Chapter 5 : Payload environment requirements

CHANGE TRACEABILITY Chapter 5

Here below are listed the changes between issue N-2 and issue N-1:

N°§	PUID	Change Status	Doc Issue	Reason of Change	Change Reference
§5.11.2.1		New in	6.2	Additional sentence	CIIS.4.1.JC.1_18

Here below are listed the changes from the previous issue N-1:

N°§	PUID	Change Status	Doc Issue	Reason of Change	Change Reference
§5.1.4			6.3	TBD removed in Table	CIIS.4.1.JC.2_2
§5.1.5			6.3	Precision: Jason replaced by Jason-1	
§5.4.1	**[PL - 5.4 -1 a]**		6.3	New wording	
§5.4.1	**[PL - 5.4 -2 a]**		6.3	New wording	PUM.6.2.EJ.15
§5.6	**[PL - 5.6 -2]**	New in	6.3	Radiation analysis requested	PUM.6.2.EJ.16
§5.11.2.2.1		Modified in	6.3	Temperature range modified	PUM.6.1.EJ.27a
§5.11.2.2.1		New in	6.3	Temperature variation added	PUM.6.1.EJ.27a
§5.11.2.2.1		Modified in	6.3	Relative humidity modified	PUM.6.1.EJ.27a

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N°§	Sentence	Planned Resolution
§5.11.3	TBD	

5. PAYLOAD ENVIRONMENT REQUIREMENTS

This chapter lists the requirements about the qualification and flight environment which the equipped payload shall meet in order to be compatible with the PROTEUS platform. It deals with the mechanical and thermal environment, the deep space vacuum, the launch pressure profile, the electromagnetic, radiation, magnetic field, meteoroid and space debris, atomic oxygen environment. These requirements depend on the launch vehicle choice and the mission environment parameters (mission objective, orbit type, mission date and duration). So, as soon as these parameters are well defined, the User shall not hesitate to contact either ALCATEL SPACE or CNES in order to make accurate the payload qualification and flight environment requirements. ALCATEL SPACE and CNES can also help the User to define the launch vehicle and the mission parameters.

5.1 MECHANICAL ENVIRONMENT

The mechanical environment is caused by the launch environment. Hereafter the levels qualifying the mechanical environment are specified considering all the launch vehicles compatible with PROTEUS. As soon as the considered launch vehicles envelope is restrained (because some or one launch vehicle is chosen among the specified launch vehicles for the studied mission), the mechanical levels are reduced. Therefore, the payload environment is less constrained, the payload design requirements are less severe.

5.1.1 QUASI-STATIC ACCELERATION LOADS

PL - 5.1.1 -1

> The quasi static qualification load factors for the payload are given in Table 5.1-1, in satellite axes.

For information, these quasi static loads are not applicable to the secondary structures or instruments because they are covered by dynamic vibration loads.

	Longitudinal Qualif. Load (g)	Lateral Qualif. Load (g)	
Payload	20	9 - 0,02 x (M-100)	for 100 kg < M < 200 kg
		7 - 0,005 x (M-200)	for 200 kg < M < 300 kg

Table 5.1-1 : Quasi-static acceleration qualification loads (launch vehicles envelope)

Lateral and longitudinal QS loads have not to be combined.

There is no quasi static test requirement since payload strength will be tested during sine vibration testing. The quasi static qualification load factors given in this section shall only be used to structurally design the payload.

5.1.2 SINE VIBRATION

PL - 5.1.2 -1

The payload shall withstand the sine vibration input qualification levels given in Table 5.1-2, in satellite axes.

These preliminary values are taken from PROTEUS (specified launch vehicles envelope) and will be refined after coupled platform/payload mechanical analysis and launch vehicle inputs.

Part	Excitation Axis	Frequency Range	Input Level (QL)
Payload	longitudinal (Xs)	5 -> 21 Hz 21 -> 30 Hz 30 -> 50 Hz 50 -> 100 Hz	11 mm 20 g linear connection 5 g
	lateral (Ys, Zs)	5 -> 14 Hz 14 -> 20 Hz 20 -> 40 Hz 40 -> 80 Hz 80 -> 100 Hz	11 mm 9 g 5 g 1.5 g 3 g

Table 5.1-2 : Sine vibration input qualification levels for the payload

The sine levels in the low frequency range (<30 Hz) aim at qualifying the payload with respect to the QS loads. This is the reason why no static test is requested.

Notching philosophy is in section 4.2.5.3.

5.1.3 RANDOM VIBRATIONS

PL - 5.1.3 -1

Random vibrations qualification levels at Payload interface are given in Table 5.1-3.

Each payload supplier shall demonstrate if this environment is negligible with respect to the acoustic or sine vibration levels according to the payload design.

Excitation axis	Frequency range	Input level	Global
All axes	20 - 100 Hz	+6 dB/oct.	9 gRMS
	100 - 1000 Hz	0.05 g^2/Hz	
	1000 - 2000 Hz	-3 dB/oct.	

