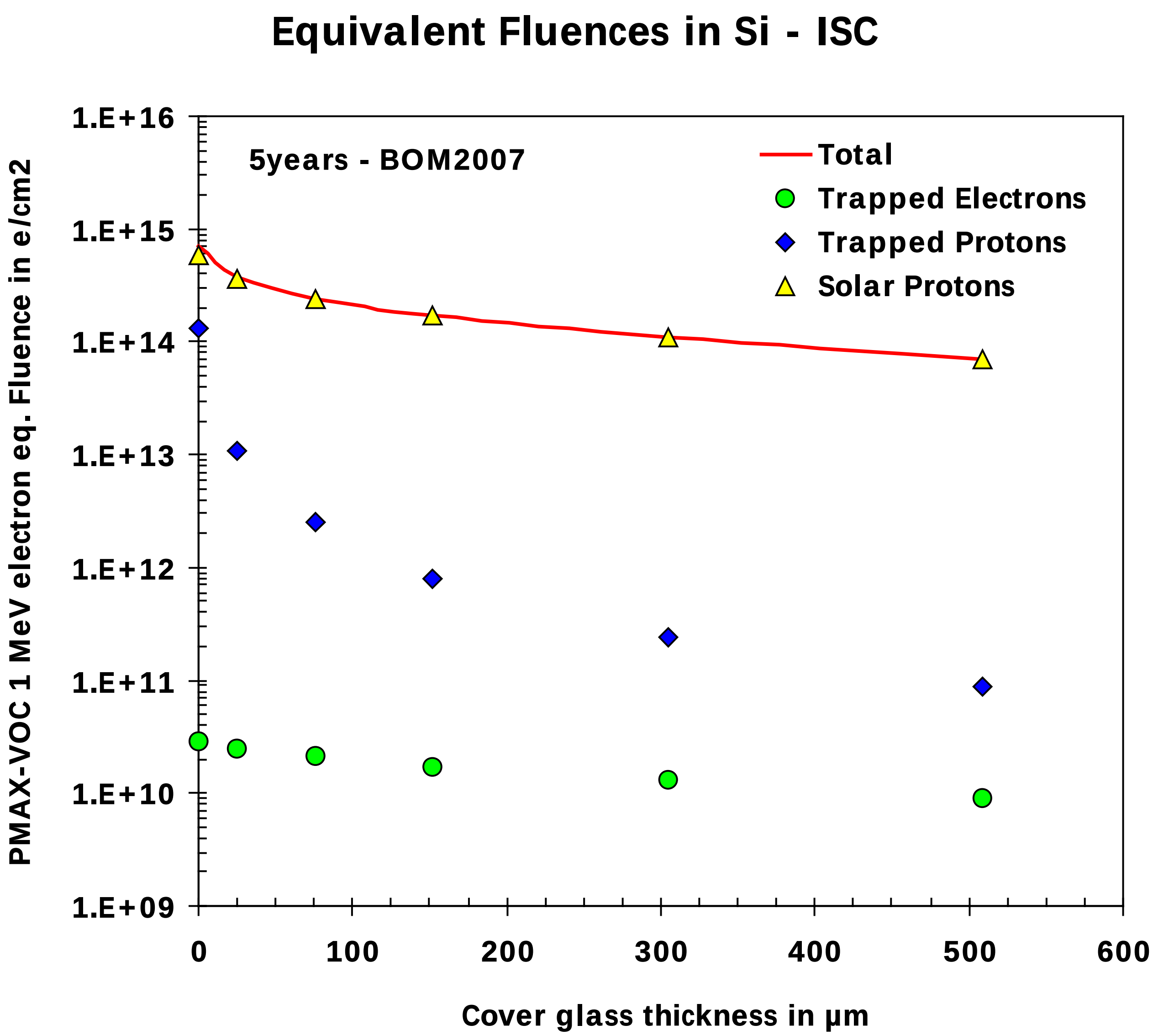


Figure 3-36: Mission 1 MeV electron Equivalent Fluence for ISC in Si

ISC	1 MeV e/cm2 in Si			
Coverglass microns	Total	Trapped Electrons	Trapped Protons	Solar Protons
0.00	7.10E+14	2.90E+10	1.30E+14	5.80E+14
25.41	3.71E+14	2.50E+10	1.10E+13	3.60E+14
76.36	2.43E+14	2.10E+10	2.50E+12	2.40E+14
152.27	1.71E+14	1.70E+10	8.00E+11	1.70E+14
305.00	1.10E+14	1.30E+10	2.40E+11	1.10E+14
509.09	7.11E+13	9.00E+09	8.90E+10	7.10E+13

