

MEMO

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From	Christian Erd	Visa	
To	Reformulation Phase Teams	Copy	

Subject: Radiation Environment Specification for Jupiter Mission Reformulation Activities

Since the Assessment Phase of the Europa Jupiter System Mission's (EJSM) Jupiter Ganymede Orbiter (JGO) the baseline model for estimating the Jupiter radiation environment was changed, and now the JOSE model is used [RD-1]. This model is still under review and refinements are taking place. It estimates a moderately more intense radiation environment. For this specification the model as release at September 2010 was used, with median estimates (50% confidence level settings).

Furthermore, based on ongoing work it was possible to confirm that the shielding factor of Ganymede is at least 40% for the low altitude orbits (<500 km). In the baseline mission 180 out of 300 days were planned to be below 500 km altitude. For this period a reduction of the space environment by 40% was included in these estimates [RD-2].

The radiation environment also includes two Europa flybys, for which segments of higher altitude orbits (11×42 R_J) are required. The radiation environment for these specific orbits was evaluated too.

Finally updated dose levels for the baseline mission trajectory (as used during the Assessment Phase) are provided. A second dose calculation was performed where the Callisto phase (9 flybys during the previous baseline mission) was replaced by two Europa flybys, assuming that the Europa flybys would be initiated after having arrived at Callisto.

This current document is a refinement of the Laplace Environmental Specification [RD-3], with respect to the total electron and proton fluences and related dose depth curve. These data shall be used as a baseline specification for the reformulation phase ending in November 2011.

- RD-1: A. Sicard et al, "JOSE: A new Jovian Specification Environment model", EPSC Abstracts Vol. 5, EPSC2010-118, 2010, European Planetary Science Congress 2010
- RD-2: Private communication with N. Andre and R. Aillioux, CNRS.
- RD-3: Laplace Environmental Specification Issue 3.1, June 2010, Sorensen & Santin; JS-14-09

Energy MeV	Interpl Traj	JOI to Callisto	Callisto	2 Europa flybys	Callisto to Ganymede	300 d Ganymede, incl. G. shielding	JGO mission baseline, incl G. shielding	No Callisto, 2 Eu flybys, incl. G. shielding
0.02		3.93E+14	5.81E+14	3.56E+14	1.17E+15	3.48E+15	5.62E+15	5.40E+15
0.03		3.86E+14	4.75E+14	2.95E+14	1.08E+15	4.03E+15	5.97E+15	5.79E+15
0.05		2.52E+14	2.64E+14	1.83E+14	6.74E+14	2.82E+15	4.01E+15	3.93E+15
0.07		1.45E+14	1.24E+14	1.17E+14	3.51E+14	1.69E+15	2.32E+15	2.31E+15
0.1		8.85E+13	7.07E+13	8.17E+13	2.07E+14	1.00E+15	1.37E+15	1.38E+15
0.2		2.66E+13	1.72E+13	2.46E+13	5.16E+13	3.29E+14	4.24E+14	4.32E+14
0.3		1.22E+13	7.64E+12	1.24E+13	2.38E+13	1.45E+14	1.89E+14	1.94E+14
0.5		5.16E+12	3.09E+12	5.99E+12	9.70E+12	5.80E+13	7.60E+13	7.89E+13
0.7		3.42E+12	1.96E+12	4.28E+12	5.79E+12	3.64E+13	4.76E+13	4.99E+13
1		1.38E+12	7.77E+11	1.91E+12	2.18E+12	1.44E+13	1.88E+13	1.99E+13
2		2.81E+11	1.55E+11	5.02E+11	3.82E+11	2.77E+12	3.59E+12	3.93E+12
3		9.71E+10	4.99E+10	2.07E+11	1.16E+11	9.10E+11	1.17E+12	1.33E+12
5		1.98E+10	8.85E+09	5.09E+10	1.99E+10	1.74E+11	2.23E+11	2.65E+11
7		7.01E+09	2.84E+09	2.04E+10	6.24E+09	5.87E+10	7.48E+10	9.24E+10
10		2.35E+09	8.56E+08	7.78E+09	1.82E+09	1.85E+10	2.36E+10	3.05E+10
20		2.50E+08	6.67E+07	1.13E+09	1.30E+08	1.68E+09	2.12E+09	3.19E+09
30		5.36E+07	1.16E+07	2.82E+08	2.12E+07	3.26E+08	4.13E+08	6.83E+08
50		7.84E+06	1.32E+06	4.92E+07	2.17E+06	4.17E+07	5.30E+07	1.01E+08
70		2.23E+06	3.21E+05	1.56E+07	4.83E+05	1.07E+07	1.38E+07	2.91E+07
100		5.90E+05	7.21E+04	4.66E+06	9.87E+04	2.56E+06	3.32E+06	7.91E+06
200		4.54E+04	4.09E+03	4.46E+05	4.52E+03	1.58E+05	2.12E+05	6.54E+05
300		1.02E+04	7.76E+02	1.14E+05	7.47E+02	3.11E+04	4.28E+04	1.56E+05
500		1.56E+03	9.71E+01	2.03E+04	7.76E+01	4.01E+03	5.75E+03	2.60E+04
700		4.57E+02	2.49E+01	6.56E+03	1.75E+01	1.04E+03	1.54E+03	8.08E+03
1000		1.24E+02	5.92E+00	1.98E+03	3.61E+00	2.50E+02	3.83E+02	2.36E+03

