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Total Ionizing Dose Study of an Instrument in the Jovian Environment

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Abstract

Jovian environment includes intense, energetic and highly penetrating electron and ion populations. Therefore any Jupiter space mission requests accurate radiation analysis. This work presents a first state shielding strategy for an instrument proposed for JUICE payload.

1. Introduction

All spacecraft (s/c), from their beginning as raw materials to the end of their operating lives, are exposed to a variety of potentially degrading factors originating from the space environment. Energetic particles can cause radiation damage to electronic components and materials, resulting in increased detector noise, part failures such as leakage current due to total dose effects, power glitches probably due to arcing dielectrics, Cerenkov and Florescence radiation in optical elements, oscillator frequency shifts, and other effects [1]. Therefore, while designing potential future missions to the giant planet and to its satellites, accurate estimates of the radiation dose in s/c become of significant importance. This Jupiter's magnetosphere is a unique plasma laboratory in our solar system and presents a paradigm of a gas giant system with a fast rotating plasma disk. The trapped populations in the radiation belts include energetic protons [3] and electrons [2], [10]. The necessity of an extended radiation study during the preparation phase of the future European's Space Agency Jupiter Icy Moons Explorer (JUICE) mission is emerging. JUICE was selected in May 2012, by the Science Program Committee (SPC) as the "L1" mission in the Cosmic Vision program, with a foreseen launch date in 2022. For JUICE s/c the most critical contribution is expected to come from relativistic radiation belt electrons; the JOSE model [11] predicts high electron fluxes for energies of up to several hundreds of MeV.

3. Radiation analysis

In this work, a shielding strategy study, initially applied for Ganymede's and Europa's Neutral Imaging Experiment (GENIE) [4], is presented. GENIE is an Energetic Neutral Particles (ENP) analyzer proposed for the JUICE mission payload (p/d). This instrument is studied to detect the Time of Flight (TOF) spectra and origin sites of the ENP (with energies in the range from a few 10s eV to a few keV) of the exospheres of Ganymede, Europa [6],[7],[8],[9] and Callisto, providing important information on the interaction between the surfaces of these moons and the impacting Jovian magnetospheric ions. The intense radiation environment at Jupiter is not expected to allow any direct detection of the incoming ENP. For this reason, the GENIE concept is based on an anticoincidence configuration to allow the discrimination of the signal from the background noise. The received total ionizing dose levels for critical component of GENIE electronic boards have been calculated through the FASTRAD 3.3.0.0 complete engineering software developed for 3D radiation shielding analyses [5]. Forward and reverse Monte Carlo algorithms for electrons and photons are included in FASTRAD. In the current preliminary study on the GENIE radiation analysis we apply the reverse Monte Carlo module. We also compare the results obtained with Monte Carlo calculation with ray tracing (sector analysis). In particular we use the slant method of the FASTRAD tool which was shown to be in good agreement with the Monte Carlo calculation [5]. For the Monte Carlo calculation we also report the convergence in % of the results. We simulate two locations inside the spacecraft, the first where only one side of the GENIE box is shielded by the spacecraft ("worst case"), and the second, more realistic, where the GENIE instrument is located inside the satellite with its entrance face at the satellite surface, and the collimator partially protruding out of the S/C MLI thermal envelope ("best case"). Then we run many simulations with increase Aluminum wall thickness to obtain acceptable TID values. Concerning the electronic boards of GENIE, heritage from several instruments previously developed for BepiColombo SERENA-ELENA, MARS EXPRESS/ASPERA-3 and VENUS EXPRESS/ ASPERA-4 is also applied. There are 6 electronic boards in the GENIE unit and the calculated deposited doses for each electronic board. We this study we observe that also in a "worst case" position 6 mm Al shielding could be enough to reach acceptable TID values in a first state radiation shielding strategy.

Table 1: Deposited Dose Results on 6 GENIE boards, with 6 mm Al shielding.

Electronic Board	**Mean TID (krad) "worst case" M-C Calc.**	**Mean TID (krad) "best case" M-C Calc.**	**Mean TID (krad) "worst case" Sector Analysis**	**Mean TID (krad) "best case" Sector Analysis**
Proximity board	27.9 (99.4%)	5.6 (93%)	59.9	7.2
HV1 board	68.3 (98.1%)	50 (88%)	94.9	29.2
HV2 board	30.87 (99.3%)	10.5 (86%)	59.8	4.4
Piezo Driver board	108.7 (95.5%)	72.5 (86%)	105.6	12.1
Main board	46.5 (99.0%)	7.6 (94.5)	85.5	9.2
Anti-Coincidence board	27.8 (91.4%)	4.7 (83%)	33.7	2.0

4. Summary and Conclusions

The results of this study constitute a necessary starting point in the design and development of any instrument that has to achieve significant scientific objectives in a harsh environment. The estimations presented here may be of help in developing of the JUICE p/d. The next step is to perform simulations aimed to minimize the instrument weight, with spot shields for critical components and use of shielding materials with different Z values.

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