Table 3.4-13: Mission 1 MeV electron Equivalent Fluence for ISC in Si

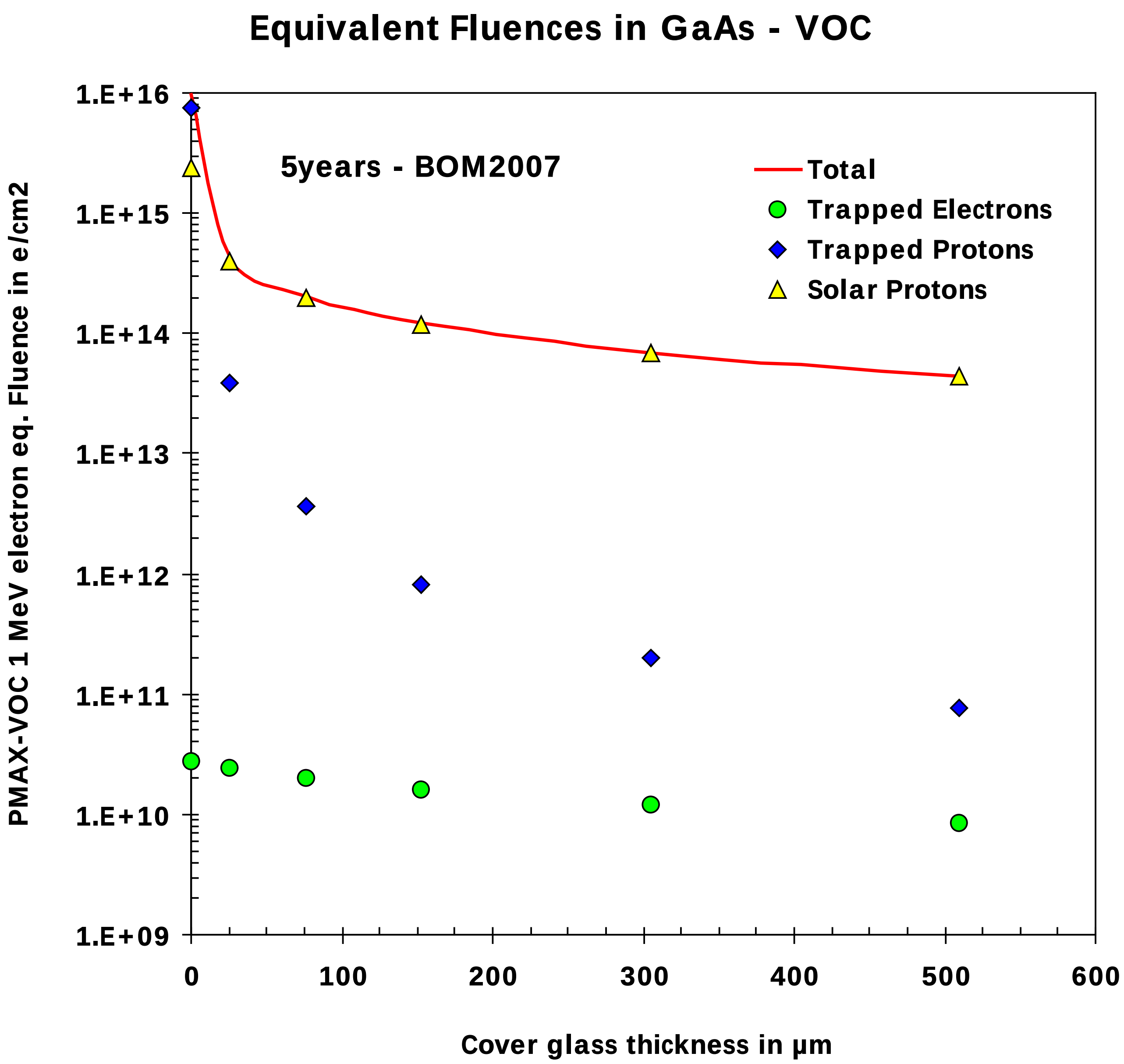


Figure 3-38: Mission 1 MeV electron Equivalent Fluence for VOC in GaAs

VOC	1 MeV e/cm2 in GaAs			
Coverglass microns	Total	Trapped Electrons	Trapped Protons	Solar Protons
0.00	9.80E+15	2.80E+10	7.40E+15	2.40E+15
25.41	4.39E+14	2.40E+10	3.90E+13	4.00E+14
76.36	2.04E+14	2.00E+10	3.60E+12	2.00E+14
152.27	1.21E+14	1.60E+10	8.10E+11	1.20E+14
305.00	6.82E+13	1.20E+10	2.00E+11	6.80E+13
509.09	4.41E+13	8.40E+09	7.60E+10	4.40E+13

Table 3.4-14: Mission 1 MeV electron Equivalent Fluence for VOC in GaAs

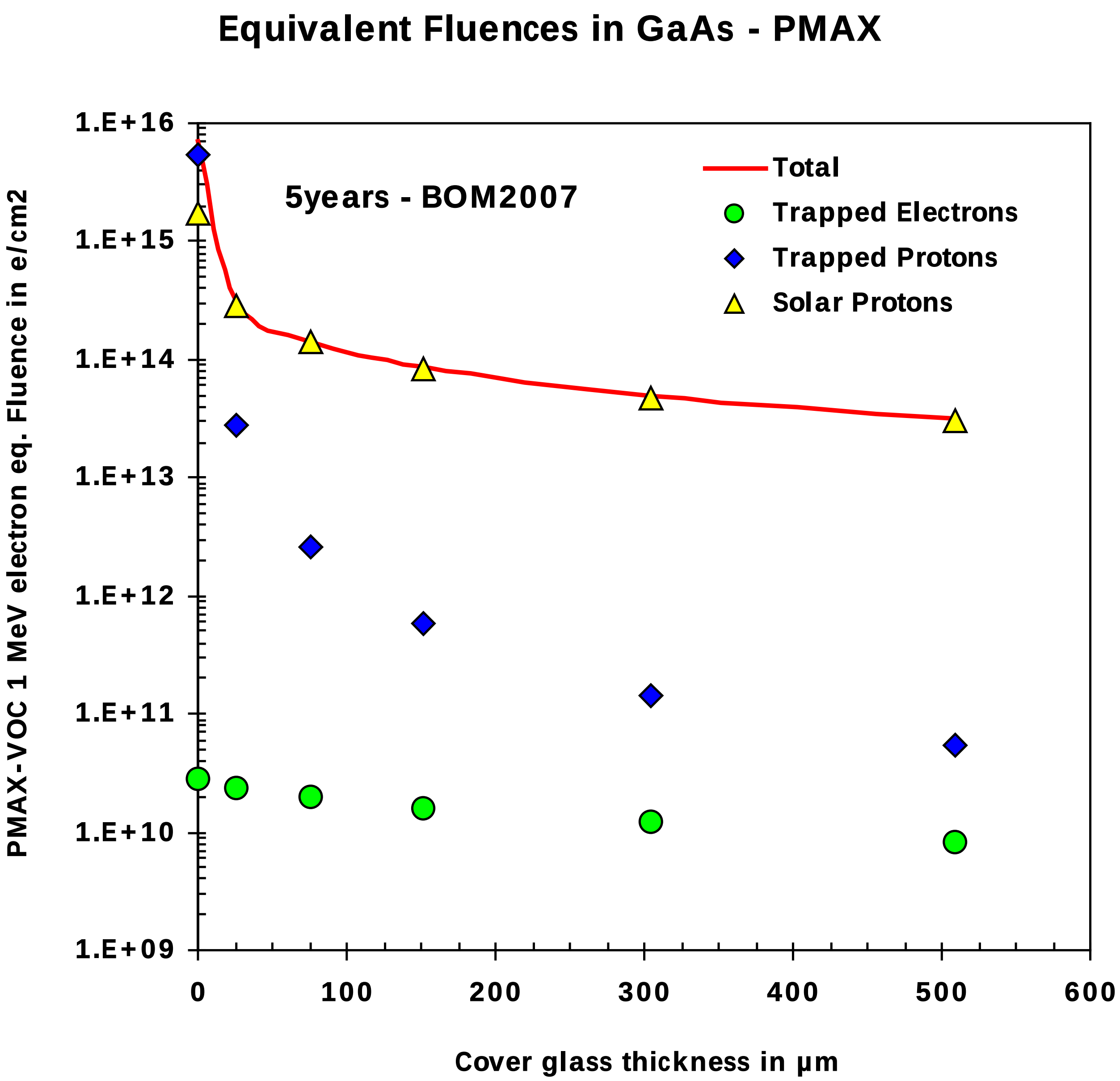


Figure 3-40: Mission 1 MeV electron Equivalent Fluence for PMAX in GaAs

PMAX	1 MeV e/cm2 in GaAs			
Coverglass microns	Total	Trapped Electrons	Trapped Protons	Solar Protons
0.00	7.00E+15	2.80E+10	5.30E+15	1.70E+15
25.41	3.18E+14	2.40E+10	2.80E+13	2.90E+14
76.36	1.43E+14	2.00E+10	2.60E+12	1.40E+14
152.27	8.56E+13	1.60E+10	5.80E+11	8.50E+13
305.00	4.82E+13	1.20E+10	1.40E+11	4.80E+13
509.09	3.11E+13	8.40E+09	5.40E+10	3.10E+13

