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subject / *objet* **L2 Radiation Environment**

Introduction

The L2 orbit is an orbit about a virtual point in space known as the 2nd Lagrangian point. This L2 point is located about 1.5 million km from the Earth in the anti-Sun direction. It is becoming the orbit of choice of many future astronomical missions (Eddington, Herschel-Planck, NGST, GAIA and IRSI/DARWIN), because it offers the possibility of long uninterrupted observations in a, in many aspects, fairly stable environment (thermal, radiation etc.).

The space radiation environment presents a major problem to space systems. In general, the environment consists of geomagnetically trapped charged particles, solar protons and galactic cosmic rays. It is the penetrating particles that pose the main problems, which include upsets to electronics, payload interference, degradation and damage to components and solar cells, and deep dielectric charging (see also [1]). In the L2 orbit only solar protons and galactic cosmic rays will be encountered. The trapped particle radiation environment will only be encountered during the transfer phase and can be ignored outside about 10RE (earth radii). For a reasonable duration mission (several years), the contribution from the trapped particle environment will except for some special slow low thrust transfer trajectories normally be insignificant compared with the contribution from the solar protons and the galactic cosmic rays.

In addition to the radiation environment described here, missions at L2 may also have to consider the plasma environment for electrostatic charging effects (mainly for payload effects since charging levels at L2 cannot give rise to electrostatic discharge) and the micrometeoroid environment for hazards to vessels and damage to baffles and shields.

The ECSS standard [1] shall apply to all space environments and effects analyses. This defines appropriate analysis methods and models, including the ones employed here.

The Radiation Environment

The main components of the L2 radiation environment are:

- **Solar Particle Events**
  Events of strongly enhanced fluxes of primarily protons originating from the Sun, usually with a duration on the order of a couple of days. The events occur randomly and mainly during periods of solar maximum. The events are also accompanied by enhanced fluxes of heavy ions.
- **Galactic Cosmic Rays**
  A continuous flux of very high energy particle radiation. Although the flux is very low, they include heavy ions capable of causing intense ionisation as they pass through matter. Although their contribution to the total dose is insignificant, they are important when analysing single event effects.

Figure 1 shows the predicted spectrum of solar protons. It has been obtained using SPENVIS [2] with the JPL solar proton model. Solar maximum conditions have been assumed in the calculation to give a worst case. The confidence level applied in the calculation is 95% for the 3 years mission duration and 90% for 5 and 10 years mission duration. The galactic cosmic rays are ignored in this calculation, since the flux is so low that its contribution to the total radiation dose is insignificant. Figure 2 shows the corresponding total ionising radiation dose in Si as a function of spherical aluminium shielding thickness. It should be remarked that due to the statistical nature of the solar proton model, the dose can not simply be scaled with the mission duration. Table 1 and 2 shows the same data in tabular form.

To be able to assess the displacement damage of electro-optics due to non-ionising dose the Non-Ionising Energy Loss (NIEL) is required. Figure 3 and table 3 shows the NIEL in MeV/g in Si again as a function of spherical aluminium shielding.

To assess Single Events Effects (SEE) the LET (dE/dx) spectrum is needed. Figure 4 and 5 shows the results from a calculation of the LET using the CREME96 software. Figure 4 shows the predicted LET spectrum for the peak 5 minutes of a solar particle event, assuming a shielding of $1g/cm^2$ (equivalent to about 3.7mm Aluminium). This represents a worst case. Figure 5 shows the background galactic cosmic ray LET spectrum also for $1g/cm^2$ shielding. This is the predicted continuous background galactic cosmic ray flux.

For other problems, other parameters may need to be considered:

- internal charging: material electric field (unlikely at L2)
- materials: surface doses.

The following environments may pose problems in special circumstances (e.g. special payload susceptibility):

- The heliospheric low-energy proton environment
- The heliospheric energetic electron environment
- Secondary radiation products (X, γ, neutrons, etc.)