Table 1: Differential electron fluence spectra in $\text{cm}^{-2} \text{sr}^{-1} \text{MeV}^{-1}$ per mission phase and total for two options (last columns).

Energy MeV	Interpl Traj	JOI to Callisto	Callisto	2 Europa flybys	Callisto to Ganymede	300 d Ganymede, incl. G shielding	JGO mission baseline, incl G shielding	No Callisto, 2 Eu flybys, incl. G shielding
0.1	1.67E+11	8.57E+12	1.09E+13	9.21E+12	2.28E+13	7.59E+13	1.18E+14	1.17E+14
0.2	8.48E+10	3.46E+12	3.69E+12	4.25E+12	8.56E+12	3.15E+13	4.73E+13	4.79E+13
0.3	4.72E+10	1.88E+12	1.60E+12	2.51E+12	4.05E+12	1.86E+13	2.62E+13	2.71E+13
0.4	3.22E+10	1.17E+12	8.62E+11	1.71E+12	2.25E+12	1.16E+13	1.59E+13	1.68E+13
0.5	2.61E+10	7.95E+11	5.52E+11	1.26E+12	1.47E+12	7.61E+12	1.05E+13	1.12E+13
0.7	2.51E+10	4.38E+11	2.86E+11	7.61E+11	7.98E+11	4.22E+12	5.76E+12	6.24E+12
1	1.93E+10	2.17E+11	1.13E+11	3.86E+11	3.01E+11	2.34E+12	2.99E+12	3.26E+12
2	8.59E+09	2.99E+10	7.51E+09	9.51E+10	1.64E+10	2.19E+11	2.81E+11	3.69E+11
3	4.64E+09	5.81E+09	1.35E+09	2.70E+10	2.95E+09	3.93E+10	5.40E+10	7.97E+10
4	2.81E+09	1.72E+09	3.99E+08	8.15E+09	8.74E+08	1.16E+10	1.74E+10	2.52E+10
5	1.64E+09	6.68E+08	1.55E+08	3.17E+09	3.40E+08	4.52E+09	7.32E+09	1.03E+10
7	1.06E+09	1.61E+08	3.73E+07	7.62E+08	8.19E+07	1.09E+09	2.43E+09	3.16E+09
10	4.44E+08	3.55E+07	8.26E+06	1.68E+08	1.81E+07	2.40E+08	7.47E+08	9.07E+08
20	1.22E+08	1.89E+06	4.42E+05	8.96E+06	9.69E+05	1.28E+07	1.38E+08	1.47E+08
30	4.97E+07	3.42E+05	7.97E+04	1.61E+06	1.75E+05	2.32E+06	5.26E+07	5.41E+07
40	2.31E+07	1.01E+05	2.37E+04	4.79E+05	5.19E+04	6.88E+05	2.40E+07	2.44E+07
50	2.00E+07	3.95E+04	9.22E+03	1.86E+05	2.02E+04	2.68E+05	2.03E+07	2.05E+07
70	9.39E+06	9.54E+03	2.23E+03	4.50E+04	4.89E+03	6.47E+04	9.47E+06	9.51E+06
100	4.53E+06	2.12E+03	4.94E+02	9.99E+03	1.08E+03	1.44E+04	4.55E+06	4.55E+06
200	6.33E+05	1.13E+02	2.64E+01	5.35E+02	5.80E+01	7.69E+02	6.34E+05	6.34E+05
300	1.53E+05	2.04E+01	4.77E+00	9.65E+01	1.05E+01	1.39E+02	1.53E+05	1.53E+05
400	5.44E+04	5.70E+00	6.79E-01	2.84E+01	8.32E-01	4.12E+01	5.45E+04	5.45E+04
500	2.34E+04	2.09E+00	2.00E-01	1.10E+01	0.00E+00	1.41E+01	2.34E+04	2.34E+04
700	6.60E+03	3.22E-01	0.00E+00	2.57E+00	0.00E+00	0.00E+00	6.60E+03	6.61E+03
1000	1.57E+03	6.28E-03	0.00E+00	4.20E-01	0.00E+00	0.00E+00	1.57E+03	1.57E+03