Table 3.4-15: Mission 1 MeV electron Equivalent Fluence for PMAX in GaAs

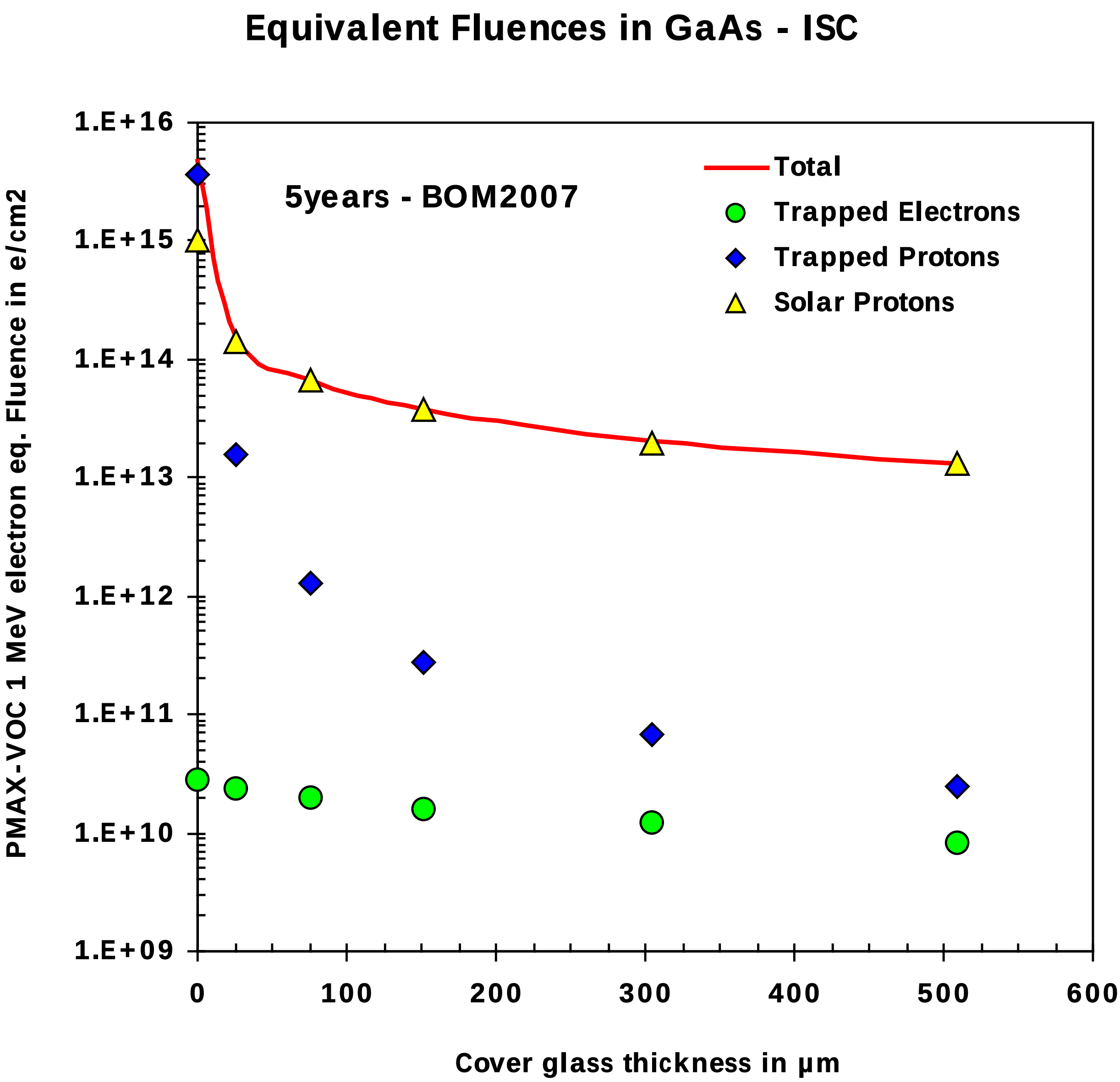


Figure 3-42: Mission 1 MeV electron Equivalent Fluence for ISC in GaAs

ISC	1 MeV e/cm2 in GaAs			
Coverglass microns	Total	Trapped Electrons	Trapped Protons	Solar Protons
0.00	4.70E+15	2.80E+10	3.70E+15	1.00E+15
25.41	1.56E+14	2.40E+10	1.60E+13	1.40E+14
76.36	6.83E+13	2.00E+10	1.30E+12	6.70E+13
152.27	3.83E+13	1.60E+10	2.80E+11	3.80E+13
305.00	2.01E+13	1.20E+10	6.80E+10	2.00E+13
509.09	1.30E+13	8.40E+09	2.50E+10	1.30E+13

Table 3.4-16: Mission 1 MeV electron Equivalent Fluence for ISC in GaAs

3.4.4.2.4 *Electrostatic Charging*

During the mission, the spacecraft will be submitted to the effects of plasma. In space, plasma extends from the ionosphere of the Earth to the far reaches of the solar system and encompasses plasmas of many different compositions, densities, and risk potentials. The plasma found at L2 and the orbits around L2 is that contained in solar wind. Solar wind plasma is essentially a neutral or cold plasma.

ENVM-490

The spacecraft shall be compatible with a plasma with the following characteristics. This characteristics are preliminary and are TBC :

- Composition = 95% H + , 5% He + + with equivalent electrons ;
- Density = 1-10 particles/cm^3 ;
- Velocity @ 450 km/s ;
- Energy (ions) @ 10 eV ;
- Energy (e -) @ 50 eV.

