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ASTEROID IMPACT MISSION: DIDYMOS REFERENCE MODEL

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Table of contents:

1. INTRODUCTION

1.1. Scope

This document shall serve as the reference model of the asteroid 65803 Didymos 1996 GT and the radiation environment encountered by the AIM spacecraft. It shall be used by the Contractor throughout the AIM phase-A/B1 study tasks.

Any missing or conflicting information deemed necessary for the AIM spacecraft design shall be reported to the Agency, which will maintain this model and make available updates as necessary in the context of the AIM Phase A/B1 work.

2. REFERENCES

[1] Minor Planet Center: PDS, radar (Lance Benner) and lightcurve (Petr Pravec) observations.

[4] Pravec, P., et al., 2006, Photometric survey of binary near-Earth asteroids, Icarus, 181:63-93.

[5] Fang, J., and J.-L. Margot, 2012, Near-Earth binaries and triples: Origin and evolution of spin-orbital properties, Astron. J., 143:24.

[6] Scheirich, P., and P. Pravec, 2009, Modeling of lightcurves of binary asteroids, Icarus, 200:531-547.

[7] JPL Small-Body Database Browser: http://ssd.jpl.nasa.gov/sbdb.cgi

[8] Asteroid Lightcurve DataBase, rev. 2014-Mar-01

[9] AIM Advisory Team Final Report: ttps://www.oca.eu/michel/AIMReport_Final.pdf

[10] [RD 1] ECSS-E-ST-10-04C, “System Engineering: Space Environment Standard”, November 2008.

[11] “Probability Model for Cumulative Solar Proton Event Fluences”, Xapsos, M. A., G.P. Summers, J.L. Barth, E. G. Stassinopoulos and E.A. Burke, IEEE Trans. Nucl. Sci., vol. 47, no. 3, June 2000, pp 486-490.

[12] [RD 3] Seltzer S., “SHIELDOSE: A Computer Code For Space Shielding Radiation Dose Calculations,” NBS Technical Note 1116, National Bureau of Standards, May 1980 .

[13] https://www.spenvis.oma.be/

[14] I. Jun et al. "Proton Nonionizing Energy Loss (NIEL) for Device Applications," IEEE Trans. Nucl. Sci. Vol 50, No 6, Dec 2003.

[15] A.J. Tylka et al. "CREME96: A Revision of the Cosmic Ray Effects on Micro-Electronics Code", IEEE Trans. Nucl. Sci. NS-44, 2150-2160 (1997).

3. TERMINOLOGY & ACRONYMS

+/-	Refers to the uncertainty of the reported value without giving the nature of the uncertainty.
[#]	Reference, as detailed in section 2.
P	period
a	semi-major axis
e	eccentricity
ρ	mass density
MPC	Minor Planet Center

4. MAIN DYNAMICAL AND OBSERVATIONAL VALUES

Parameter	Value	Reference / comments
Official minor planet number of primary	65803	[1]
Official name of primary	Didymos	[1]
Provisional designation of primary	1996 GT	[1]
Dynamical type	Apollo	[1]
Method of discovery of companion	photometric lightcurve	[1]
Last update in MPC database	2013	[1]
Diameter of Primary	0.8 km	
Diameter of Secondary	0.17 km	[see D2/D1 below]
Bulk density of the secondary (assumed)[1]	2 g/cc	
Distance between the centre of primary and secondary	1.1 km	
Total mass of system	5.27e11 kg	[5]
Geometric Albedo	0.147	
Rotation period of the primary	2.2593 h	[8]
Radar albedo	0.24 +/-25%	
Heliocentric eccentricity (e)	e = 0.383752494 +/- 9e-9	[7]
Heliocentric semimajor	1.64443277 +/- 1e-8 AU[2]	[7]

[1] The bulk density of the secondary is not known. However, based on the estimated mass density of the system as well as the bulk density known for S-type objects (about 2 to 2.7 g/cc), we assume a value of 2 g/cc for the secondary. In effect, even if the secondary may be a rubble pile, it should be relatively compact because indications are that it is tidally locked along its major axis -- this implies internal dissipation that may have helped drive the system to a lower energy state commensurate with compaction. If true, then the minimum density of the secondary should be close (but no necessarily identical) to the primary density, hence the assumed value of 2 g/cc. This results in an escape speed of the secondary about 7.7 cm/s.

axis (a)		
Heliocentric inclination to the ecliptic (i)	3.407650° +/- 2e-6°	[7]
Absolute magnitude of the primary (H)	18.0	[7]

5. BINARY ORBIT SOLUTIONS

The values in the table below show that there are two possible solutions for the binary orbit with two pole orientations that are both compatible with existing observations. Which one of the two is the real one is not known at the time of writing. Observations in April 2015 should allow the pole orientation to be better constrained. Figure 1 shows the two possible values.

Synchronous rotation of secondary is compatible with existing observations. This would imply the secondary rotational period P_s is the same as the secondary orbital period P.

Binary Orbit Solution 1		
Pole solution 1 (3σ)	λ=157° +4°/-7°, β=19° +45°/-15°	[6] (ecliptic coordinates)
Diameter ratio D2/D1	0.22 +/- 0.01	[6] (ecliptic coordinates)
Secondary orbital period (P)	11.906h +0.004/-0.1	[6] (ecliptic coordinates)
Secondary eccentricity (e)	0.09 +0.07/-0.09	[6] (ecliptic coordinates)
Mass density (ρ)	1.7 +0.6/-0.4 g/cc	[6] (ecliptic coordinates)

Binary Orbit Solution 2		
Pole solution 2 (3σ)	λ=329 +11°/-194°, β=-70 °+25°/-15°	[6] (ecliptic coordinates)
Diameter ratio D2/D1	0.21 +/- 0.01	[6] (ecliptic coordinates)
Secondary orbital period (P)	11.920h +0.004/-0.006	[6] (ecliptic coordinates)
Secondary eccentricity (e)	0.02 +0.01/-0.02	[6] (ecliptic coordinates)
Mass density (ρ)	2.1 +0.8/-0.5 g/cc	[6] (ecliptic coordinates)

[2] The uncertainties of the orbital parameters will be translated in a next phase into the ¨uncertainty region at AIM arrival to Didymos vicinity; e.g. the approximate maximum linear dimension of the ¨uncertainty region¨ (i.e. the longest semi axis if it is an ellipsoid) will be estimated.