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References:

[1] ECSS-E-10-04 Space Environment Standard
version linked to software tools is available at www.spenvis.oma.be/spenvis/

[2] SPENVIS – Space Environment Information System
http://www.spenvis.oma.be/spenvis/

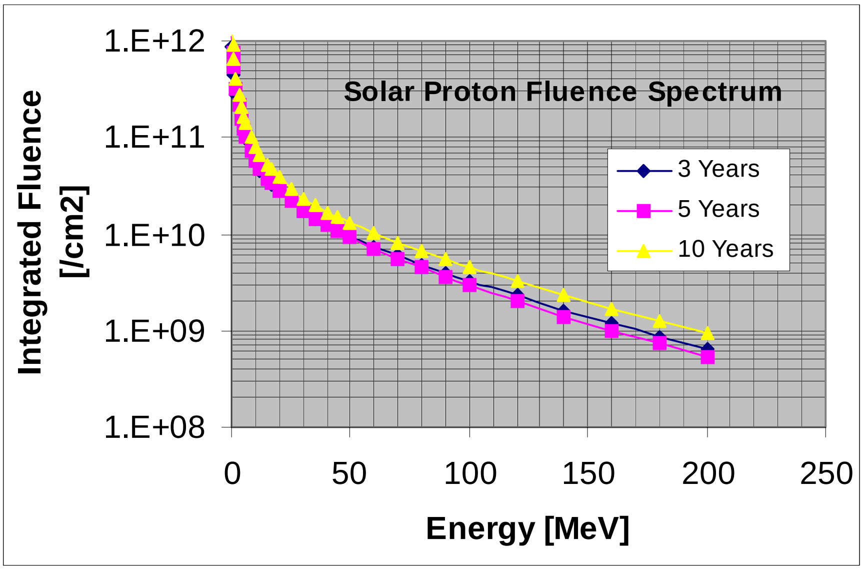

Figure 1: Solar Proton Spectrum for an L2 orbit for various mission durations.

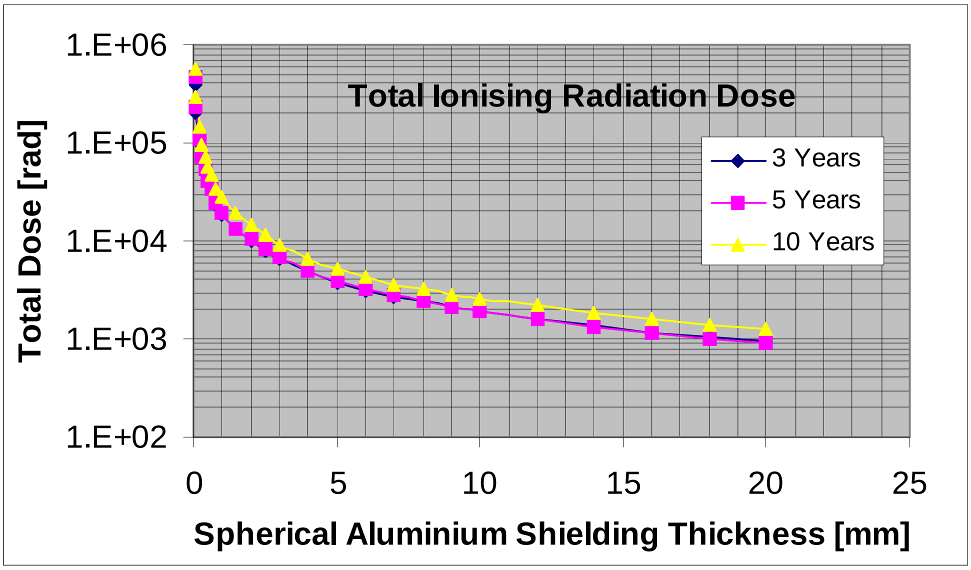

Figure 2: Total ionising radiation dose in Si as a function of shielding thickness for an L2 orbit for various mission durations.