Table 2: Differential proton fluence spectra in $\text{cm}^{-2} \text{sr}^{-1} \text{MeV}^{-1}$ per mission phase and total for two options (last columns).



Energy MeV	Interpl Traj	JOI to Callisto	Callisto	2 Europa flybys	Callisto to Ganymede	300 d Ganymede, incl. G shielding	JGO mission baseline, incl G shielding	No Callisto, 2 Eu flybys, incl. G shielding
0.02		2.75E+13	2.52E+13	2.48E+13	6.55E+13	3.04E+14	4.22E+14	4.22E+14
0.03		2.42E+13	2.07E+13	2.20E+13	5.61E+13	2.74E+14	3.75E+14	3.77E+14
0.05		1.76E+13	1.32E+13	1.72E+13	3.80E+13	2.01E+14	2.70E+14	2.74E+14
0.07		1.37E+13	9.66E+12	1.42E+13	2.84E+13	1.57E+14	2.09E+14	2.13E+14
0.1		1.05E+13	6.96E+12	1.14E+13	2.07E+13	1.19E+14	1.58E+14	1.62E+14
0.2		5.75E+12	3.45E+12	6.93E+12	1.03E+13	6.49E+13	8.44E+13	8.79E+13
0.3		3.98E+12	2.31E+12	5.23E+12	6.92E+12	4.32E+13	5.64E+13	5.93E+13
0.5		2.50E+12	1.41E+12	3.59E+12	3.98E+12	2.61E+13	3.40E+13	3.61E+13
0.7		1.55E+12	8.50E+11	2.44E+12	2.30E+12	1.57E+13	2.04E+13	2.20E+13
1		9.02E+11	4.83E+11	1.59E+12	1.24E+12	8.92E+12	1.15E+13	1.27E+13
2		3.19E+11	1.61E+11	7.15E+11	3.75E+11	2.96E+12	3.81E+12	4.37E+12
3		1.36E+11	6.13E+10	3.53E+11	1.39E+11	1.19E+12	1.53E+12	1.82E+12
5		4.68E+10	1.82E+10	1.47E+11	3.97E+10	3.81E+11	4.86E+11	6.15E+11
7		2.34E+10	8.23E+09	8.33E+10	1.74E+10	1.80E+11	2.29E+11	3.04E+11
10		1.13E+10	3.55E+09	4.58E+10	7.28E+09	8.12E+10	1.03E+11	1.46E+11
20		1.74E+09	3.90E+08	9.11E+09	7.21E+08	1.07E+10	1.35E+10	2.22E+10
30		5.66E+08	1.04E+08	3.42E+09	1.76E+08	3.12E+09	3.97E+09	7.28E+09
50		1.39E+08	1.99E+07	1.00E+09	3.01E+07	6.66E+08	8.55E+08	1.83E+09
70		5.58E+07	6.82E+06	4.47E+08	9.41E+06	2.41E+08	3.13E+08	7.53E+08
100		2.12E+07	2.21E+06	1.91E+08	2.75E+06	8.20E+07	1.08E+08	2.97E+08
200		3.29E+06	2.56E+05	3.67E+07	2.53E+05	1.01E+07	1.40E+07	5.04E+07
300		1.11E+06	7.34E+04	1.41E+07	6.27E+04	2.99E+06	4.25E+06	1.82E+07
500		2.87E+05	1.54E+04	4.21E+06	1.09E+04	6.45E+05	9.58E+05	5.15E+06
700		1.17E+05	5.57E+03	1.90E+06	3.43E+03	2.35E+05	3.61E+05	2.26E+06
1000		4.58E+04	1.90E+03	8.23E+05	1.01E+03	8.05E+04	1.29E+05	9.50E+05