Table 5.1-3 : Random vibration qualification loads

Notching philosophy is in section 4.2.5.4.

Qualification levels = 1.56 x Flight levels.

5.1.4 ACOUSTICS

PL - 5.1.4 -1

The payload shall withstand the qualification sound pressure levels defined Table 5.1-4.

These levels are the envelope of 4 launch vehicles (Rockot, PSLV, Delta 2, Soyuz) for which PROTEUS is compatible. As soon as the mission specific launch vehicle is chosen, these levels will be updated and recorded in the Payload Design Interface Specification

Octave Band Center Frequency (Hz)	Qualification levels (dB)
31.25	128.5
62.5	135
125	137
250	140
500	141
1000	136
2000	132
4000	129
8000	126
Overall	146

Table 5.1-4 : Acoustic qualification environment

The acceptance levels are 3 dB lower than qualification levels.

5.1.5 PYROTECHNIC SHOCK

PL - 5.1.5 -1

The following shock levels are applicable on the payload at the mating interface (at each pod upper face). The shock levels experienced by the payload comes from the launch vehicle separation and from the solar arrays deployment.

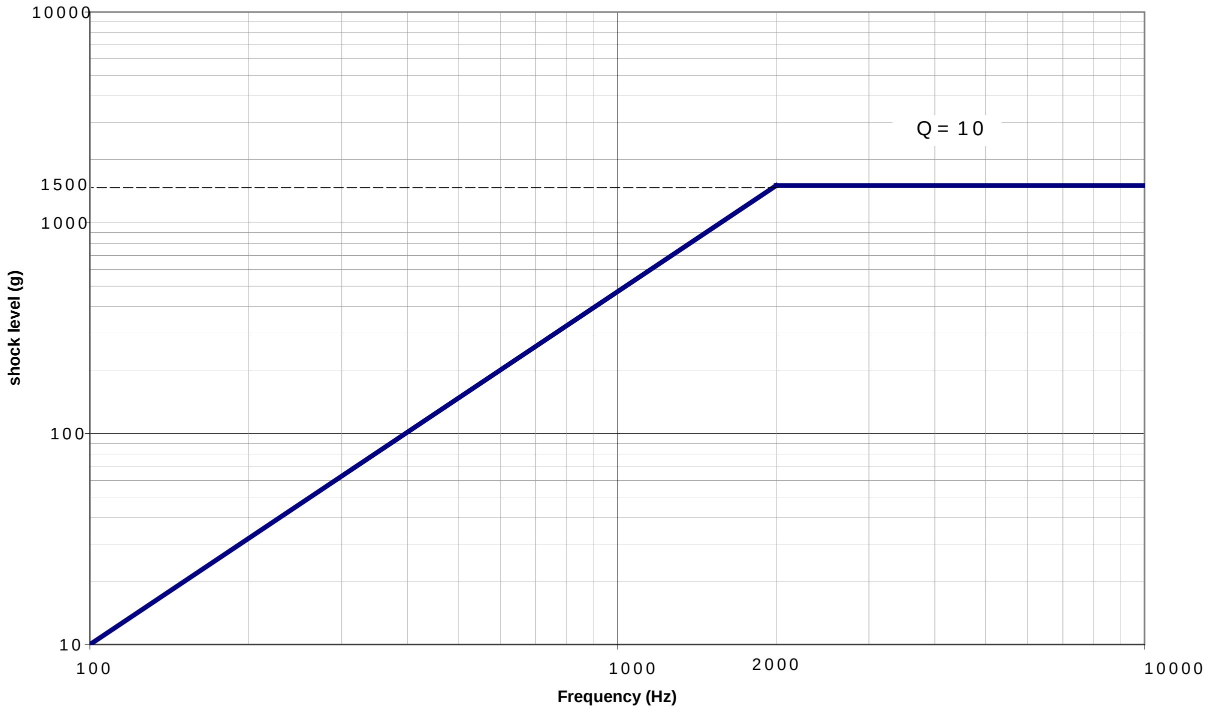

Figure 5.1-1 : Shock levels at payload interface

As explained in PL-5.1.5-1 requirement, this spectrum is given at the PF/PL interface plane level. The overall payload can be tested with this level, but it is generally difficult to perform such a test.

In case of verification at payload equipment level only (test philosophy to be analysed by CNES on the basis of the payload validation plan delivered by the Payload Supplier), it may be noticed that, in the framework of the JASON-1 program, the payload equipment had been successfully qualified with a shock spectrum corresponding to an half sine of 900 g amplitude and 0.5 ms duration. This payload equipment level qualification has allowed to cover shock levels measured during JASON-1 satellite shock tests, even for the equipments very close to the PF/PL interface.

It may be noticed that the payload shall not generate shock levels higher than those required in section 3.1.5.2 (for PF/PL interface plane) and Section 3.6.2.3.3 (for PL/STA interface plane).

5.2 THERMAL ENVIRONMENT

The payload is submitted to albedo, Earth and Sun fluxes.

PL - 5.2 -1

Sizing conditions (orbital parameters, satellite attitude) are given in Table 5.2-1.