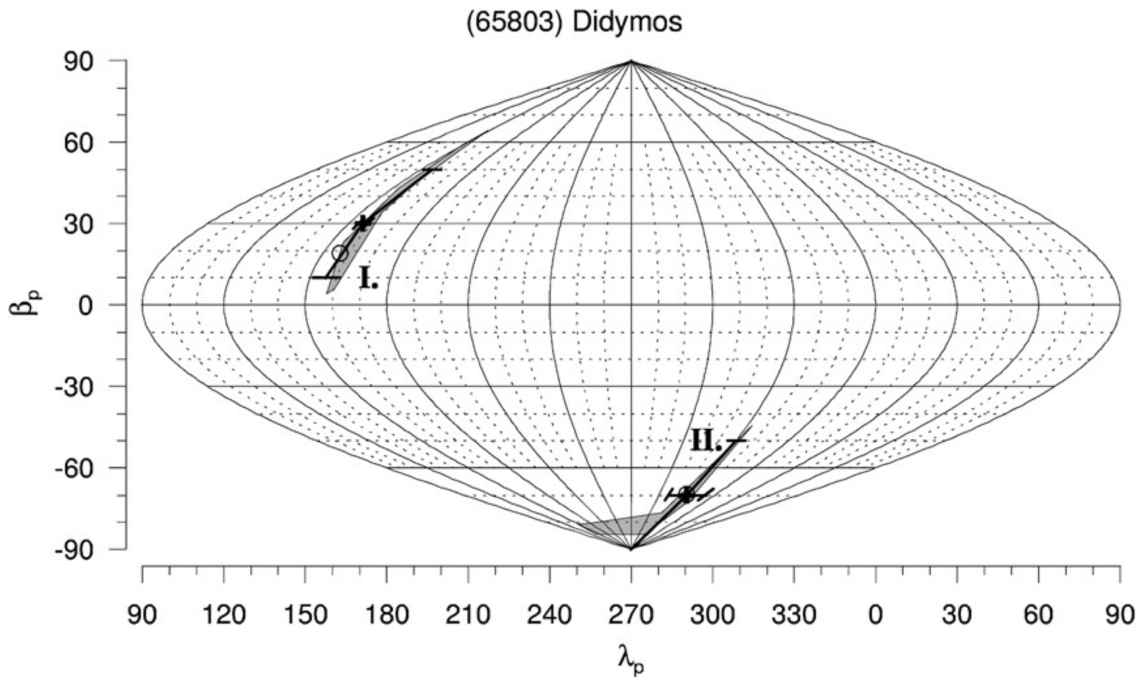

Table 5-1 Range of plausible poles of the mutual orbit of (65803) Didymos in ecliptic coordinates

6. RADAR SHAPE MODEL

A preliminary shape model on the Didymos primary based on the past radar observations is shown below in figure 2. Radar data cannot provide a model of the secondary: the SNR is too weak, echoes are not sufficiently resolved, and the rotation coverage is limited.

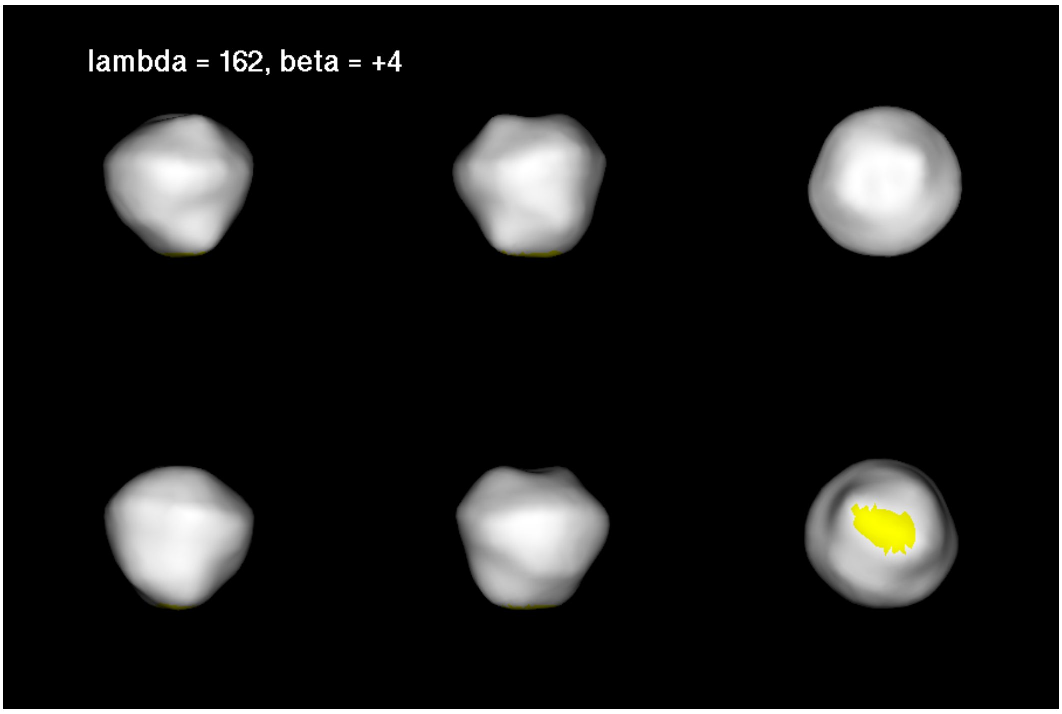

Table 6-1 Preliminary shape model of the primary (principal axis view). The secondary (not imaged) estimated to be more elongated from other data (courtesy of Lance Benner).