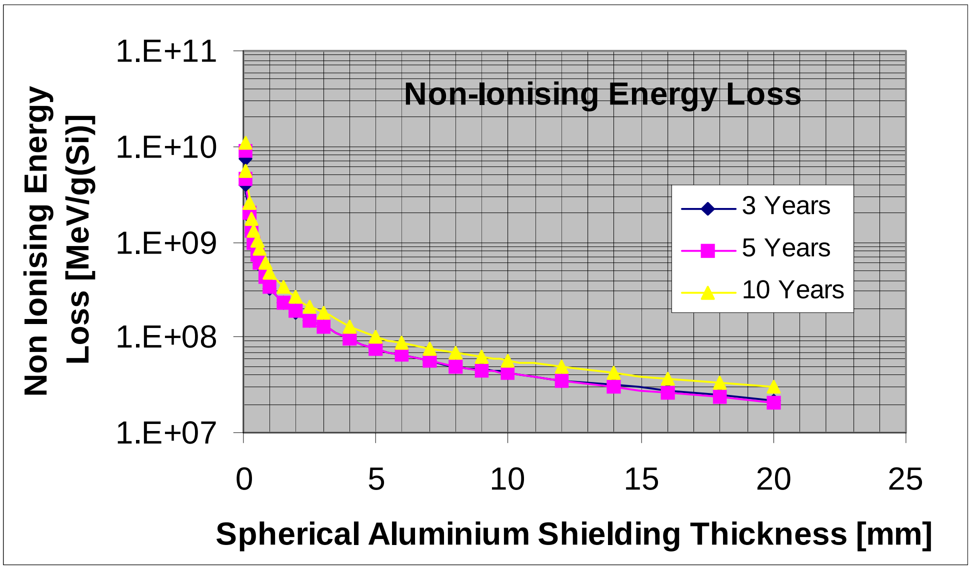

Figure 3: Non- ionising energy loss in Si as a function of shielding thickness for an L2 orbit for various mission durations.