SATELLITE MODE	DURATION	APPARENT DIRECTION OF THE SUN
Launch phase (payload thermal control OFF)	Mission dependent (up to 90 min)	Mission dependent
SHM mode (RDP and SPP phases)	360 min	Random
SHM mode (BBQ phase)	Unlimited	$-X_s \pm 30°$
Normal mode	Mission dependent	
Transient	Mission dependent	

Table 5.2-1 : Sizing conditions

The following data will be incorporated in mission environment specifications when it is issued.

PL - 5.2 -2

- solar constant : the solar constant variations are given in Table 5.2-2. The ± 5 W/m2 variation is due to the 11 year solar cycle.

TIME OF YEAR	SOLAR CONSTANT (W/m^2)
Winter solstice (perihelion)	1415 ±5
Vernal equinox	1380 ±5
Summer solstice (aphelion)	1326 ±5
Autumnal equinox	1365 ±5

Table 5.2-2 : Solar constant variations

PL - 5.2 -3

- <u>albedo and Earth infrared (IR) fluxes</u>: the Earth and its atmosphere radiate like a black body at an equivalent temperature of 255 K. The albedo coefficient is the ratio of the Earth reflected solar flux by the overall incident solar flux. The mean value of the albedo coefficient is 0.3 but this value varies from zone to zone on Earth. The same albedo coefficient shall be considered for the albedo and Earth IR fluxes calculations. This yields the following formulas:
- albedo flux = albedo coefficient x solar flux
- Earth IR flux = (1 - albedo coefficient)/4 x solar flux
    - with albedo coefficient = 0.3 ±0.05

PL - 5.2 -4

- deep space flux: the deep space thermal radiation is equivalent to a black body at a 4 K temperature.

5.3 DEEP SPACE VACUUM

PL - 5.3 -1

The payload shall withstand the deep space vacuum conditions. Free space vacuum pressure to be considered in orbit life is below 10^{-8} Pa.

5.4 LAUNCH PRESSURE AND THERMAL FLUX PROFILES

PL - 5.4 -1 a

The payload shall withstand an expected maximum pressure decay during the launch ascent phase up to 4000 Pa/s.

PL - 5.4 -2 a

The payload shall withstand the aerothermal flux after fairing jettisoning lower than 1135 W/m^2.

5.5 ELECTROMAGNETIC ENVIRONMENT

PL - 5.5 -1

The design shall comply with requirements of Section 3.5.7 regarding design guidelines and of section 6.1.8 regarding test procedures and set-up.

5.6 CHARGED PARTICLES RADIATIONS

The dose of radiation received by the payload depends on the satellite orbit. The yearly received doses depending on the altitude and the inclination of the orbit are shown for two typical equivalent of aluminium thicknesses :

0.05 mm which corresponds to an external dose (cf. Figure 5.6-1),

3.0 mm which corresponds to a minimal shielding : 2 mm brought by the structure, 1 mm brought by the studied equipment box and the neighbouring equipment (cf. Figure 5.6-2)

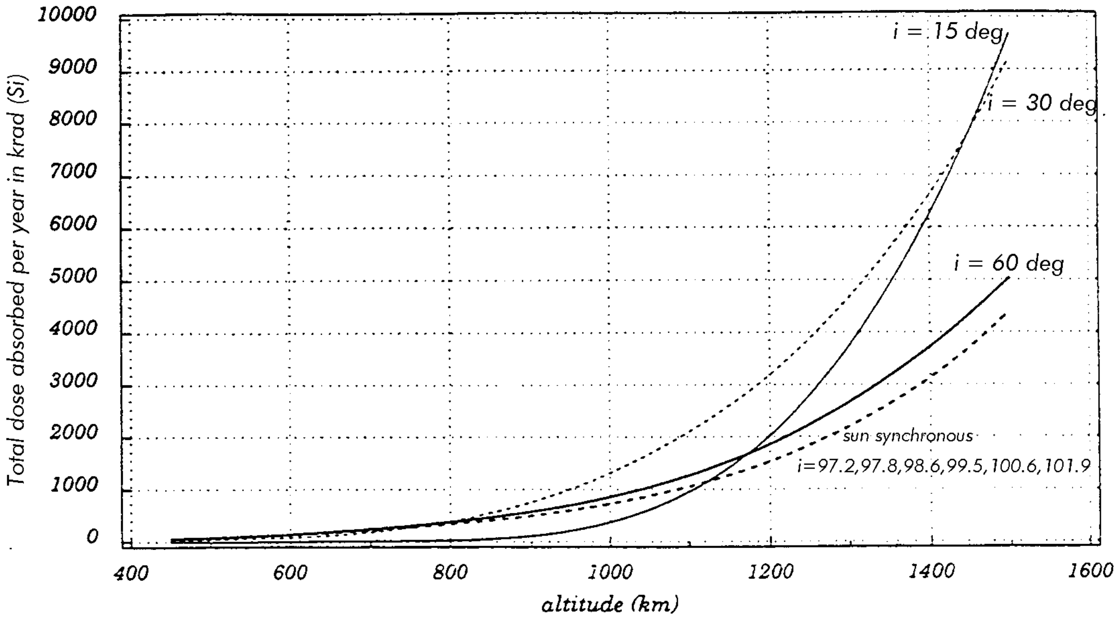

Figure 5.6-1 : Total radiation dose per year under 0.05 mm of aluminium for different inclinations