7. THEORETICAL THERMAL MODEL

The thermal properties of the surface (e.g. thermal inertia) will not be known in advance. Figure 3 shows a preliminary temperature distribution at the surface of the asteroid Didymos (primary) calculated at 1.664 AU from the Sun for a thermal inertia of $100 m^{-2} s^{-0.5} K^{-1}$, bolometric Bond albedo of 0.1, emissivity of 0.9 and assuming that the asteroid spins perpendicular to the direction toward the Sun, (which is not necessarily the case).

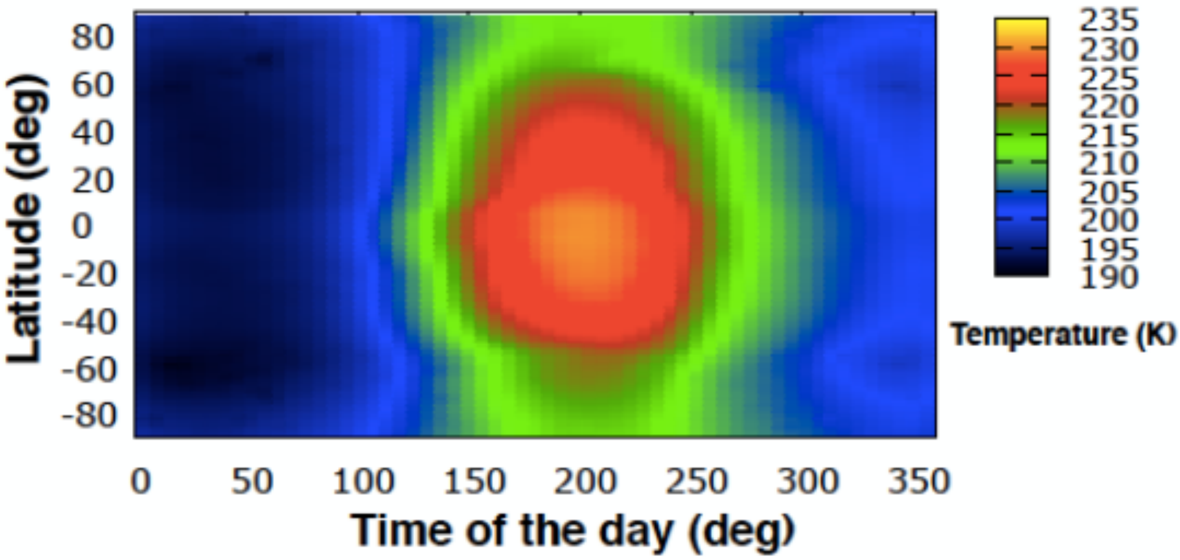

Table 7-1 Preliminary temperature distribution at the surface of the asteroid Didymos calculated at 1.664 AU from the Sun.

Local midnight corresponds to 0 degrees. The hottest spot is not at 180 degrees (noon), but is slightly shifted because of the thermal inertia.

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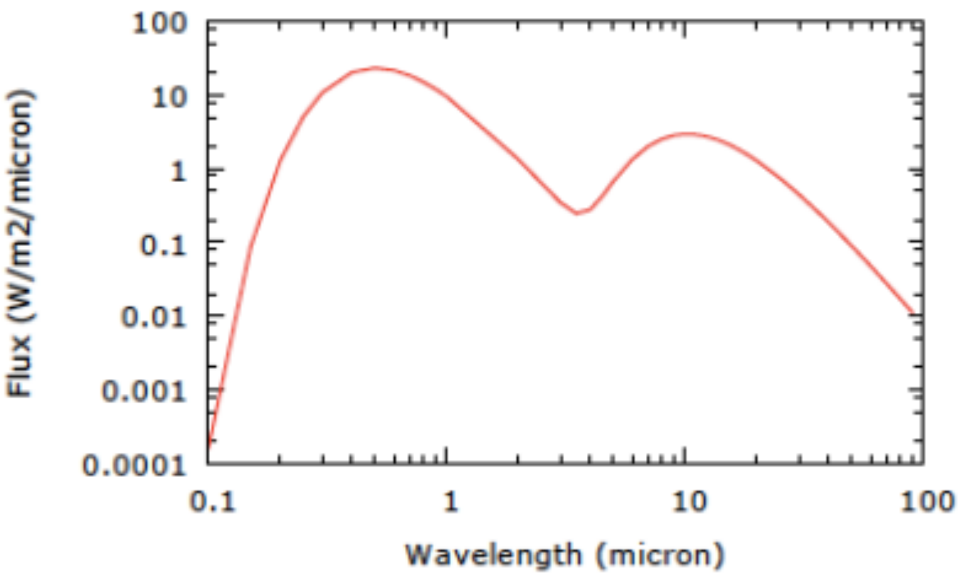

Table 7-2 Spectral energy distribution (SED) at the distance of 1 km of the asteroid.

The total power from the asteroid and thus heating the spacecraft is given by the integral of the SED, shown in figure 4. This gives a flux of about 66 W/m^2.

8. RADIATION ENVIRONMENT

8.1. The underlying environment model

This section contains a preliminary specification for the environment to be encountered by the planned Asteroid Impact Mission (AIM). See Appendix A for a list of all applicable assumptions to the analysis.

Based on the present ECSS standard the solar energetic particle model applied is the PSYCHIC model [10] which is run with a confidence of 95% due to uncertainties in the present mission parameters. Figure 8-1 and Table 0-1 in Appendix B provide the solar proton fluence spectra for the different mission phases.