Table 3: Integral electron fluence spectra in cm⁻² sr⁻¹ per mission phase and total for two options (last columns).



Energy MeV	Interpl Traj	JOI to Callisto	Callisto	2 Europa flybys	Callisto to Ganymede	300 d Ganymede, incl. G shielding	JGO mission baseline, incl G shielding	No Callisto, 2 Eu flybys, incl. G shielding
0.1	6.96E+10	1.77E+12	1.74E+12	2.25E+12	3.98E+12	1.68E+13	2.43E+13	2.49E+13
0.2	5.73E+10	1.07E+12	8.51E+11	1.51E+12	2.16E+12	1.08E+13	1.49E+13	1.56E+13
0.3	5.17E+10	7.91E+11	5.64E+11	1.16E+12	1.49E+12	8.19E+12	1.11E+13	1.17E+13
0.4	4.77E+10	5.92E+11	3.92E+11	8.97E+11	1.05E+12	6.11E+12	8.19E+12	8.69E+12
0.5	4.52E+10	4.57E+11	2.89E+11	7.10E+11	7.87E+11	4.71E+12	6.29E+12	6.71E+12
0.7	3.98E+10	3.23E+11	1.97E+11	4.97E+11	5.43E+11	3.42E+12	4.52E+12	4.82E+12
1	3.30E+10	1.88E+11	9.83E+10	3.10E+11	2.59E+11	2.01E+12	2.59E+12	2.80E+12
2	2.08E+10	3.04E+10	1.11E+10	8.38E+10	2.76E+10	2.60E+11	3.50E+11	4.22E+11
3	1.45E+10	8.31E+09	2.97E+09	2.63E+10	7.33E+09	6.97E+10	1.03E+11	1.26E+11
4	1.10E+10	3.25E+09	1.15E+09	1.04E+10	2.82E+09	2.72E+10	4.54E+10	5.47E+10
5	8.67E+09	1.57E+09	5.56E+08	5.04E+09	1.37E+09	1.30E+10	2.52E+10	2.97E+10
7	6.37E+09	5.21E+08	1.87E+08	1.69E+09	4.62E+08	4.32E+09	1.19E+10	1.34E+10
10	4.06E+09	1.63E+08	5.91E+07	5.22E+08	1.46E+08	1.37E+09	5.80E+09	6.26E+09
20	2.08E+09	1.75E+07	6.33E+06	5.51E+07	1.57E+07	1.47E+08	2.27E+09	2.32E+09
30	1.22E+09	4.72E+06	1.71E+06	1.49E+07	4.24E+06	3.97E+07	1.27E+09	1.28E+09
40	9.23E+08	1.87E+06	6.78E+05	5.90E+06	1.68E+06	1.57E+07	9.43E+08	9.48E+08
50	6.96E+08	9.11E+05	3.30E+05	2.87E+06	8.18E+05	7.65E+06	7.05E+08	7.08E+08
70	4.34E+08	3.08E+05	1.12E+05	9.71E+05	2.77E+05	2.59E+06	4.38E+08	4.39E+08
100	2.37E+08	9.75E+04	3.54E+04	3.08E+05	8.76E+04	8.20E+05	2.38E+08	2.38E+08
200	4.87E+07	1.04E+04	3.79E+03	3.30E+04	9.38E+03	8.78E+04	4.88E+07	4.88E+07
300	1.67E+07	2.83E+03	1.03E+03	8.92E+03	2.54E+03	2.38E+04	1.67E+07	1.67E+07
400	7.80E+06	9.95E+02	1.57E+02	3.45E+03	2.41E+02	9.40E+03	7.81E+06	7.81E+06
500	4.14E+06	4.39E+02	5.48E+01	1.66E+03	0.00E+00	3.96E+03	4.14E+06	4.14E+06
700	1.75E+06	8.28E+01	0.00E+00	5.29E+02	0.00E+00	0.00E+00	1.75E+06	1.75E+06
1000	7.16E+05	1.91E+00	0.00E+00	1.15E+02	0.00E+00	0.00E+00	7.16E+05	7.16E+05