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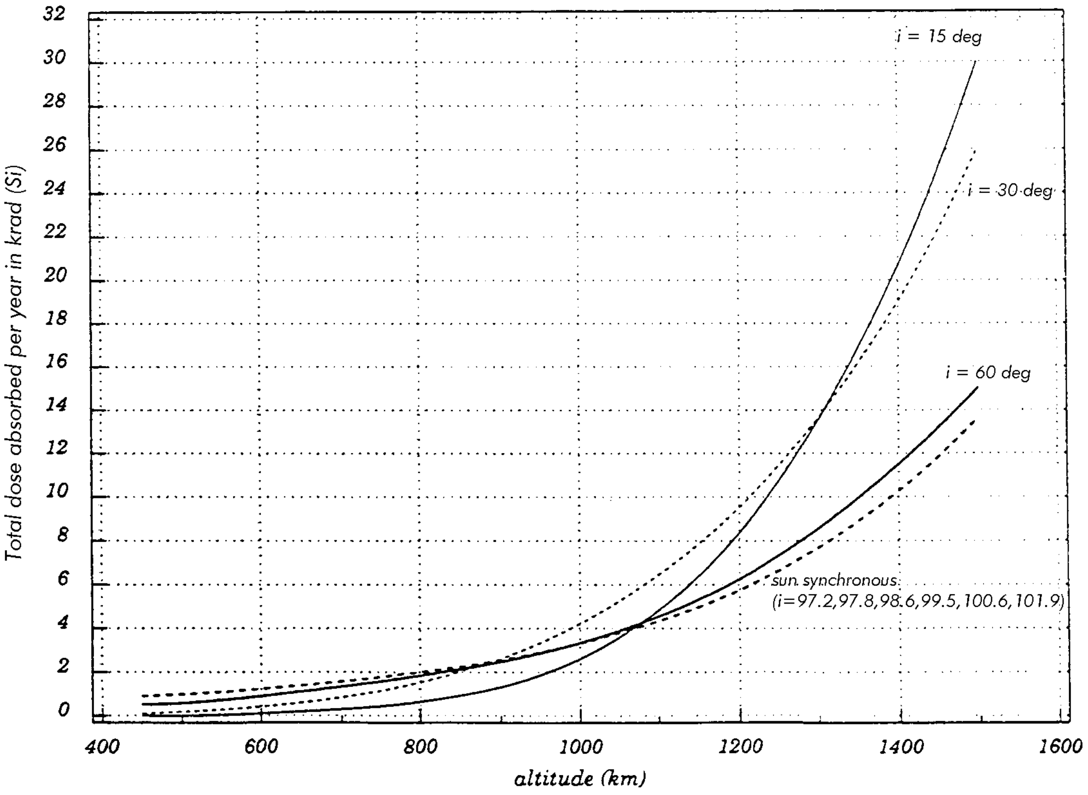

Figure 5.6-2 : Total radiation dose per year under 3 mm of aluminium for different inclinations

The radiation dose received at EEE parts level is a function of the protection given by:

the other units and the satellite structure,

the unit box and the other elements of the unit.

PL - 5.6 -1

The payload sizing shall take into account the total radiation dose (4 pi steradian) versus shielding protection thickness (margins included).

PL - 5.6 -2

The Payload Supplier shall provide the Satellite Supplier with a radiations analysis at parts level, accounting for every protection (satellite structure, unit structure, other electronics parts), and with the radiation dose versus thickness given hereafter.

Table 5.6-1 presents, for information, the maximal radiation dose cumulated over 5 years for different Aluminium equivalent thickness shielding and for different altitudes.

Table 5.6-1 presents, for information, the maximal radiation dose cumulated over 5 years for different Aluminium equivalent thickness shielding and for different altitudes.

Figure 5.6-3 gives a graphical representation of the data provided in Table 5.6-1.