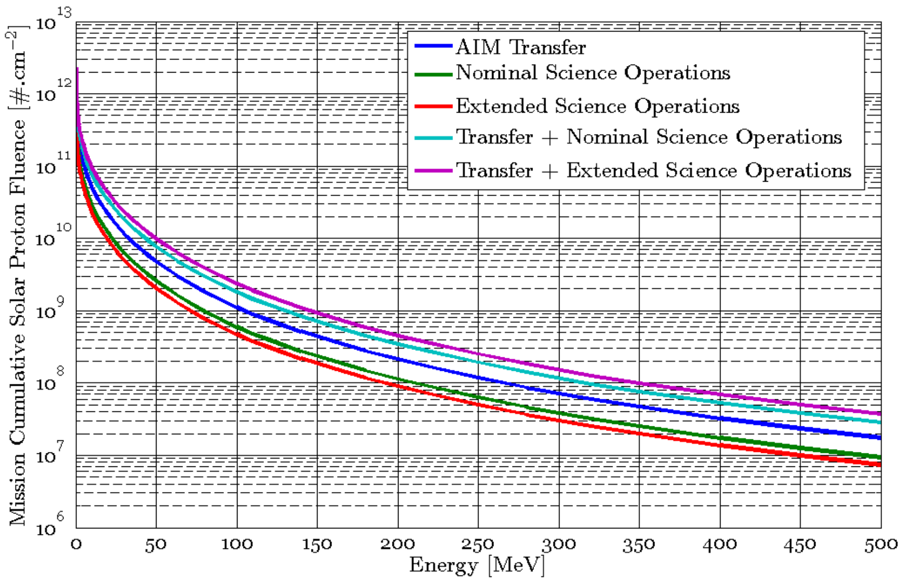

Figure 8-1 Solar proton spectrum as a function of integral energies for the various mission phases for AIM based on a 2020 launch.

8.2. Total Ionizing Dose

The total ionizing dose (TID) environment is represented by the dose-depth curve. This may provide dose as a function of shield thickness in planar geometry or as a function of spherical shielding about a point. The planar model is appropriate for surface materials or for locations near to a planar surface. In general, electronic components are not in such locations and a spherical model is recommended for general specification.

The SHIELDOSE model shall be used [12] for ionizing dose. This method uses a pre-computed data set of doses from electrons, electron-induced Bremsstrahlung and protons, as derived from Monte-Carlo analysis. The doses are provided as functions of material shielding thickness. The reference geometrical configuration for this dose-depth curve shall be a solid aluminium sphere. The TID calculations are shown in Figure 8-2 and Table 0-2 in Appendix B.

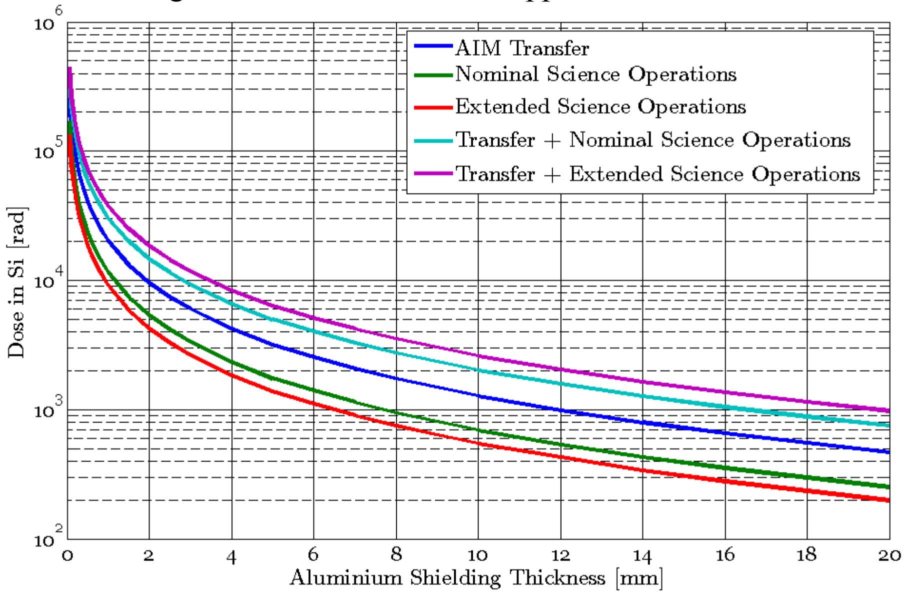

Figure 8-2 Total ionizing dose in silicon as a function of spherical shielding thickness for the various mission phases for AIM based on a 2020 launch.

8.3. Non-ionizing dose

The non-ionising dose (NID) is calculated by folding the shielded fluence as a function of energy with the non-ionizing energy loss (NIEL) damage curve (NIEL as a function of energy). In order to obtain damage equivalent fluences at a single energy for the testing of components the NIEL damage curve is normalised to the given energy and then the shielded fluences can be reduced to a single value for each shielding thickness. The NIEL damage curve used for this analysis is that labelled 'Messenger Si' on the Spenvis system [13] following result published by Jun et al. [14] and is shown in Figure 8-3 along with the normalisation to 10 MeV. The equivalent fluence for 10 MeV protons is provided to compare with NID dose limits is given in Figure 8-4 and Table 0-3 (Appendix B). The NIEL data are given in Figure 8-5 and Table 0-4 (Appendix B).

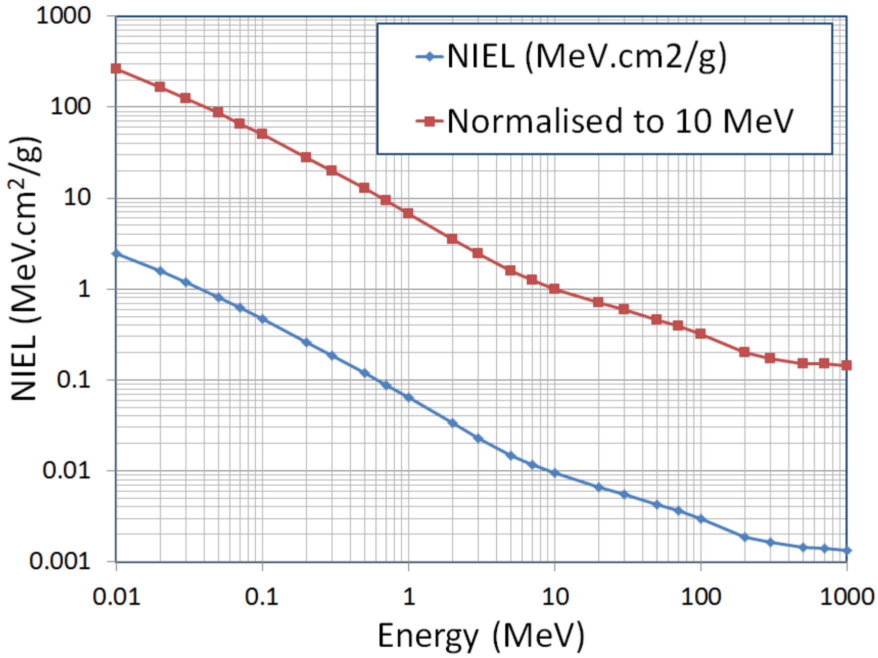

Figure 8-3 NIEL damage curve in silicon and normalisation to 10 MeV protons (from [RD 5]).