Table 4: Integral proton fluence spectra in $\text{cm}^{-2} \text{sr}^{-1}$ per mission phase and total for two options (last columns).



Shielding mm	Interpl Traj	JOI to Callisto	Callisto	2 Europa flybys	Callisto to Ganymede	300 d Ganymede, incl. G shielding	JGO mission baseline, incl G shielding	No Callisto, 2 Eu flybys, incl. G shielding
0.05	3.86E+05	8.85E+06	5.84E+06	1.06E+07	1.73E+07	1.01E+08	1.33E+08	1.38E+08
0.1	1.93E+05	4.86E+06	3.03E+06	5.58E+06	9.08E+06	5.63E+07	7.35E+07	7.60E+07
0.2	9.88E+04	2.73E+06	1.63E+06	3.31E+06	4.93E+06	3.09E+07	4.03E+07	4.20E+07
0.3	6.86E+04	1.98E+06	1.16E+06	2.54E+06	3.48E+06	2.17E+07	2.84E+07	2.98E+07
0.4	5.06E+04	1.58E+06	9.16E+05	2.12E+06	2.70E+06	1.71E+07	2.23E+07	2.35E+07
0.5	3.89E+04	1.33E+06	7.59E+05	1.83E+06	2.20E+06	1.41E+07	1.84E+07	1.95E+07
0.6	3.08E+04	1.14E+06	6.45E+05	1.61E+06	1.84E+06	1.20E+07	1.56E+07	1.66E+07
0.8	2.20E+04	8.56E+05	4.77E+05	1.28E+06	1.32E+06	8.82E+06	1.15E+07	1.23E+07
1	1.81E+04	6.56E+05	3.62E+05	1.03E+06	9.78E+05	6.67E+06	8.69E+06	9.35E+06
1.5	1.30E+04	3.89E+05	2.10E+05	6.80E+05	5.41E+05	3.86E+06	5.01E+06	5.48E+06
2	9.88E+03	2.67E+05	1.42E+05	5.07E+05	3.53E+05	2.60E+06	3.37E+06	3.73E+06
2.5	7.91E+03	1.97E+05	1.03E+05	3.99E+05	2.48E+05	1.88E+06	2.43E+06	2.73E+06
3	6.47E+03	1.50E+05	7.66E+04	3.22E+05	1.82E+05	1.41E+06	1.83E+06	2.07E+06
4	4.49E+03	9.37E+04	4.54E+04	2.20E+05	1.05E+05	8.54E+05	1.10E+06	1.28E+06
5	3.38E+03	6.25E+04	2.88E+04	1.58E+05	6.56E+04	5.55E+05	7.15E+05	8.45E+05
6	2.84E+03	4.40E+04	1.94E+04	1.19E+05	4.36E+04	3.82E+05	4.92E+05	5.92E+05
7	2.48E+03	3.25E+04	1.37E+04	9.25E+04	3.06E+04	2.77E+05	3.56E+05	4.35E+05
8	2.19E+03	2.50E+04	1.02E+04	7.43E+04	2.24E+04	2.08E+05	2.68E+05	3.32E+05
9	1.98E+03	1.97E+04	7.76E+03	6.12E+04	1.70E+04	1.62E+05	2.08E+05	2.62E+05
10	1.78E+03	1.60E+04	6.10E+03	5.14E+04	1.33E+04	1.29E+05	1.66E+05	2.12E+05
12	1.49E+03	1.11E+04	4.01E+03	3.80E+04	8.61E+03	8.69E+04	1.12E+05	1.46E+05
14	1.26E+03	8.10E+03	2.80E+03	2.93E+04	5.95E+03	6.20E+04	8.01E+04	1.07E+05
16	1.09E+03	6.14E+03	2.04E+03	2.32E+04	4.30E+03	4.60E+04	5.96E+04	8.08E+04
18	9.67E+02	4.81E+03	1.54E+03	1.89E+04	3.22E+03	3.53E+04	4.58E+04	6.33E+04
20	8.48E+02	3.80E+03	1.18E+03	1.55E+04	2.45E+03	2.74E+04	3.57E+04	5.00E+04