Aluminium Equivalent thickness (mm)	Radiation dose (rad)				
	700 km	900 km	1100 km	1336 km Jason orbit	1336 km Worst case
0	7.65E+06	1.31E+07	3.38E+07	2,96E+07	8.40E+07
0.1	1.30E+06	4.47E+06	1.22E+07	1,85E+07	3.11E+07
0.2	5.90E+05	1.84E+06	5.12E+06	8,24E+06	1.32E+07
0.3	3.17E+05	7.53E+05	2.15E+06	4,11E+06	5.53E+06
0.4	2.00E+05	3.87E+05	1.11E+06	2,22E+06	2.87E+06
0.5	1.38E+05	2.26E+05	6.50E+05	1,32E+06	1.69E+06
0.6	1.02E+05	1.48E+05	4.23E+05	8,67E+05	1.10E+06
0.8	6.39E+04	7.74E+04	2.19E+05	4,71E+05	5.74E+05
1	4.52E+04	5.00E+04	1.39E+05	3,11E+05	3.65E+05
1.5	2.54E+04	2.65E+04	7.04E+04	1,60E+05	1.81E+05
2	1.60E+04	1.87E+04	4.78E+04	1,01E+05	1.20E+05
2.5	1.08E+04	1.51E+04	3.75E+04	7,03E+04	9.21E+04
3	7.52E+03	1.29E+04	3.15E+04	5,17E+04	7.58E+04
4	4.15E+03	1.04E+04	2.45E+04	3,20E+04	5.77E+04
5	2.58E+03	8.96E+03	2.06E+04	2,25E+04	4.75E+04
6	1.87E+03	8.15E+03	1.84E+04	1,82E+04	4.23E+04
7	1.54E+03	7.67E+03	1.72E+04	1,60E+04	3.92E+04
8	1.37E+03	7.31E+03	1.63E+04	1,49E+04	3.69E+04
9	1.27E+03	6.94E+03	1.56E+04	1,39E+04	3.51E+04
10	1.21E+03	6.69E+03	1.50E+04	1,31E+04	3.35E+04
12	1.12E+03	6.23E+03	1.39E+04	1,19E+04	3.11E+04
14	1.04E+03	5.88E+03	1.30E+04	1,11E+04	2.91E+04
16	9.76E+02	5.53E+03	1.22E+04	1,03E+04	2.73E+04
18	9.15E+02	5.22E+03	1.16E+04	9,56E+03	2.58E+04
20	8.69E+02	4.96E+03	1.10E+04	9,19E+03	2.45E+04

Table 5.6-1 : Radiation dose over 5 years vs Aluminium equivalent thickness and altitude

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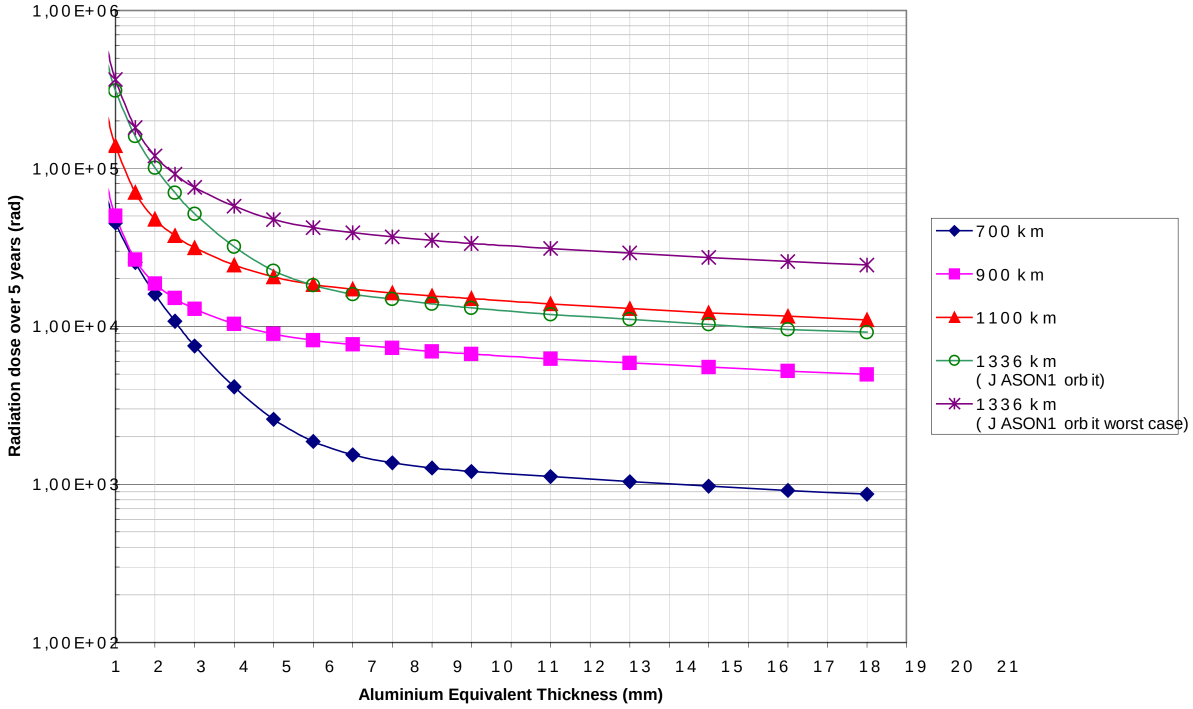

Figure 5.6-3: Radiation dose over 5 years vs Aluminium equivalent thickness and altitude

5.7 MAGNETIC FIELD

5.7.1 PAYLOAD SUSCEPTIBILITY

PL - 5.7.1 -1

Deleted (see PL - 3.5.9 - 2).

PL - 5.7.1 -2

Deleted (see PL - 3.5.9 - 4).