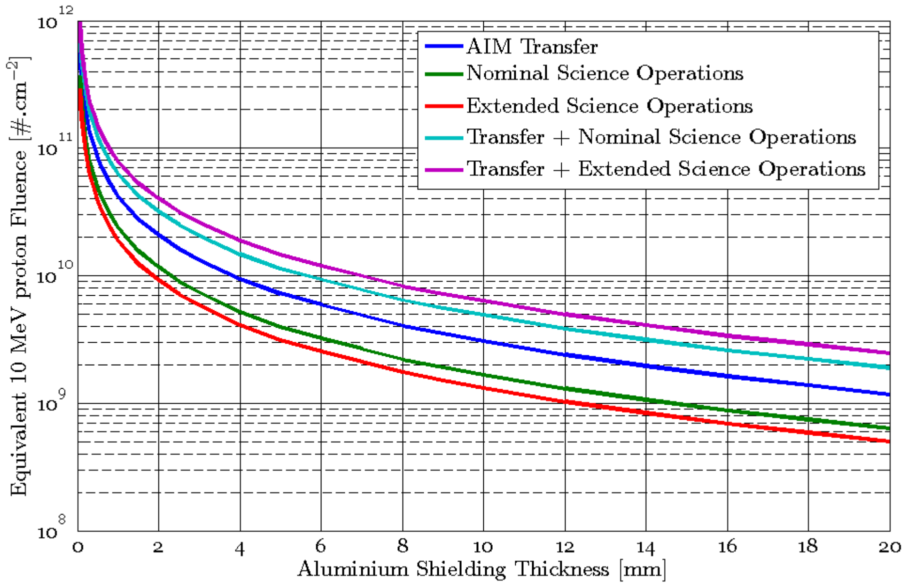

Figure 8-4 Non-ionising energy loss equivalent 10 MeV proton fluence as a function of shielding thickness for the various phases of the mission based on 2020 launch of AIM.

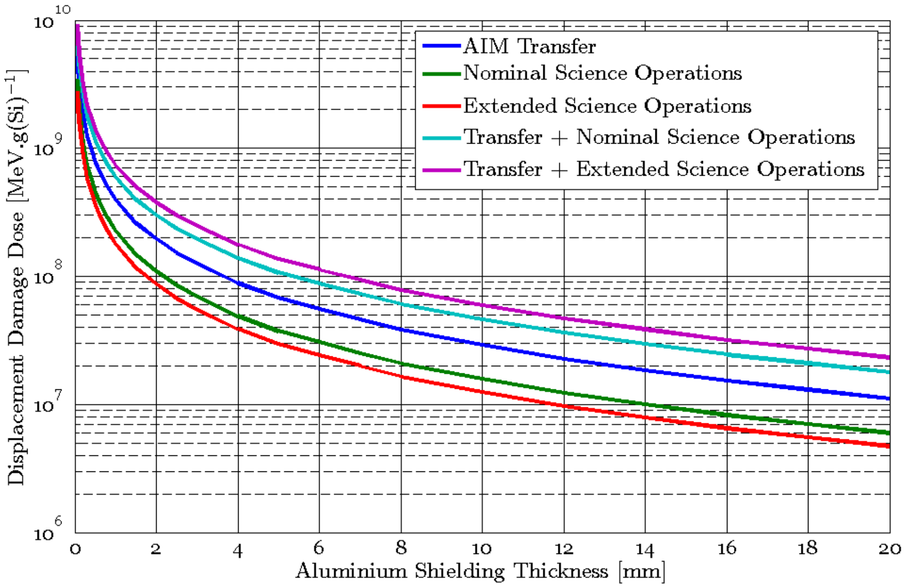

Figure 8-5 Non-Ionising Energy Loss as a function of shielding thickness for the various phases of the mission based on 2020 launch of AIM.

8.4. Single Event Effects Environment

Single Event Effects (SEEs) are a function of the density of energy deposition by ionizing radiation as this is governs the probability of such events. This energy deposition is characterised by the particle linear energy transfer (LET) which gives the amount of dose being deposited per unit shielding thickness. The CREME96 [15] spectra for GCR background, worst week and worst 5-minutes covering protons and heavy ions are given in Table 0-5 in Appendix B and shown in Figure 8-6. In order to derive the upset rate for an electronic device the geometry and critical charge to cause upsets are needed. The precursor analysis herein is performed assuming a nominal shielding thickness of 1 $g.cm^{-2}$.