Table 5: Dose as in rad as a function of equivalent Al shielding assuming solid sphere per mission phase and total for two options (last columns).

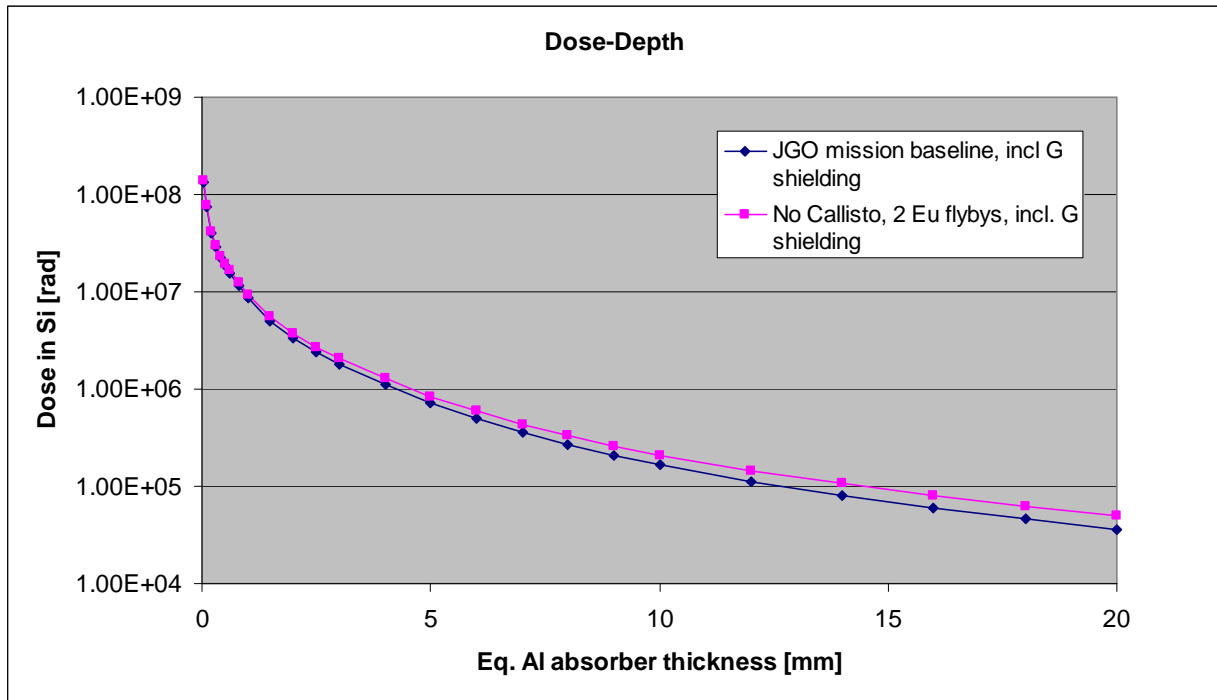


Figure 1: Dose-depth curve for two mission scenarios (see inset)