*

This plasma is relatively benign compared to those at Low and Geosynchronous orbits and will generate a low surface charging potential.

ENVM-500

Moreover, surface charging is also expected when the spacecraft passes through the radiation belts of the Earth, though this phase will not last very long. Assuming Geosynchronous orbit to be the worst case as regards plasma energy, the spacecraft shall be compatible with a plasma with the following characteristics:

- Density (e -) = 1.12 e - /cm^3 ;
- Density (ions) = 0.236 ions/cm^3 ;
- Energy (e -) @ 12 keV ;
- Energy (ions) @ 29.5 keV.

*

This characteristics are preliminary and are TBC.

3.4.4.3 Micrometeorites

The predicted micrometeorites environment in the vicinity of L2 is given in AD-10. All protection means for external items are left to be defined by the Contractor.

ENVM-080

Deleted.

*

Table 3.4-17: Deleted

Figure 3-44: Deleted

3.4.4.4 EMC

The satellites shall be designed to meet the requirements specified in AD- 1.

4. ENVIRONMENTAL TEST REQUIREMENTS

4.1 General

4.1.1 Ambient conditions

ENVT-010

Unless otherwise specified herein, all tests required by this specification and conducted in ambient conditions shall be done in the conditions defined in § 3.2.4.

*

Actual ambient test conditions should be recorded regularly during the tests. In case of ambient conditions exceeding the allowable limits, the decision not to test or to halt any test in progress shall lie with the responsible Test Manager who must have adequate evidence that there will be no adverse influences on component performance. However, the temperature of the unit shall not be allowed to exceed the specified range.

4.1.2 Accuracy of test apparatus

ENVT-020

The accuracy of the instrument and test equipment used to control or monitor the test parameters shall be verified periodically by calibration procedures.

*

4.1.3 Test tolerances

ENVT-030

The maximum allowable tolerances on test conditions during environmental testing shall be as indicated in Table 4.1-1 unless otherwise specified (Relaxation of tolerance can be proposed to ALCATEL for cost saving purpose).

*

4.1.4 Cleanliness of test equipment

ENVT-040

The inner cleanliness of the test equipment, as far as it can affect the cleanliness of the unit, shall be checked and minimum cleanliness level has to be assured before, during and after each test.

*

4.1.5 Temperature stabilisation

ENVT-050

Time shall be allowed for the unit to reach required temperature during testing. Temperature has been reached when all temperature readings have remained within measurement tolerance for more than 1 hour (TBC).

Parameter	Measurement Range	Tolerances
Temperature	• -55°C to +180°C - maximum temperature - minimum temperature • below –55°C and above 10 K - maximum temperature - minimum temperature • below 10 K - maximum temperature - minimum temperature	 0°C/+ 3°C - 3°C/0°C 0K/+1 K -1 K/0 K 0K/+0.1 K -0.1 K/0 K
Pressure	- p > 0,1 mbar - p < 0,1 mbar	< ± 1 % ± 10 %
Solar intensity		± 3 %
Relative Humidity		+ 5 % RH
Static test	Force	0 % / 5 %
Sinusoidal Vibration	Acceleration/amplitude Frequency below 50 Hz Frequency above 50 Hz	0 % / +5 % ± 0.5 Hz ± 2 %
Random Vibration	Power Spectral Density (g^2/Hz) Overall g RMS	-1 dB/ +1.5 dB ± 10%
Acoustic Vibration	1/3 octave band overall	-1.0 dB/3.0 dB (63 to 2000 Hz) -2.0 dB/4.0 dB (31.5 Hz) -1.0 dB/3.0 dB
Shock response	(Q=10) 1/6 octave band	± 3.0 dB
Test Duration		0 %/ 5 %
RF Power Level		< ± 0.3 dB
Spurious level	< -20 dBc and up to 80 dBc	< ± 0.5 dB
Frequencies	Audio < 20 kHz Video > 10 MHz Video < 10 Mz	10 ppm 1 ppm 0.01 ppm
Voltage	< 5 Volt > 5 Volt	≤ 0.2 % ≤ 0.5 %
Current	< 1 A > 1 A	≤ 0.5 % ≤ 0.1 %
DC Power		≤ 1.0 %
VSWR		0.2 dB
Leak Rate		$\pm 10^{-5}$ Pa $m^3 s^{-1}$ of Helium at 1013 hPa pressure differential

Table 4.1-1: Test Tolerances

4.2 System level TESTS

4.2.1 Environmental test summary

ENVT-110

The spacecraft and their modules shall be able to support the following tests to be performed at system level :

	Herschel		Planck	
Test	**STM**	**PFM**	**STM**	**PFM**
Sine vibrations	Q	A	Q	A
Acoustic	Q	A	Q	A
Shock test	X (*) (Q on unit)	-	X (*) (Q on unit)	-
Fit check	X	X	X	X
Mass properties	X	X	X	X
Alignments	X	X	X	X
Sun Simulation	at SVM level only	X (step #2)	Simulated by skin heaters	Simulated by skin heaters
Thermal Balance	Q at SVM A at Cryostat level	Q (A for cryo)	Q (A for cryo)	Q (A for cryo)
Thermal Vacuum		A		A
Leak test	X	X	X	X
Cryogenic	On EQM	X	X	X
EMC R	On EQM	Q	-	Q
EMC C	Q (on EQM)	Q	Q	Q
RF perfos.	-	-	On RFQM	LFI low freq.
IST	-	X	-	X
SFT	-	X	-	X
SW compatibility	-	X	-	X
SVT	-	SVT 1 &2	-	SVT 1 &2

X = test performed
Q = at qualification level when relevant
A = at acceptance level when relevant
"-" = no test
(*) final qualification achieved by analysis

Table 4.2-1: System environmental test summary

*

4.2.2 Mechanical environmental tests

4.2.2.1 Static test

ENVT-120

The static test is performed at Structure Subsystem level in order to validate the design and the manufacturing of the Primary Structure with regards to Quasi-Static loads. Due to the commonality between Herschel and Planck primary structure, only one static load test will be performed, the test specimen being the Herschel primary structure and the applied loads being the envelope of Planck and Herschel static loads.

*

4.2.2.2 Sine vibration test levels

ENVT-130

These test shall be conducted in each of the three orthogonal direction, on the fully assembled spacecraft in configuration defined in RD-6 (Design and Development Plan).

*

ENVT-140

The satellite shall be mounted on the vibration adapter representative of the launcher interfaces. The clamp band shall be mechanically identical to a flight one.