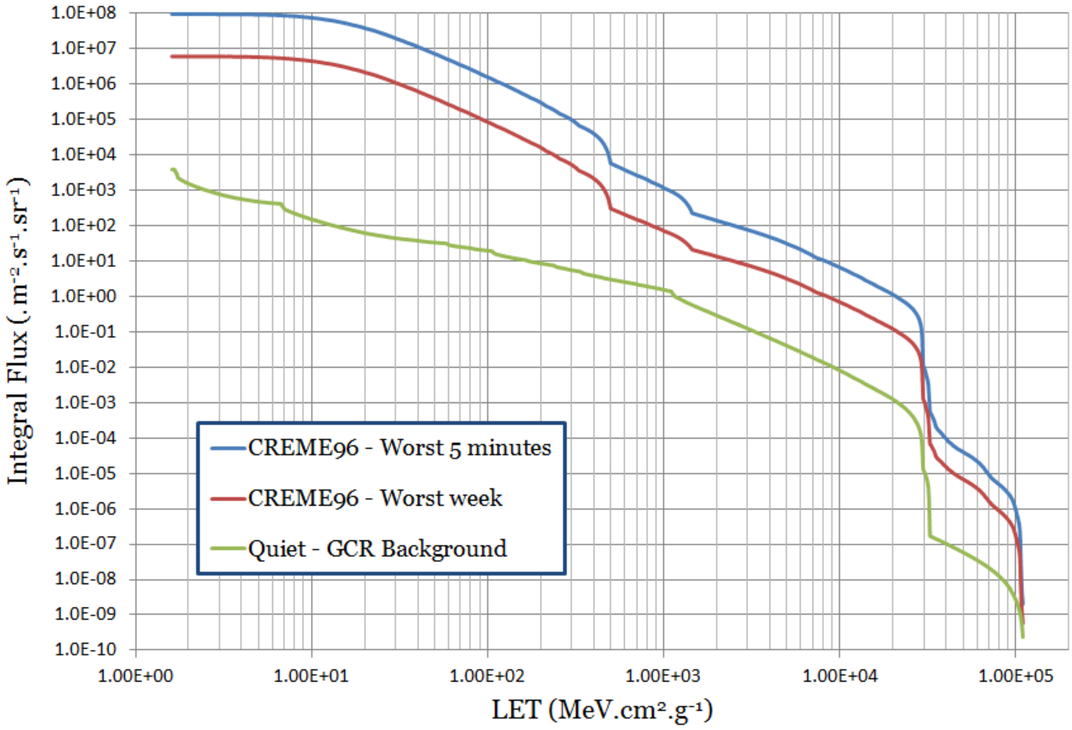

Figure 8-6 LET spectra for CREME96 worst 5 minutes, worst week and quiet (GCR-only) as a function of LET for calcualtion of SEE/SEU rates.

9. ADDITIONAL NOTES

- Regarding its spectral properties, Didymos is now classified as an S-type (DeLeon et al. 2010), even if it was originally classified as an Xk-type (Binzel et al. 2004) due to limited wavelength coverage.
- The radar albedo is consistent with silicates and inconsistent with pure metal.

APPENDIX A

The following assumptions have been made in the radiation analysis:

- Due to a lack of certainty on the mission parameters (namely the duration of the different mission segments) a conservative confidence level of 95% has been selected.
- Due to a lack of information about the type of solar cells to be used solar cell degradation analyses are not included.
- In the absence of the mission ephemeris it is assumed that this interplanetary mission spends very little time travelling through the Earth's radiation belts and it is therefore inherently assumed that their contribution to dose is negligible when compared to solar energetic particle fluxes.
- The local environment of the asteroid may have a significant dust/plasma effects.
- The longest mission period considered is 3 years, as such all dose analyses are done based on an assumption of the complete mission at solar maximum that being the most conservative approach.
- It is assumed that the spacecraft will spend no time closer to the Sun than 1 AU, as such, in accordance with the present ECSS standard [10], the 1 AU solar energetic particle fluxes are unscaled.

	Start Date [yyyy-mm-dd]	End Date [yyyy-mm-dd]	Duration [days]	Confidence Level [%]
Transfer (Cruise)	2020-10-17	2022-04-17	547	95
Science Operations (Nominal)	2022-04-17	2023-02-17	306	95
Science Operations (Extended)	2023-02-17	2023-10-17	242	95
Total Mission (Nominal)	2020-10-17	2023-02-17	853	95
Total Mission (Extended)	2020-10-17	2023-10-17	1095	95

Table 9-1 Mission parameters for each phase used in this analysis.

APPENDIX B

The following tables provide the corresponding numerical values to the tables given in chapter 8.

Proton Energy [MeV]	AIM - Integrated Solar Proton Fluence [#/cm2]				
	Transfer	Operation (nominal)	Operation (extended)	Mission Total (nominal)	Mission Total (extended)
1.00E-01	1.48E+12	9.87E+11	7.81E+11	1.95E+12	2.31E+12
2.00E-01	9.40E+11	6.14E+11	4.86E+11	1.26E+12	1.50E+12
5.00E-01	5.17E+11	3.28E+11	2.59E+11	7.06E+11	8.46E+11
1.00E+00	3.29E+11	2.04E+11	1.61E+11	4.56E+11	5.48E+11
2.00E+00	2.09E+11	1.27E+11	1.00E+11	2.94E+11	3.56E+11
2.80E+00	1.68E+11	1.01E+11	7.96E+10	2.38E+11	2.88E+11
4.00E+00	1.26E+11	7.46E+10	5.90E+10	1.82E+11	2.21E+11
5.00E+00	1.05E+11	6.13E+10	4.85E+10	1.53E+11	1.87E+11
6.30E+00	8.40E+10	4.86E+10	3.85E+10	1.24E+11	1.52E+11
8.00E+00	6.58E+10	3.77E+10	2.98E+10	9.81E+10	1.22E+11
1.00E+01	5.18E+10	2.94E+10	2.33E+10	7.81E+10	9.75E+10
1.20E+01	4.16E+10	2.34E+10	1.85E+10	6.32E+10	7.93E+10
1.60E+01	2.91E+10	1.62E+10	1.28E+10	4.48E+10	5.66E+10
2.00E+01	2.15E+10	1.19E+10	9.40E+09	3.34E+10	4.25E+10
2.50E+01	1.55E+10	8.51E+09	6.73E+09	2.43E+10	3.11E+10
2.80E+01	1.30E+10	7.10E+09	5.62E+09	2.04E+10	2.62E+10
3.50E+01	9.02E+09	4.91E+09	3.88E+09	1.43E+10	1.84E+10
4.00E+01	7.17E+09	3.89E+09	3.08E+09	1.14E+10	1.48E+10
5.00E+01	4.77E+09	2.58E+09	2.04E+09	7.65E+09	9.92E+09
6.30E+01	3.03E+09	1.63E+09	1.29E+09	4.88E+09	6.35E+09
8.00E+01	1.84E+09	9.85E+08	7.79E+08	2.98E+09	3.88E+09
1.00E+02	1.11E+09	5.94E+08	4.70E+08	1.81E+09	2.36E+09
1.20E+02	7.35E+08	3.93E+08	3.11E+08	1.19E+09	1.56E+09
1.40E+02	5.11E+08	2.73E+08	2.16E+08	8.31E+08	1.09E+09
1.60E+02	3.70E+08	1.98E+08	1.56E+08	6.01E+08	7.86E+08
2.00E+02	2.12E+08	1.14E+08	8.98E+07	3.45E+08	4.51E+08
2.50E+02	1.19E+08	6.36E+07	5.03E+07	1.93E+08	2.53E+08
3.20E+02	6.02E+07	3.22E+07	2.54E+07	9.78E+07	1.28E+08
4.00E+02	3.25E+07	1.74E+07	1.37E+07	5.28E+07	6.90E+07
5.00E+02	1.75E+07	9.36E+06	7.40E+06	2.85E+07	3.72E+07