5.7.2 PAYLOAD EMISSION

PL - 5.7.2 -1

Deleted (See PL - 3.5.9 - 1).

PL - 5.7.2 -2

Deleted (see PL - 3.5.9 - 3).

5.8 METEROID AND SPACE DEBRIS

For information, Figure 5.8-1 plots spatial density values out to 2000 km altitude for trackable objects of various sizes.

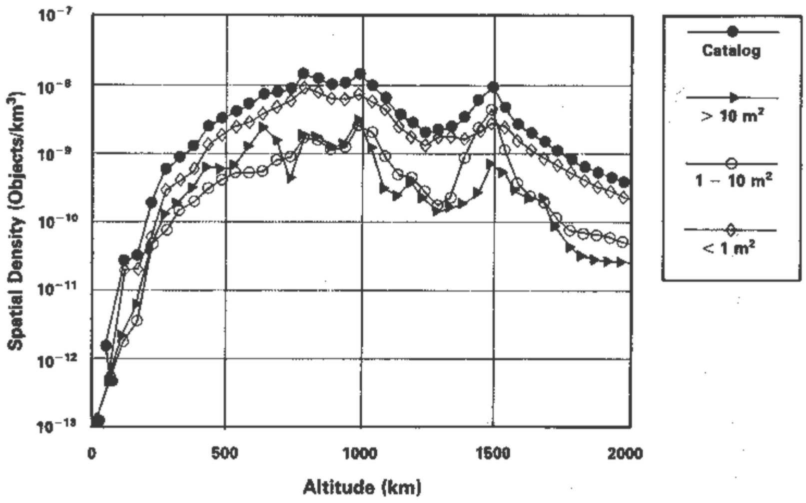

Figure 5.8-1 : Spatial Density Values in Low Earth Orbits (Jan. 1989)

5.9 ATOMIC OXYGEN

PL - 5.9 -1

The payload may be exposed to the atomic oxygen environment. The design shall consider performance in this environment.

The atomic oxygen, mostly fixed, follow the rotation of the Earth and its atmosphere. Therefore, they hit the satellite front face with a velocity around 26000 km/h. This kinetic energy adds to the high chemical reactivity of oxygen atoms that imply a fast reaction with the hit materials. A chemical effect occurs and induces a materials surfaces fragilization and a mechanical effect with a materials surfaces erosion. The erosion thickness depends on the oxygen dose and the materials kind. Table 5.9-1 gives the reactivity of main materials usually used in space technology.

Material	Erosion 10^{-24} cm^3/atom
Kapton H polyimide	3.0
Mylar polyester	2.7 to 3.9
Polyethylene	3.3 to 3.7
Epoxy	1.7
Polycarbonate	2.9 to 6.0
Polystyrene	1.7
Polysulfone	2.4
Urethane (black, conductor)	0.3
Silver	10.5
Carbon	0.9 to 1.7
Chemglaze Z306 (cblack) paint	0.35
FEP Teflon	0.037 to 0.35
Aluminium	0.0
Copper	0.0
Gold	0.0
SiO2	0.0

Table 5.9-1 : Material reactivity to the atomic oxygen

Table 5.9-2 gives some typical values of eroded thickness per year for a mean solar activity.

Altitude (km)	Oxygen flux (atomes/cm2.s)	kapton erosion (μm)	Teflon erosion (μm)
300	8.10^{14}	750	87
400	10^{14}	95	10
500	2.10^{13}	20	2.3
600	4.10^{12}	3.8	0.45
700	10^{12}	0.95	0.1
800	2.10^{11}	0.20	0.023
900	4.10^{10}	0.04	0.005
1000	8.10^{9}	0.008	0.001

Table 5.9-2 : Annual erosion of kapton and teflon

5.10 HEAVY IONS AND TRAPPED PROTONS ENVIRONMENT

PL - 5.10 -1

The payload may be exposed to the heavy ions and trapped protons environment. The design shall consider performance in this environment.

The orbital environment in terms of LET (Linear Energy Transfer) and Trapped Protons for a worst case in the PROTEUS flight domain (z = 1336 km) is shown on Figure 5.10-1 and Figure 5.10-2 (corresponding to the Jason case). It includes contributions from solar flares.