*

ENVT-150

The levels define in Table 4.2-2 shall be applied at the base of the satellite (separation plane). Prior to (frequency search) and after (check-out) a test, a low level sine sweep shall be applied on all 3 axes. Level, frequency range and sweep rate shall be defined with the instrumentation by the structural analysis responsible in the relevant test specification.

The notching philosophy depends on results of coupled load analyses and is TBD.

The electronic units that are active at launch shall be operating during the tests.

Axis	Frequency range (Hz)	Qualification level (0-peak)	Acceptance level (0-peak)
Axial (X)	4 - 5 5-100	12.4 mm 1.25 g	9.9 mm 1.0 g
Lateral (Y,Z)	2 - 5 5-25 25-100	9.9 mm 1.00 g 0.80 g	8.0 mm 0.8 g 0.6 g
	Sweep rate	2 oct/min per axis	4 oct/min per axis

Table 4.2-2: Sine vibration levels and duration

*

4.2.2.3 Acoustic noise test levels

ENVT-160

These test shall be conducted on the fully assembled spacecraft in configuration defined in RD-6 (Design and Development Plan).

*

ENVT-170

The levels defined in Table 4.2-3 shall be applied to the overall satellite. The instrument shall be defined by the structural analysis responsible in the relevant test specification.

The electronic units that are active at launch shall be operating during the tests.

Octave band Centre Frequency (Hz)	Qualification Level (dB) Ref. 0 dB=2x10^{-5} Pa	Acceptance Level (dB) Ref. 0 dB=2x10^{-5} Pa	Test tolerance (dB)
31.5	132	128	-2,+4
63	134	130	-1,+3
125	139	135	-1,+3
250	143	139	-1,+3
500	138	134	-1,+3
1000	132	128	-1,+3
2000	128	124	-1,+3
Integrated level	146	142	-1,+3
Test duration	2 min	1 min	

Table 4.2-3: Acoustic test levels and duration

*

4.2.2.4 Shock tests

ENVT-180

Shock tests shall qualify the spacecraft to the ARIANE 5 flight shock environment. It shall be performed at Satellite AIT Contractor premises on the STM. Baseline shock test is SHOGUN (SHOck Generation UNit, supplied by Arianespace) followed by clampband release with drop of the ACU.

*

The shock spectrum to be considered is given in Figure 3-5.

Notes :

- The shock spectrum given in Figure 3-5 takes into account the launch configuration using the standard 2624 adaptors and the SYLDA 5.
- Details on these tests will be provided by «Shock Test Requirements Specification».

4.2.3 Thermal environment tests

ENVT-200

Thermal environment tests at system level shall consist in :

- Thermal balance,
- Thermal vacuum on Herschel and Planck PFM.

*

Details on these tests will be provided by the relevant «Thermal Test Requirements Specification».

4.2.4 Electromagnetic compatibility tests

Detail on these tests are described in document AD-1.

4.3 Subsystem and unit level TESTS

4.3.1 Verification/Test Sequence

Qualification and protoflight model shall be qualification tested, the flight models have to be acceptance tested.

ENVT-060

The tests on qualification model shall include as a minimum the following sequence :

- inspection,
- physical properties,
- initial full performance tests,
- shock tests,
- sine vibration,
- random vibration (qualification level, qualification duration),
- post vibration functional tests,
- temperature cycling thermal vacuum (qualification level, 8 (TBC) cycles),
- post temperature functional tests,
- EMC tests,
- final full performance tests,
- final inspection.

*

ENVT-070

The tests on protoflight model shall include as a minimum the following sequence :

- inspection,
- physical properties,

- initial full performance tests,
- sine vibration,
- random vibration (qualification level, acceptance duration),
- post vibration functional tests,
- temperature cycling thermal vacuum (qualification level, 4 (TBC) cycles),
- post temperature functional tests,
- EMC tests: limited to the conducted part if the radiated part is performed on EM,
- final full performance tests,
- final inspection.

*

ENVT-080

The acceptance test sequence shall include as a minimum the following :

- inspection,
- physical properties,
- initial full performance tests,
- sine vibration (*),
- random vibration (acceptance level, acceptance duration),
- post vibration functional tests,
- temperature cycling thermal vacuum (acceptance level, 4 (TBC) cycles),
- post temperature functional tests,
- EMC tests: limited to the conducted part,
- final full performance tests,
- final inspection.

(*) The sine vibration tests shall be performed only in case of a subsystem/unit resonance frequency below 140 Hz.

*

4.3.2 Tests methods

ENVT-210

During all test to be performed, the test data and parameter values shall be continuously recorded.

*

4.3.2.1 Initial tests

ENVT-220

Prior to conducting any of the tests identified in this section, the test item shall be operated under ambient conditions, and a record shall be made of all data necessary to determine compliance with the required performance in the subsequent performance tests conducted before, during and after the environmental exposure. The only exceptions to this requirement are for those items which cannot be tested realistically in ambient conditions. In such cases, initial testing shall be designed to prove compliance as far as possible without causing damage to the test item.

*

4.3.2.2 Inspections and examinations

4.3.2.2.1 Initial Inspection and examination

ENVT-230

The unit shall be examined to verify compliance with the following criteria :

- Configuration,
- Interface Requirements,
- Parts, Materials and Process,
- Identification and Marking,
- Interchangeability,
- Workmanship.

*

4.3.2.2.2 Visual inspection

ENVT-240

The unit shall be examined visually to verify that there are no handling damages.

*

4.3.2.2.3 Final examination

ENVT-250

The unit shall be examined visually to verify compliance with :

- no handling damages,
- workmanship.

*

4.3.2.2.4 End Item acceptance

ENVT-260

After completion of all acceptance tests, the quality assurance responsible shall perform a final inspection of the hardware. Accepted items shall be appropriately sealed by the supplier's QA and released for storage or transportation.

*

ENVT-270

End item acceptance shall include proper review of the documentation.

*

4.3.2.3 Physical properties

ENVT-280

The mass shall be determined by weighing. The mass of the unit shall be in accordance with requirement. The moment of inertia and the centre of gravity may be determined by analysis (see AD- 2).

*

4.3.2.4 Performance tests

ENVT-290

The functional requirements specified in § 4.3.1. have to be verified by test including application of expected voltages, impedances, frequencies, pulses and wave forms at the electrical interfaces.