Table 0-1 Solar proton spectrum for selected integral energies for AIM based on a 2020 launch.

Aluminium shielding thickness [mm]	Total ionising radiation dose in Si [rad]				
	Transfer	Operation (nominal)	Operation (extended)	Mission Total (nominal)	Mission Total (extended)
5.00E-02	2.73E+05	1.70E+05	1.34E+05	3.75E+05	4.47E+05
1.00E-01	1.62E+05	9.94E+04	7.86E+04	2.25E+05	2.70E+05
2.00E-01	9.33E+04	5.59E+04	4.42E+04	1.32E+05	1.59E+05
3.00E-01	6.56E+04	3.88E+04	3.07E+04	9.42E+04	1.14E+05
4.00E-01	5.00E+04	2.93E+04	2.31E+04	7.25E+04	8.84E+04
5.00E-01	4.04E+04	2.35E+04	1.86E+04	5.90E+04	7.23E+04
6.00E-01	3.41E+04	1.97E+04	1.56E+04	5.02E+04	6.18E+04
8.00E-01	2.55E+04	1.46E+04	1.16E+04	3.79E+04	4.69E+04
1.00E+00	2.02E+04	1.15E+04	9.11E+03	3.02E+04	3.75E+04
1.50E+00	1.32E+04	7.46E+03	5.90E+03	2.01E+04	2.51E+04
2.00E+00	9.56E+03	5.35E+03	4.23E+03	1.46E+04	1.84E+04
2.50E+00	7.42E+03	4.14E+03	3.27E+03	1.14E+04	1.45E+04
3.00E+00	6.00E+03	3.33E+03	2.64E+03	9.29E+03	1.18E+04
4.00E+00	4.22E+03	2.33E+03	1.84E+03	6.58E+03	8.38E+03
5.00E+00	3.16E+03	1.74E+03	1.37E+03	4.95E+03	6.33E+03
6.00E+00	2.54E+03	1.39E+03	1.10E+03	3.99E+03	5.12E+03
7.00E+00	2.07E+03	1.13E+03	8.95E+02	3.27E+03	4.20E+03
8.00E+00	1.73E+03	9.44E+02	7.47E+02	2.74E+03	3.53E+03
9.00E+00	1.49E+03	8.09E+02	6.40E+02	2.36E+03	3.04E+03
1.00E+01	1.28E+03	6.94E+02	5.49E+02	2.03E+03	2.62E+03
1.20E+01	9.95E+02	5.40E+02	4.27E+02	1.59E+03	2.05E+03
1.40E+01	7.92E+02	4.29E+02	3.39E+02	1.27E+03	1.64E+03
1.60E+01	6.52E+02	3.52E+02	2.79E+02	1.04E+03	1.35E+03
1.80E+01	5.50E+02	2.97E+02	2.35E+02	8.84E+02	1.15E+03
2.00E+01	4.65E+02	2.51E+02	1.98E+02	7.48E+02	9.72E+02

Table 0-2 TID in silicon for selected spherical shielding thicknesses for AIM based on a 2020 launch.

Aluminium shielding thickness [mm]	Non ionising energy loss equivalent 10 MeV proton fluence [#/cm2]				
	Transfer	Operation (nominal)	Operation (extended)	Mission Total (nominal)	Mission Total (extended)
5.00E-02	5.93E+11	3.69E+11	2.92E+11	8.16E+11	9.77E+11
1.00E-01	3.56E+11	2.19E+11	1.73E+11	4.92E+11	5.87E+11
2.00E-01	1.92E+11	1.15E+11	9.12E+10	2.72E+11	3.28E+11
3.00E-01	1.32E+11	7.80E+10	6.17E+10	1.89E+11	2.30E+11
4.00E-01	1.03E+11	6.01E+10	4.76E+10	1.49E+11	1.82E+11

5.00E-01	8.23E+10	4.79E+10	3.79E+10	1.20E+11	1.48E+11
6.00E-01	6.99E+10	4.04E+10	3.20E+10	1.03E+11	1.27E+11
8.00E-01	5.26E+10	3.01E+10	2.38E+10	7.83E+10	9.69E+10
1.00E+00	4.17E+10	2.37E+10	1.88E+10	6.25E+10	7.77E+10
1.50E+00	2.76E+10	1.56E+10	1.23E+10	4.20E+10	5.27E+10
2.00E+00	2.08E+10	1.16E+10	9.19E+09	3.18E+10	4.01E+10
2.50E+00	1.62E+10	8.99E+09	7.11E+09	2.49E+10	3.16E+10
3.00E+00	1.33E+10	7.36E+09	5.82E+09	2.06E+10	2.61E+10
4.00E+00	9.40E+09	5.18E+09	4.10E+09	1.47E+10	1.87E+10
5.00E+00	7.21E+09	3.96E+09	3.13E+09	1.13E+10	1.45E+10
6.00E+00	5.88E+09	3.22E+09	2.54E+09	9.27E+09	1.19E+10
7.00E+00	4.87E+09	2.66E+09	2.10E+09	7.71E+09	9.92E+09
8.00E+00	4.05E+09	2.21E+09	1.75E+09	6.43E+09	8.29E+09
9.00E+00	3.53E+09	1.92E+09	1.52E+09	5.61E+09	7.24E+09
1.00E+01	3.08E+09	1.67E+09	1.32E+09	4.91E+09	6.34E+09
1.20E+01	2.40E+09	1.30E+09	1.03E+09	3.84E+09	4.96E+09
1.40E+01	1.96E+09	1.06E+09	8.38E+08	3.14E+09	4.07E+09
1.60E+01	1.62E+09	8.72E+08	6.90E+08	2.59E+09	3.37E+09
1.80E+01	1.38E+09	7.42E+08	5.87E+08	2.21E+09	2.88E+09
2.00E+01	1.17E+09	6.30E+08	4.98E+08	1.88E+09	2.45E+09

Table 0-3 10 MeV equivalent proton fluence for selected shielding thickness for a 2020 launch of AIM.