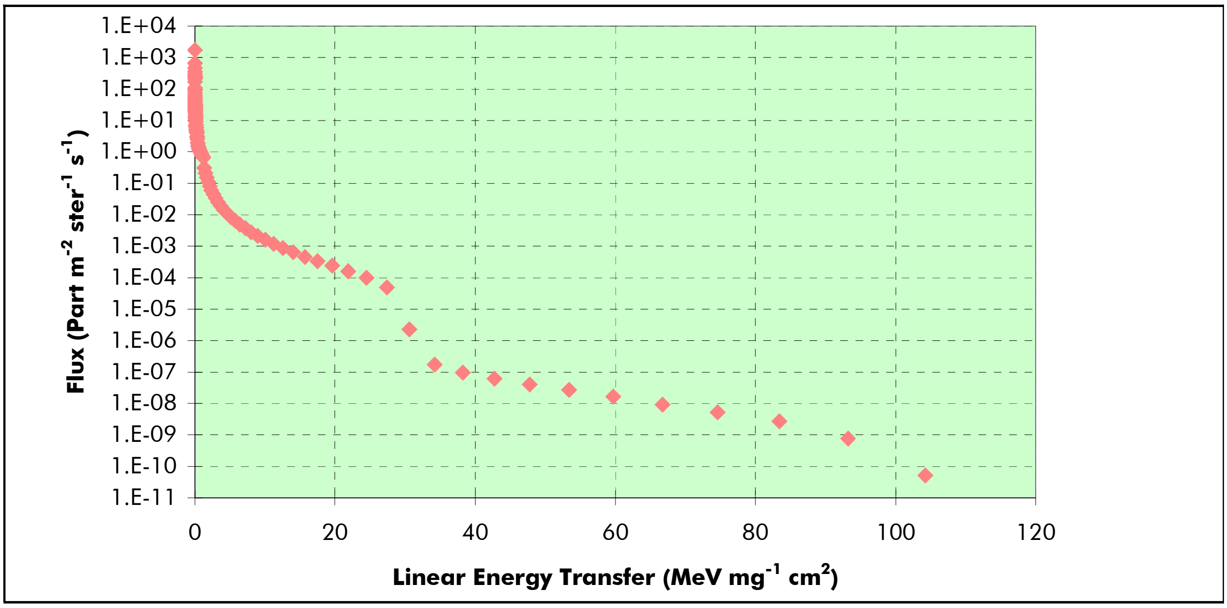

Figure 5.10-1 : LET Spectrum

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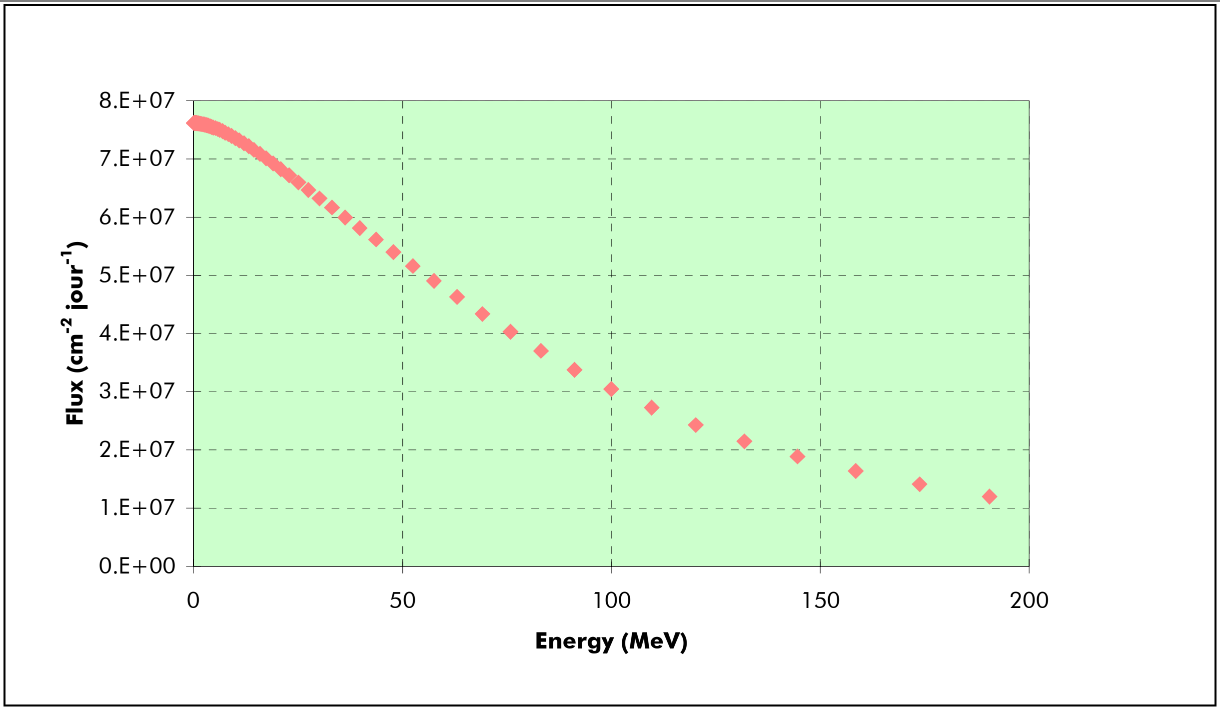

Figure 5.10-2 :Trapped PROTONS Spectrum

5.11 GROUND OPERATIONS, STORAGE, TRANSPORTATION AND HANDLING REQUIREMENTS

5.11.1 STORAGE REQUIREMENTS

PL - 5.11.1 -1

Any payload shall be able to withstand a storage period of 6 months after payload delivery to the satellite added to 1,5 year between the AIT and the launch without degradation of its functions or performance

This storage will occur under the following conditions :

temperature :	20° C ± 10° C
relative humidity :	40% ± 20%

5.11.2 HANDLING & TRANSPORTATION REQUIREMENTS

PL - 5.11.2 -1

It shall be possible to transport the payload integrated on the satellite with the environment described in the following paragraphs

5.11.2.1 Mechanical environment

The static and dynamic mechanical environment affecting the payload during all ground operations is covered by the envelope of the defined launch mechanical environment (i.e. ground operations shall not drive the design).