*

4.3.2.5 Mechanical environment tests

4.3.2.5.1 General

ENVT-300

Before and after the Vibration tests (Sinusoidal and random), a resonance search test shall be performed on each axis with the objective to demonstrate that the unit has not been degraded. Test parameters are as follows :

- Acceleration amplitude 0.5 g (TBC),
- Frequency 5 Hz to 2000 Hz (TBC),
- Sweep rate 2 octave per minute, one sweep up (TBC).

*

ENVT-310

The unit shall be mounted on a rigid vibration adapter. Prior to installation of the unit to be tested, an empty fixture vibration test shall be performed.

*

ENVT-320

Functional tests shall be conducted after full level exposure (including low levels) in the three axes.

*

ENVT-330

Electronic units active at launch shall be operating during the tests and limited functional tests shall be conducted during full level exposure.

*

4.3.2.5.2 Sinusoidal vibration test levels

ENVT-340

The levels given in Table 4.3-1 shall be used for sinusoidal vibration design qualification. These levels are preliminary and are still TBC.

The input levels should be notched, after approbation at system level. Notching should be allowed in order not to exceed loads and moments at the interface with the Structure. These loads and moments are based on Quasi-Static Loads defined for each unit (see GDME-280 of AD-2). Notching requests shall be managed via the RFW process (see AD-3).

Sweep rate shall be 2 Oct/min per axis for qualification and 4 Oct/min per axis for acceptance.

Electronic boxes in HERSCHEL and Planck SVM

	Frequency (Hz)	Qualification level	Acceptance level
In box mounting plane	5-100 Hz	20 g	16 g
Perpendicular to box mounting plane	5-100 Hz	25 g	20 g

Fuel tanks

	Frequency (Hz)	Qualification level	Acceptance level
Longitudinal	5-16 16-60 60-100	14 mm 14.4 g 4 g	11 mm 11.5 g 3.2 g
Lateral	5-13.3 13.3-60 60-100	14 mm 10 g 4 g	11 mm 8 g 3.2 g

Table 4.3-1: Sinusoidal Vibration Levels

*

4.3.2.5.3 Random vibration test levels

The random vibration test levels given in this section are preliminary and TBC.

ENVT-350

The levels apply at the interface with the Structure. The frequency range and levels depend on the mass of the Subsystem or units considered as first order mass system.

If brackets or fixation devices are provided with the unit, the interface is the bracket/fixation device interface.

For units belonging to the same subsystem, delivered in more than one box but accommodated closely on the same structure part (i.e. panels), the mass to be considered is the total mass of the grouped units.

The lateral axes are in the plane of the mounting plane, the vertical axis is perpendicular to the mounting plane.

The input levels should be notched, after approbation at system level. Notching should be allowed in order not to exceed loads and moments at the interface with the Structure. These loads and moments are based on Quasi-Static Loads defined for each unit (see GDME-280 of AD-2). Notching requests shall be managed via the RFW process (see AD-3).

The test duration shall be 2 min per axis.

The qualification levels apply on STM, EM, QM or EQM pending on model philosophy.

The acceptance levels applied on FMs are qualification levels divided by a factor 1.5625 for PSD and 1.25 for the global level in g RMS. The test duration shall be 1 min per axis.

Units applying PFM philosophy shall be tested at qualification level and acceptance duration.

Levels specific to Herschel

The levels in the following table have to be applied specifically to Herschel:

Frequency Range	Qualification levels
20-100 Hz	+3 dB/oct
100-300 Hz	See next table
300-2000 Hz	-5 dB/oct

Item	Mounted Panel	Out of Plane Level [g²/Hz]	In plane Level [g²/Hz]
Battery	[+Y]	0.2	0.1
PCDU		0.2	0.1
ACC		0.2	0.1
CDMU		0.2	0.1
Gyroscopes	[+Z;-Y]	0.6	0.3
QRS		0.6	0.3
X/B transponders	[+Z;+Y]	0.6	0.3
TWTA		0.6	0.3
EPC		0.6	0.3
RFDN		0.6	0.3
RWDE	[+Z;-Y]	0.2	0.1
RWs		0.2	0.1
CCU	[-Z]	0.2	0.1
STR Elec	Web [–Z]	1.5	0.75

Table 4.3-2: Random levels for unit inside Herschel SVM

Levels specific to Planck

The levels in the following table have to be applied specifically to Planck:

Frequency Range	Qualification levels
20-100 Hz	+3 dB/oct
100-300 Hz	See next table
300-2000 Hz	-5 dB/oct

Item	Mounted Panel	Out of Plane Level [g²/Hz]	In plane Level [g²/Hz]
Battery	[+Z;-Y]	0.2	0.1
PCDU		0.2	0.1
ACC		0.2	0.1
CDMU		0.2	0.1
QRS	[-Y]	0.6	0.3
X/B transponders		0.6	0.3
TWTA		0.6	0.3
EPC		0.6	0.3
RFDN		0.6	0.3
STR Elec	[+Z]	0.2	0.1

Table 4.3-3: Random levels for unit inside Planck SVM

\# *

General case by default for SVM items

\# ENVT-360

When not specified for Herschel or Planck above, the levels in Table 4.3-4 shall be used for random vibration design qualification.

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	1.0 g^2/Hz
500-700 Hz	0.5 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.1 g^2/Hz
GLOBAL	**27.3 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	2.0 g^2/Hz
500-700 Hz	1.0 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.2 g^2/Hz
GLOBAL	**38.6 g RMS**

Random vibrations for units with mass < 1 kg

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.5 g^2/Hz
500-700 Hz	0.25 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.05 g^2/Hz
GLOBAL	**19.3 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	1.0 g^2/Hz
500-700 Hz	0.5 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.1 g^2/Hz
GLOBAL	**27.3 g RMS**

Random vibrations for units with mass < 5 kg

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.2 g^2/Hz
500-700 Hz	0.1 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.02 g^2/Hz
GLOBAL	**12.2 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.4 g^2/Hz
500-700 Hz	0.2 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.04 g^2/Hz
GLOBAL	**17.3 g RMS**

Random vibrations for units with mass < 10 kg

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.14 g^2/Hz
500-700 Hz	0.07 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.014 g^2/Hz
GLOBAL	**10.2 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.28 g^2/Hz
500-700 Hz	0.14 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.028 g^2/Hz
GLOBAL	**14.5 g RMS**

Random vibrations for units with mass < 20 kg

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.1 g^2/Hz
500-700 Hz	0.05 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.01 g^2/Hz
GLOBAL	**8.6 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.2 g^2/Hz
500-700 Hz	0.1 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.02 g^2/Hz
GLOBAL	**12.2 g RMS**

Random vibrations for units with mass < 50 kg

Lateral	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.07 g^2/Hz
500-700 Hz	0.035 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.007 g^2/Hz
GLOBAL	**7.2 g RMS**

Axial	
Frequency Range	Qualification Levels
20-100 Hz	+ 3dB/Oct
100-500 Hz	0.14 g^2/Hz
500-700 Hz	0.07 g^2/Hz
700-1200 Hz	-9 dB/Oct
1200-2000 Hz	0.014 g^2/Hz
GLOBAL	**10.2 g RMS**

Random vibrations for units with mass ≥ 50 kg

Table 4.3-4: Random Vibration Levels

*

4.3.2.5.4 Shocks at unit level

ENVT-370

The level in Table 4.3-5 shall be used for shock level design qualification at the unit baseplate interface.