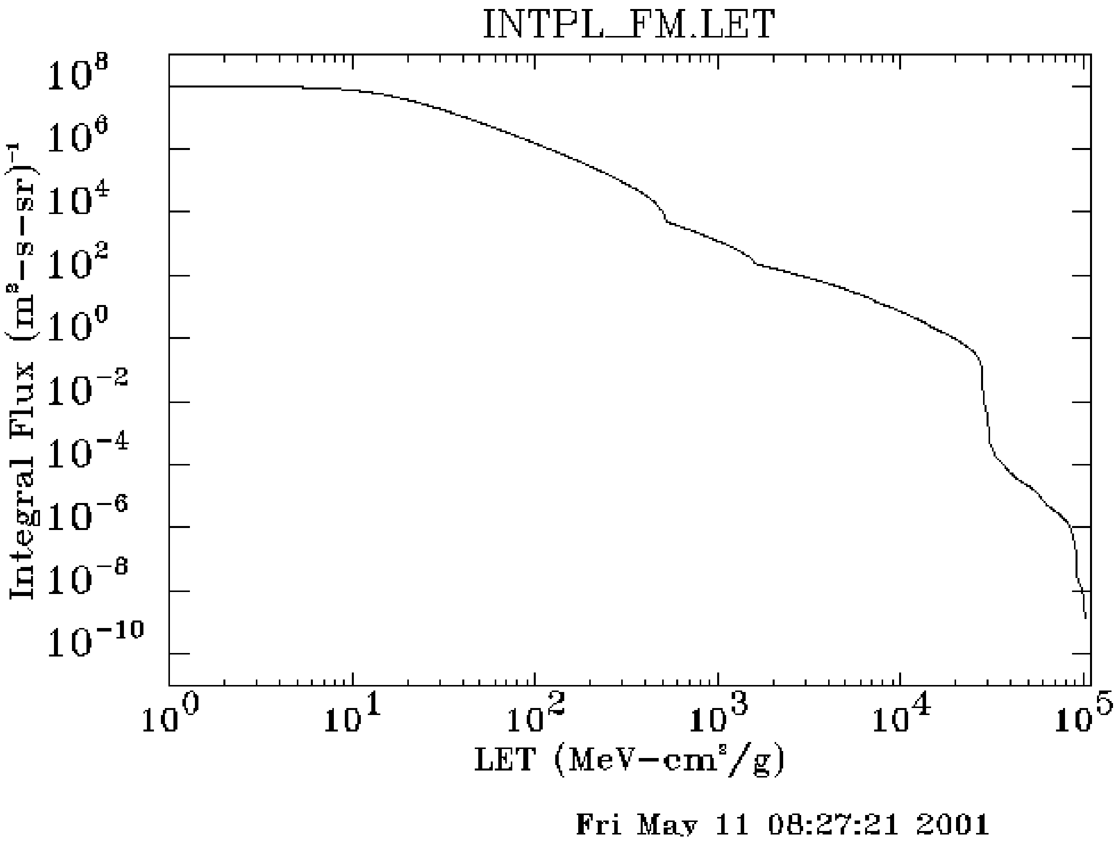

Figure 4: Peak 5 minute LET spectrum for the L2 orbit for 1g/cm2 shielding

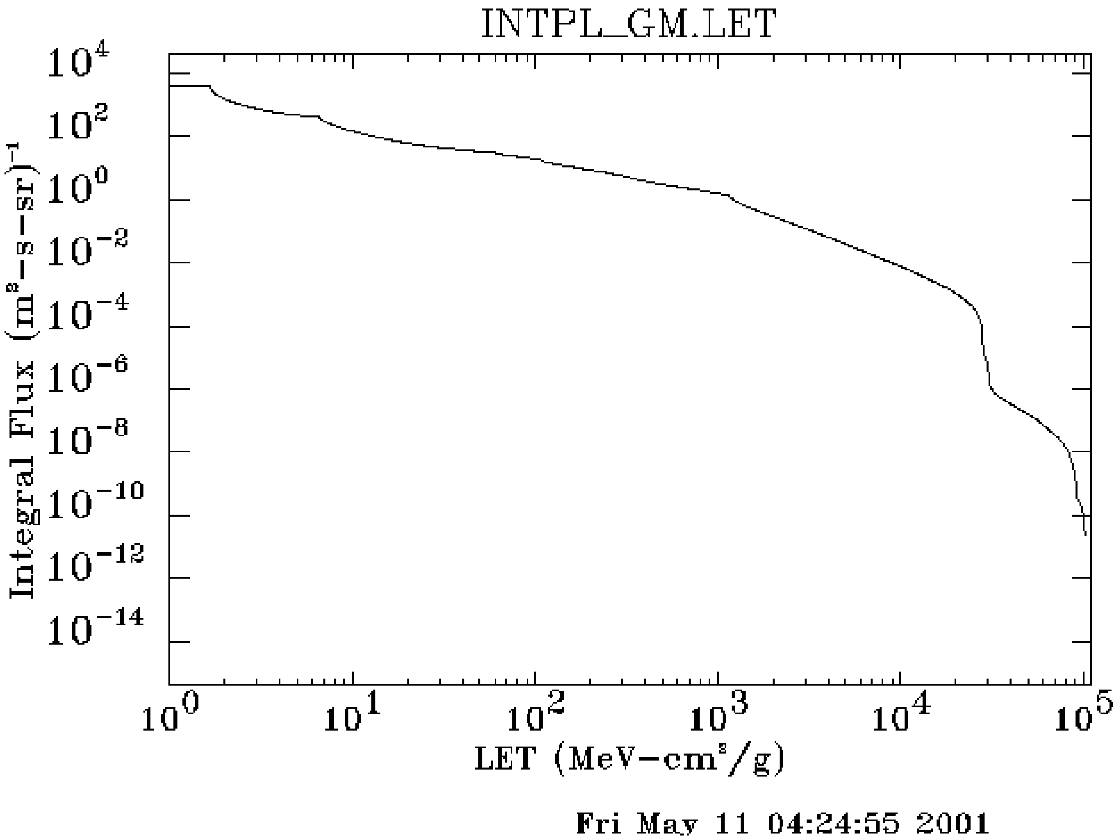

Figure 5: Background galactic cosmic ray LET spectrum for the L2 orbit for 1g/cm2 shielding

Proton Energy [MeV	Integrated Solar Proton Fluence [#/cm2]		
	3 Years	5 Years	10 Years
1.00E-01	8.47E+11	1.12E+12	1.32E+12
5.00E-01	6.02E+11	7.66E+11	9.17E+11
1.00E+00	4.36E+11	5.34E+11	6.52E+11
2.00E+00	2.73E+11	3.15E+11	3.96E+11
3.00E+00	1.93E+11	2.13E+11	2.75E+11
4.00E+00	1.47E+11	1.58E+11	2.07E+11
5.00E+00	1.18E+11	1.25E+11	1.66E+11
6.00E+00	9.79E+10	1.03E+11	1.39E+11
8.00E+00	7.13E+10	7.36E+10	1.02E+11
1.00E+01	5.55E+10	5.67E+10	8.01E+10
1.20E+01	4.60E+10	4.68E+10	6.62E+10
1.50E+01	3.71E+10	3.76E+10	5.28E+10
1.70E+01	3.29E+10	3.32E+10	4.64E+10
2.00E+01	2.77E+10	2.79E+10	3.87E+10
2.50E+01	2.15E+10	2.15E+10	2.95E+10
3.00E+01	1.73E+10	1.72E+10	2.35E+10
3.50E+01	1.45E+10	1.43E+10	1.96E+10
4.00E+01	1.24E+10	1.22E+10	1.69E+10
4.50E+01	1.08E+10	1.06E+10	1.48E+10
5.00E+01	9.53E+09	9.21E+09	1.30E+10
6.00E+01	7.47E+09	7.11E+09	1.02E+10
7.00E+01	5.96E+09	5.60E+09	8.21E+09
8.00E+01	4.82E+09	4.47E+09	6.67E+09
9.00E+01	3.95E+09	3.61E+09	5.49E+09
1.00E+02	3.27E+09	2.96E+09	4.56E+09
1.20E+02	2.28E+09	2.02E+09	3.20E+09
1.40E+02	1.63E+09	1.41E+09	2.30E+09
1.60E+02	1.18E+09	1.00E+09	1.68E+09
1.80E+02	8.71E+08	7.26E+08	1.25E+09
2.00E+02	6.48E+08	5.31E+08	9.36E+08

Table 1: Solar Proton Spectrum for an L2 orbit for various mission durations.

