A Review of Solar-Proton Fluence Models for ISO Specification

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Statistical models of high-energy (typically above 10MeV) solar proton fluence in a given period and solar activity are commonly used to assess the cumulative effects of space radiation on spacecraft, with respect to degradation (displacement damage) of solar cell generating power and total dose effects (ionization damage) of EEE parts of spacecraft. Several models have been proposed from statistical studies of solar flare proton events over a few solar cycles; these include models by Feynman et al. (JPL91 model), Xapsos et al. (ESP Model), and Nymmik et al. (MSU model) in the framework of ISO technical standardization (TC20/SC14/WG4; Space environment). A brief review of these three models and the merits and demerits of each are reported. New engineering needs have arisen. Current geosynchronous (GEO) commercial satellites have a longer design life (about 15 years, exceeding the 11-year solar cycle) than these 2 former models have supposed (about 7 solar active years). We evaluated the JPL 91 model using GOES-5-11 (total 14 years) and IMP-8 (total 28 years) fluence data. Over two mission years (including a solar maximum), total fluence does not steadily increase. The JPL 91 model overestimates cumulative damage for longer mission years. That is why the European Cooperation for Space Standardization; ECSS-E-10-04A, "Space engineering, Space environment," Table 31 compensates the JPL 91 model by changing the Confidence Level; 97% for one year, 95% for two to three years, and 90% for four to seven years. Also, the JPL and ESP models underestimate damage in years of low solar activity. That is, these models estimate zero solar proton fluence in the solar minimum period (about four years). However, we added solar proton fluence data (GOES and IMP) in the solar minimum period and found out these added fluences are 0.3 to 0.9 solar max. equivalent years based on GOES data or 0.6 to 1.2 solar max. equivalent years based on IMP data. While the MSU model takes solar proton fluence in solar minimum period into consideration. But the dependence of the number of solar events on Wolf number in the MSU model was one of controversy in ISO working group discussion. In conclusion, we propose a new empirical solar proton fluence model based on 22-year proton fluence measuring data set of GOES or IMP-8 to estimate cumulative solar fluence for the purpose of solar cell degradation prediction with respect to a long mission period.