	Frequency (Hz)	**Shock Qualification Level (g)**
Radial and Longitudinal Direction	100	20
	200	200
	300	320
	500	650
	600	800
	1 000	1 200
	2 000	2 000
	10 000	2 000

Table 4.3-5: Shock Levels

*

These levels are preliminary and are still TBC.

4.3.2.6 Thermal environment tests

4.3.2.6.1 Qualification thermal vacuum tests

The thermal vacuum tests are required to evaluate and demonstrate the functional performance of the units under the extreme and nominal modes of operation while in simulated vacuum and at temperatures more extreme than flight guaranteed temperatures. The purpose of the more severe temperatures stress is to demonstrate a design safety margin and to accelerate failure in marginal design.

ENVT-380

The evaluation and demonstration of the correct behaviour of Subsystem or Unit at Maximum/Minimum operating temperatures shall be done at the beginning of this test as represented in Figure 4-1 and shall be reflected in the relevant Subsystem or Unit test documentation.

*

ENVT-390

Performance characteristics parameters of each unit shall be measured :

- at a pressure equal or less than 1.33 10^{-3} Pa,
- under the temperature conditions defined in Table 4.3-6. Values in this table are preliminary and are TBC.

The temperature monitoring is made at the unit Temperature Reference Point (TRP).

Unit Definition	Operating Mode		Non Operating Mode		Start Up	
	TO-MIN	TO-MAX	TNO-MIN	TNO-MAX	TSU-MIN	TSU-MAX
Herschel units						
Reaction wheels	-20	+60	-30	+70	-30 TBC	+70 TBC
Reaction wheels electronics	-20	+55	-30	+65	-30 TBC	+65 TBC
Star Tracker Head	-20	+40	-30	+50	-30	+50 TBC
Star Tracker Electronics	-30	+60	-30	+60	-30 TBC	+60
Gyros	-25	+55	-35	+65	-35 TBC	+65 TBC
Planck units						
Star Mapper Head	-30	+60	-30	+60	-30 TBC	+60
Star Mapper Electronics	-30	+60	-30	+60	-30 TBC	+60
Common units						
CDMU	-20	+55	-30	+65	-30 TBC	+65 TBC
ACC	-20	+55	-30	+65	-30 TBC	+65 TBC
PCDU	-20	+55	-30	+65	-30 TBC	+65 TBC
QRS	-25	+55	-35	+65	-35 TBC	+65 TBC
Battery	TBD	TBD	TBD	TBD	TBD	TBD
EPC	-25	+55	-35	+65	-35 TBC	+65 TBC
TWT	-25	+60	-35	+70	-35 TBC	+70 TBC
Transponder	-20	+60	-30	+70	-30 TBC	+70 TBC
RFDN	-25	+55	-35	+65	-35 TBC	+65 TBC
VMC	-20	+40	-30	+50	-20	+50 TBC
SREM	-20	+60	-55	+100	-20	+100 TBC
Tanks RCS elements Filters Thrusters (valves)	0 0 0 0	+50 +60 +70 +75	0 0 0 0	+50 +60 +70 +75	0 0 0 0	+50 +60 +70 +75
Antennae RF Harness	-140 -140	+90 +90	-140 -140	+90 +90	-140 -140	+90 +90
Sun Acquisition Sensors CSS AAD	-80 -40 -80	+90 +95 +80	-80 -145 -80	+90 +100 +80	-80 TBC -145 TBC -80 TBC	+90 +100 TBC +80