Energy MeV	Flux $\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ in 24 h	Flux $\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ in 20 min
0.02	1.33e+7	1.86e+7
0.03	1.21e+7	1.70e+7
0.05	1.01e+7	1.32e+7
0.07	8.66e+6	1.06e+7
0.1	7.22e+6	8.27e+6
0.2	4.62e+6	4.80e+6
0.3	3.59e+6	3.30e+6
0.5	2.54e+6	2.22e+6
0.7	1.78e+6	1.39e+6
1	1.20e+6	8.15e+5
2	5.66e+5	2.88e+5
3	2.87e+5	1.23e+5
5	1.23e+5	4.24e+4
7	7.09e+4	2.10e+4
10	3.96e+4	9.97e+3
20	8.10e+3	1.60e+3
30	3.08e+3	5.29e+2
50	9.18e+2	1.31e+2
70	4.14e+2	5.24e+1
100	1.78e+2	1.98e+1
200	3.49e+1	2.99e+0
300	1.35e+1	9.89e-1
500	4.07e+0	2.45e-1
700	1.85e+0	9.80e-2
1000	8.05e-1	3.70e-2

Table 6: Worst case integral electron flux spectra in $\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ for worst averaged over 24 h and 20 min.

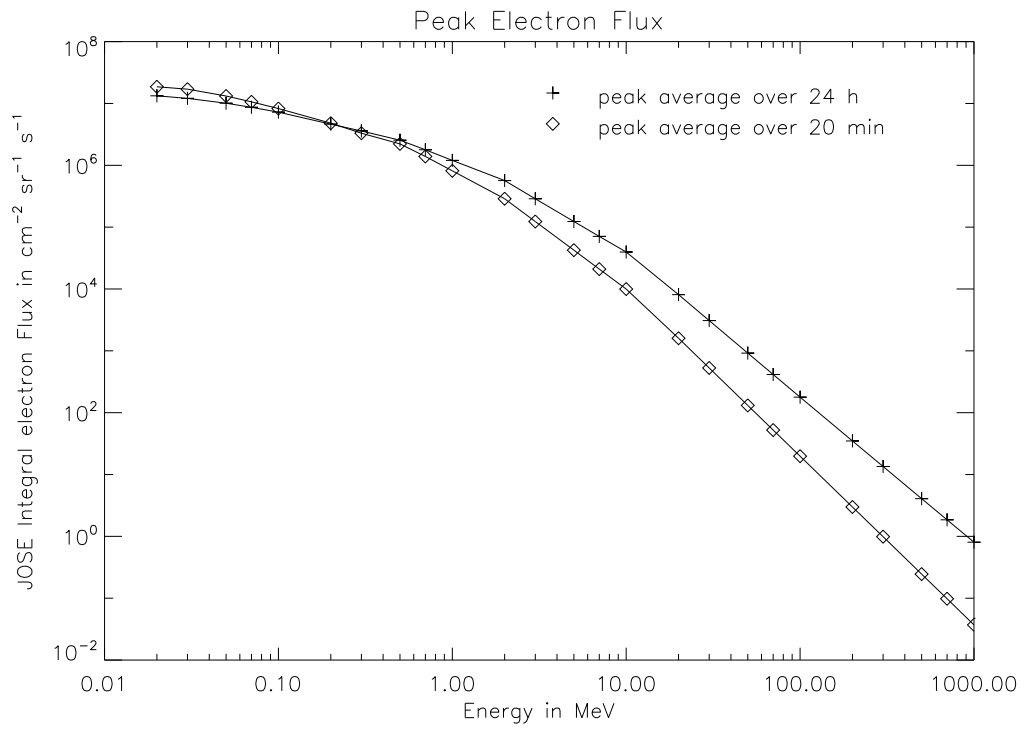


Figure 2: Worst case integral electron flux spectra in $\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ for worst averaged over 24 h and 20 min.