Aluminium shielding thickness [mm]	Total ionising radiation dose in Si [rad]		
	3 Years	5 Years	10 Years
5.0000E-02	3.85E+05	4.66E+05	5.72E+05
1.0000E-01	2.03E+05	2.31E+05	2.88E+05
2.0000E-01	1.02E+05	1.11E+05	1.43E+05
3.0000E-01	6.88E+04	7.33E+04	9.69E+04
4.0000E-01	5.12E+04	5.40E+04	7.32E+04
5.0000E-01	3.98E+04	4.17E+04	5.76E+04
6.0000E-01	3.21E+04	3.34E+04	4.69E+04
8.0000E-01	2.32E+04	2.39E+04	3.43E+04
1.0000E+00	1.87E+04	1.92E+04	2.76E+04
1.5000E+00	1.30E+04	1.33E+04	1.90E+04
2.0000E+00	1.01E+04	1.04E+04	1.46E+04
2.5000E+00	8.04E+03	8.22E+03	1.14E+04
3.0000E+00	6.63E+03	6.78E+03	9.27E+03
4.0000E+00	4.83E+03	4.94E+03	6.61E+03
5.0000E+00	3.79E+03	3.88E+03	5.11E+03
6.0000E+00	3.15E+03	3.21E+03	4.23E+03
7.0000E+00	2.70E+03	2.75E+03	3.63E+03
8.0000E+00	2.40E+03	2.43E+03	3.23E+03
9.0000E+00	2.13E+03	2.14E+03	2.86E+03
1.0000E+01	1.91E+03	1.92E+03	2.58E+03
1.2000E+01	1.61E+03	1.60E+03	2.18E+03
1.4000E+01	1.36E+03	1.34E+03	1.84E+03
1.6000E+01	1.17E+03	1.15E+03	1.59E+03
1.8000E+01	1.04E+03	1.01E+03	1.41E+03
2.0000E+01	9.35E+02	9.07E+02	1.27E+03

Table 2: Total ionising radiation dose in Si as a function of spherical shielding thickness for an L2 orbit for various mission durations

Aluminium shielding thickness [mm]	Non-ionising energy loss [MeV/g(Si)]		
	3 Years	5 Years	10 Years
0.050	7.41E+09	9.06E+09	1.10E+10
0.100	3.87E+09	4.48E+09	5.57E+09
0.200	1.83E+09	1.99E+09	2.54E+09
0.300	1.24E+09	1.33E+09	1.74E+09
0.400	9.23E+08	9.78E+08	1.31E+09
0.500	7.05E+08	7.40E+08	1.01E+09
0.600	5.84E+08	6.09E+08	8.44E+08
0.800	4.16E+08	4.30E+08	6.09E+08
1.000	3.25E+08	3.34E+08	4.78E+08
1.500	2.28E+08	2.33E+08	3.31E+08
2.000	1.83E+08	1.86E+08	2.62E+08
2.500	1.48E+08	1.50E+08	2.09E+08
3.000	1.27E+08	1.29E+08	1.78E+08
4.000	9.54E+07	9.67E+07	1.31E+08
5.000	7.57E+07	7.66E+07	1.03E+08
6.000	6.45E+07	6.50E+07	8.70E+07
7.000	5.70E+07	5.71E+07	7.69E+07
8.000	5.01E+07	4.99E+07	6.77E+07
9.000	4.59E+07	4.55E+07	6.21E+07
10.000	4.21E+07	4.16E+07	5.70E+07
12.000	3.57E+07	3.49E+07	4.85E+07
14.000	3.13E+07	3.05E+07	4.27E+07
16.000	2.73E+07	2.64E+07	3.73E+07
18.000	2.46E+07	2.36E+07	3.37E+07
20.000	2.19E+07	2.08E+07	3.00E+07

Table 3: Non-ionising energy loss in Si as a function of spherical shielding thickness for an L2 orbit for various mission durations