Aluminium shielding thickness [mm]	**Non ionising energy loss (NIEL) [MeV/g(Si)]**				
	Transfer	Operation (nominal)	Operation (extended)	Mission Total (nominal)	Mission Total (extended)
5.00E-02	5.59E+09	3.48E+09	2.76E+09	7.70E+09	9.21E+09
1.00E-01	3.35E+09	2.06E+09	1.63E+09	4.64E+09	5.53E+09
2.00E-01	1.81E+09	1.09E+09	8.60E+08	2.57E+09	3.09E+09
3.00E-01	1.24E+09	7.36E+08	5.82E+08	1.79E+09	2.17E+09
4.00E-01	9.68E+08	5.67E+08	4.48E+08	1.40E+09	1.71E+09
5.00E-01	7.77E+08	4.52E+08	3.57E+08	1.14E+09	1.39E+09
6.00E-01	6.59E+08	3.81E+08	3.02E+08	9.71E+08	1.20E+09
8.00E-01	4.96E+08	2.84E+08	2.25E+08	7.38E+08	9.14E+08
1.00E+00	3.93E+08	2.24E+08	1.77E+08	5.89E+08	7.33E+08
1.50E+00	2.61E+08	1.47E+08	1.16E+08	3.96E+08	4.97E+08
2.00E+00	1.96E+08	1.10E+08	8.67E+07	3.00E+08	3.78E+08
2.50E+00	1.52E+08	8.48E+07	6.71E+07	2.35E+08	2.98E+08
3.00E+00	1.25E+08	6.94E+07	5.49E+07	1.94E+08	2.46E+08
4.00E+00	8.86E+07	4.88E+07	3.86E+07	1.39E+08	1.77E+08

5.00E+00	6.79E+07	3.73E+07	2.95E+07	1.07E+08	1.37E+08
6.00E+00	5.54E+07	3.03E+07	2.40E+07	8.75E+07	1.12E+08
7.00E+00	4.60E+07	2.51E+07	1.98E+07	7.27E+07	9.35E+07
8.00E+00	3.82E+07	2.08E+07	1.65E+07	6.07E+07	7.82E+07
9.00E+00	3.33E+07	1.81E+07	1.43E+07	5.29E+07	6.83E+07
1.00E+01	2.91E+07	1.58E+07	1.25E+07	4.63E+07	5.98E+07
1.20E+01	2.26E+07	1.23E+07	9.69E+06	3.62E+07	4.68E+07
1.40E+01	1.85E+07	1.00E+07	7.90E+06	2.96E+07	3.84E+07
1.60E+01	1.52E+07	8.23E+06	6.50E+06	2.45E+07	3.17E+07
1.80E+01	1.30E+07	7.00E+06	5.54E+06	2.09E+07	2.71E+07
2.00E+01	1.10E+07	5.94E+06	4.70E+06	1.78E+07	2.31E+07

Table 0-4 NIEL for selected shielding thickness for AIM based on 2020 launch.

LET [MeV cm^2/g]	**Integral Flux [#/m^2/sec/sr]**		
	Quiet	Worst Week	Peak 5 Min
1.61E+00	9.46E+07	6.06E+06	3.87E+03
2.30E+00	9.46E+07	6.06E+06	1.17E+03
3.51E+00	9.40E+07	5.99E+06	6.42E+02
8.18E+00	8.25E+07	5.01E+06	2.12E+02
1.24E+01	6.54E+07	3.83E+06	1.11E+02
1.89E+01	4.19E+07	2.38E+06	6.63E+01
2.88E+01	2.14E+07	1.19E+06	4.56E+01
4.35E+01	9.63E+06	5.27E+05	3.57E+01
6.64E+01	3.94E+06	2.14E+05	2.61E+01
1.00E+02	1.57E+06	8.48E+04	1.97E+01
1.50E+02	6.17E+05	3.32E+04	1.14E+01
2.34E+02	1.95E+05	1.05E+04	7.62E+00
3.57E+02	5.62E+04	3.01E+03	4.35E+00
5.39E+02	4.84E+03	2.59E+02	2.83E+00
8.23E+02	1.88E+03	1.09E+02	1.87E+00
1.26E+03	6.16E+02	4.15E+01	8.11E-01
1.90E+03	1.51E+02	1.45E+01	3.23E-01
2.90E+03	8.05E+01	8.02E+00	1.33E-01
4.42E+03	3.99E+01	4.03E+00	5.32E-02
6.68E+03	1.62E+01	1.68E+00	2.10E-02
1.02E+04	6.30E+00	6.62E-01	7.68E-03
1.56E+04	2.19E+00	2.33E-01	2.51E-03
2.35E+04	6.74E-01	7.17E-02	6.84E-04
3.59E+04	1.72E-04	2.56E-05	1.34E-07
5.48E+04	3.07E-05	5.22E-06	4.59E-08

8.37E+04	4.04E-06	7.25E-07	1.01E-08
1.00E+05	8.65E-07	1.56E-07	2.56E-09
1.09E+05	2.03E-09	5.83E-10	2.35E-10
1.61E+00	9.46E+07	6.06E+06	3.87E+03

Table 0-5 Fluxes for the calculation of SEE/SEU rate as a function of LET.