The mechanical environment is generated by air/road transportation and handling.

Factors of safety are given in section 4.2.5.2.

Following acting loads are transportation/handling loads.

5.11.2.1.1 Road transport

Sine vibration

The following accelerations act in any three axes simultaneously

Frequency range	Level
10 Hz - 100 Hz	1.2 g

Table 5.11-1: Sine vibration during road transport

3-axis random vibration (standard environment)

Frequency range	Level	Global (g_{RMS})
5 Hz - 10 Hz	+ 6 dB/oct.	0.64
10 Hz - 100 Hz	0.003 g^2/Hz	
100 Hz - 200 Hz	-12 dB/oct	
200 Hz - 400 Hz	0.0001875 g^2/Hz	

Table 5.11-2: Random vibration during road transport

Shock

10 g during 10 ms according to the following shock profile.

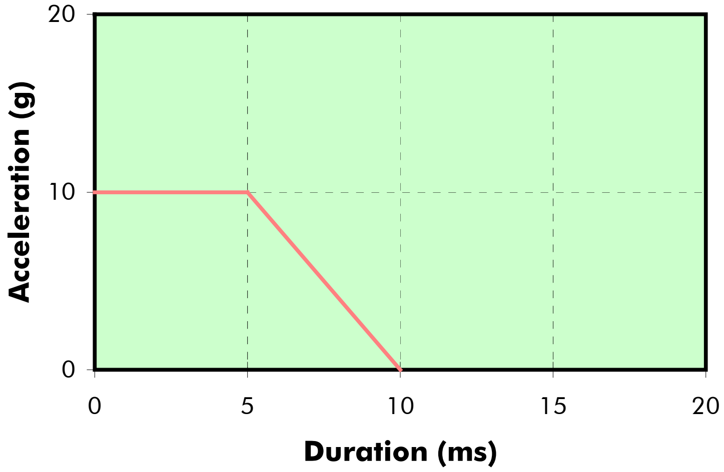

Figure 5.11-1: Shock during road transport

Quasi-static (40 km/h top speed)

X	Y	Z
± 1.1 g	± 1.2 g	+1.0 g / -3.0 g

** X velocity, Z vertical*

Table 5.11-3: QSL during road transport

Accelerations act simultaneously along all the 3 axes.

5.11.2.1.2 Air transport

3-axes sine vibration (standard environment)

Frequency band	Level
2- 20 Hz	± 0.2 mm
20- 50 Hz	0.85 g
50-100 Hz	2 g

Table 5.11-4: Sine vibration during air transport

3-axis random vibration (standard environment)

Frequency range	Level	Global (g_{RMS})
5 Hz - 10 Hz	+ 6 dB/oct.	0.64
10 Hz - 100 Hz	0.003 g^2/Hz	
100 Hz - 200 Hz	-12 dB/oct	
200 Hz - 400 Hz	0.0001875 g^2/Hz	

Table 5.11-5: Random vibration during air transport

Shock :

Half sine profile of 4.2 g amplitude and 20 ms duration

Quasi-static

Aircraft axis	X (forward)	Y	Z (+ up)
Landing	+ 1.5 g	± 1.5 g	-2.0 g
Take-off	- 1.5 g	0 g	+2.0 g / -1.5 g

Table 5.11-6: QSL during air transport

Accelerations act simultaneously along all the 3 axes.

5.11.2.1.3 Handling/hoisting

Acceleration

Hoisting sling	VERTICAL	1.3 g	} Act simultaneously
	HORIZONTAL	0.1 g	
Assembly and integration jig	VERTICAL	1.5 g	} Act simultaneously

Table 5.11-7: Acceleration during handling/hoisting

The gravity acceleration is included in the vertical acceleration

Shock

Equivalent to a 10 cm drop, considering that there is already a MGSE / ground contacting point.

5.11.2.2 Thermal and climatic environment (TBC)

The thermal and climatic environment during transportation is :

Temperature :	in the [5°C, 50°C] range
Temperature variation :	+5° C/h maximum
Relative humidity :	< 55 %
Cleanliness :	better than class 100000

5.11.3 INTEGRATION CONSTRAINTS

TBD

5.11.4 MAINTAINABILITY

PL - 5.11.4 -1

The payload shall be designed to require a minimum of special tools and test equipment to maintain calibration, perform adjustments and accomplish fault identification

Marking and location of the connectors shall be easily distinguished without any mistake possibility

5.11.5 SAFETY

PL - 5.11.5 -1

The payload shall comply with the standard rules for the utilisation in Clean Room.

END OF CHAPTER