Table 4.3-6: Unit qualification test temperature

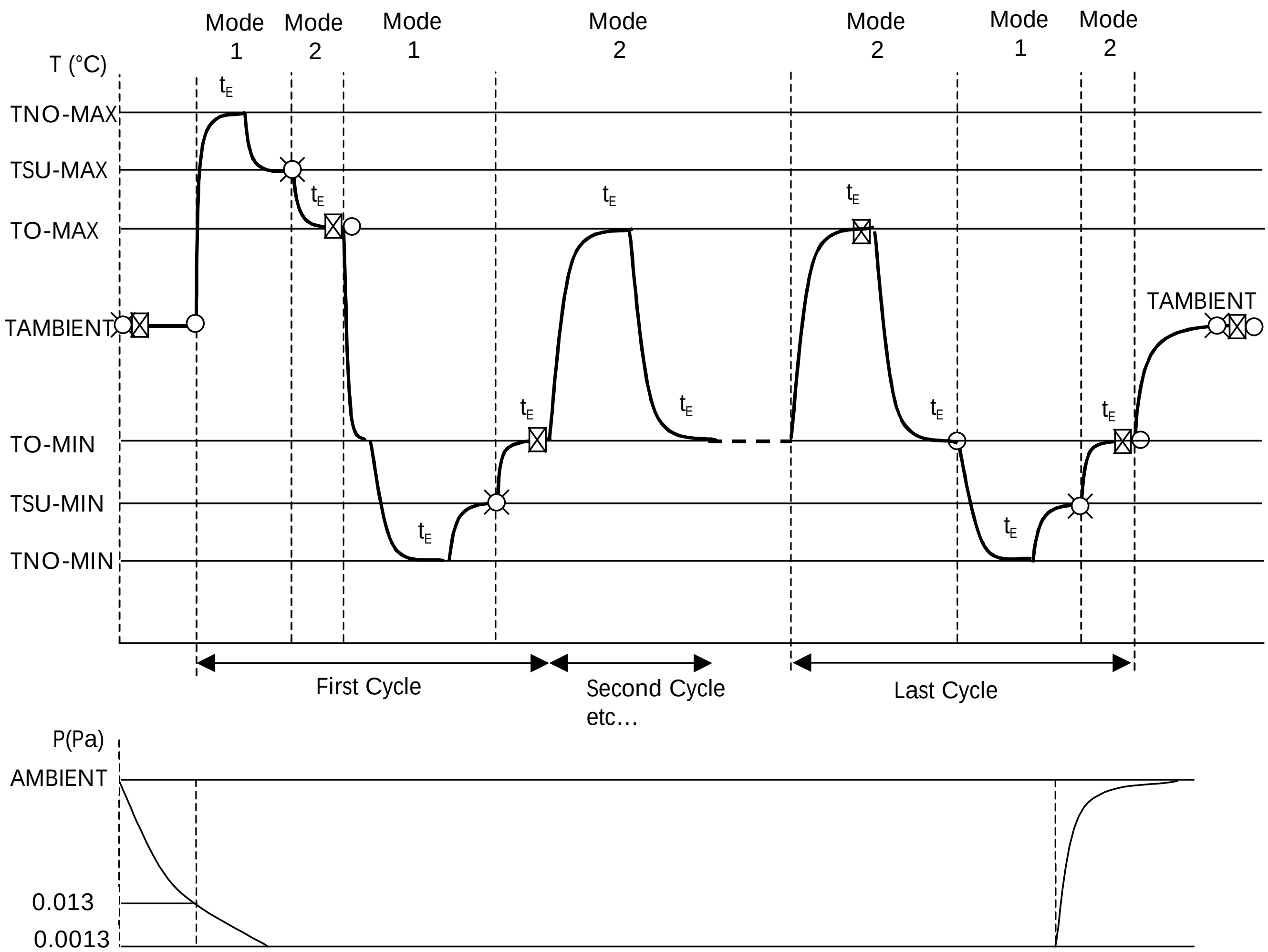
*

ENVT-400

The thermal cycle is shown in Figure 4-1. The number of cycle is 8 for qualification and 4 for acceptance. The maximum and minimum operating temperatures shall be maintained during 2 hours after the permanent state temperature establishment.

Health parameters shall be continuously checked during all permanent and transient states to look for any intermittent behaviour. For the permanent state, unit performances shall be performed once the steady state is reached.

Cold start-up capability shall be demonstrated on the first and last cycles.



TNO-MAX	Maximum Non-Operating Temperature (the highest design temperature the equipment has to survive not powered)
TNO-MIN	Minimum Non-Operating Temperature (the lowest design temperature the equipment has to survive not powered)
TAMBIENT	Ambient Temperature
TO-MAX	Maximum Operating Temperature (the highest design temperature at which the equipment has to demonstrate full design capability)
TO-MIN	Minimum Operating Temperature (the lowest design temperature at which the equipment has to demonstrate full design capability)
TSU-MAX	Maximum Start-up Temperature (the highest design temperature at which the equipment may be switched-on)
TSU-MIN	Minimum Start-up Temperature (the lowest design temperature at which the equipment may be switched-on)
MODE 1	Functionally inert (test item not energised) normally applicable to the non-operating condition
MODE 2	Fully functioning (test item fully enegised and fully stimulated). Normally applicable to conditions during orbit
⊠	Intermediate performance check
☼	Switch-on
○	Switch-off
t_E	Intermediate Equilibrium Temperature Time (2 hours)

Figure 4-1: Temperature cycling during thermal test

4.3.2.6.2 *Acceptance thermal vacuum tests*

ENVT-410

Thermal vacuum acceptance tests are the same as for the qualification vacuum tests except temperature limits which are 5 °C below the maximum and 5°C above the minimum qualification temperature limits.

The number of cycles is reduced to 4.

*

4.3.2.6.3 *Corona tests*

The purpose of the corona test is to verify that no permanently damaging electrical discharge occurs during transition to vacuum conditions.

ENVT-420

This test is only applicable to units which are operating during launch phase. It is applicable to units with internal voltages of more than 70 V and to RF power units.

*

ENVT-430

While the test chamber is evacuated, these units will be put on and their operations checked.

*

ENVT-440

During the vacuum establishment, the chamber pressure must be maintained for a short period of time at a value of 13.3 Pa and then reduced to 1.33 10^{-3} Pa (pressure of vacuum temperature test)

*

ENVT-450

During the corona test, the temperature will be near the ambient temperature. The unit shall be continuously monitored from the start with pump down, until 1.33 10^{-3} Pa is reached.

*

ENVT-460

The time to reach 1.33 10^{-3} Pa will be in accordance with the launch pressure time profile (see Figure 3-10).

*

4.3.2.7 Operating time

ENVT-090

Mechanisms ad ON/OFF operating shall be submitted to a cumulated number of actuations to be proposed by the supplier. It shall be representative of the in-orbit operating conditions and selected in order to avoid infant mortality.

*

4.3.3 EMC-tests

Refer to AD- 1.

4.4 Test documentation

4.4.1 Test Procedures

ENVT-100

The Subcontractor shall establish procedures for performing all required tests in accordance with detailed test plans approved by the Prime Contractor. The test plans shall be based upon the specified performance, a failure modes and effects analysis, and the test requirement. The test procedures to be used in conducting required tests shall be detailed so that there is no doubt as to what is to be done. The pass-fail test criteria shall be determined prior to the start of every test. Pattern or lot associated failures that may occur shall be identified as potentially critical failures. Corrective action for potentially critical failures, including retest requirements, shall be approved by the Prime Contractor. The test plans and procedures shall provide traceability to the test requirements.

*

4.4.2 Test Reports

ENVT-470

Following completion of formal tests, test reports shall be prepared as defined in the Statement of Work.

*

4.4.3 Test Failure

ENVT-480

If a unit fails, malfunctions or if out-of-tolerance performance occurs during or after a test, the test shall be discontinued as appropriate and a NCR has to be issued. A NRB shall be held with the Prime (see AD- 3).

*

4.4.4 Failure Definition

A failure shall include, but not be limited to, an occurrence of any of the following :

a. Unit performance functionally beyond the design limits, test specification, criteria, or procedures. This applies to qualification, and acceptance tests.

b. Intermittent or erratic unit performance.

c. Necessity of repeated adjustment to sustain acceptable unit operation, initial or setup adjustments excepted.

d. Unit operation which has unexplainable drift from initial or setup performance conditions. This applies even though unit performance may still be within specification limits.

e. Overstress of end-item hardware caused by test equipment when an evaluation of the overstress has not or cannot be ascertained.

f. Part failure.

g. Any deviation with respect to the Test Procedure as agreed during the TRR.

h. Any failure of test equipment.

4.4.5 Test Failure Procedures

The Test Failure Procedure to be applied is defined in PA applicable documents.

END OF DOCUMENT