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IONIZATION RADIATION ENVIRONMENTS

S.L. Huston*, Space Environments and Effects: **Trapped Proton Model**, **NASA/CR-2002-211784**, George C. Marshall Space Flight Center, Marshall Space Flight Center, AL 35812, National Aeronautics and Space Administration, Washington, DC 20546-0001, The Boeing Company, 5301 Bolsa Avenue, Huntington Beach, CA 92647, Prepared for NASA's Space Environments and Effects (SEE) Program * The Boeing Company; Technical Monitor: W. Kauffman, June 2002, pp. 28.

T. W. Armstrong and B. L. Colborn**, Evaluation of Trapped Radiation Model Uncertainties for Spacecraft Design, NASA/CR-2000-210072,** NASA, Marshall Space Flight Center, Alabama 35812, March 2000, pp52.

Keywords: Trapped radiation model uncertainties, AP8, AE8, space radiation, space ionizing radiation environments

Abstract: The standard AP8 and AE8 models for predicting trapped proton and electron environments have been compared with several sets of flight data to evaluate model uncertainties. Model comparisons are made with flux and dose measurements made on various U.S. low-Earth orbit satellites (APES, CRRES, DMSP, LDEF, NOAA) and Space Shuttle flights, on Russian satellites (Photon-8, Cosmos-1887, Cosmos-2044), and on the Russian Mir Space Station. This report gives a summary of the model-data comparisons - detailed results are given in a companion report. Results from the model comparisons with flight data show, for example, the AP8 model underpredicts the trapped proton flux at low altitudes by a factor of about two (independent of proton energy and solar cycle conditions), and that the AE8 model overpredicts the flux in the outer electron belt by an order of magnitude or more.

T. W. Armstrong and B. L. Colborn**, Trapped Radiation Model Uncertainties: Model-Data and Model-Model Comparisons, NASA/CR-2000-210071,** NASA, Marshall Space Flight Center, Alabama 35812, March 2000, pp82.

Keywords: Trapped radiation model uncertainties, AP8, AE8, space radiation, space ionizing radiation environments

Abstract: The standard AP8 and AE8 models for predicting trapped proton and electron environments have been compared with several sets of flight data to evaluate model uncertainties. Model comparisons are made with flux and dose measurements made on various U.S. low-Earth orbit satellites (APES, CRRES, DMSP, LDEF, NOAA) and Space Shuttle flights, on Russian satellites (Photon-8, Cosmos-1887, Cosmos-2044), and on the Russian Mir Space Station. This report gives the details of the model-data comparisons-summary results in terms of empirical model uncertainty factors that can be applied for spacecraft design applications are given in a combination report. The results of model-model comparisons are also presented from standard AP8 and AE8 model predictions compared with the European Space Agency versions of AP8 and AE8 and with Russian-trapped radiation models.

T. W. Armstrong and B. L. Colborn**, TRAP/SEE Code Users Manual for Predicting Trapped Radiation Environments, NASA/CR-2000-209879,** NASA, Marshall Space Flight Center, Alabama 35812, pp. 48.

Keywords: Trapped Radiation Models, Trapped Radiation Code, Space Radiation Software, Space Ionizing Radiation Environments.

Abstract: TRAP/SEE is a PC-based computer code with a user-friendly interface which predicts

the ionizing radiation exposure of spacecraft having orbits in the Earth's trapped radiation belts. The code incorporates the standard AP8 nad AE8 trapped proton and electron models but also allows application of an improved database interpolation method developed by Daly and Evans. The code treats low-Earth as well as highly-elliptical Earth orbits, taking into account trajectory perturbations due to gravitational forces from the Moon and Sun, atmospheric drag, and solar radiation pressure. Orbit-average spectra, peak spectra per orbit, and instantaneous spectra at points along the orbit trajectory are calculated. Described in this report are the features, models, model limitations and uncertainties, input and output descriptions, and example calculations and applications for the TRAP/SEE code.

E. R. Benton and E. V. Benton, **A Survey of Radiation Measurements Made Aboard Russian Spacecraft in Low-Earth Orbit**, **NASA/CR-1999-209256**, NASA Marshall Space Flight Center, AL 35812, March 1999, pp. 104.

Keywords: Radiation, Space Radiation, Radiation Environment

Abstract: The accurate prediction of ionizing radiation exposure in low-Earth orbit is necessary in order to minimize risks to astronauts, spacecraft and instrumentation. To this end, models of the radiation environment, the AP-8 trapped proton model and the AE-8 trapped electron model, have been developed for use by spacecraft designers and mission planners. It has been widely acknowledged for some time now by the space radiation community that these models possess some major shortcomings. Both models cover only a limited trapped particle energy region and predictions at low altitudes are extrapolated from higher altitude data. With the launch of the first components of the *International Space Station* with numerous constellations of low-Earth orbit communications satellites now being planned and deployed, the inadequacies of these trapped particle models need to be addressed. Efforts are now underway both in the U.S. and in Europe to refine the AP-8 and AE-8 trapped particle models. This report is an attempt to collect a significant fraction of data for use in validation of trapped radiation models at low altitudes.

M.A. Xapsos,* J.L. Barth,** E.G. Stassinopoulos,** E.A. Burke,*** and G.B. Gee****, **Space Environment Effects: Model for Emission of Solar Protons (ESP)** – Cumulative and Worst-Case Event Fluences, **NASA/TP-1999-209763**, *Naval Research Laboratory, Washington DC, **NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, ***Consultant, Woburn, Massachusetts, ****SGT, Inc., Greenbelt, Maryland, December 1999, pp. 30.

Keywords: radiation, space radiation, radiation environment, solar protons, radiation modeling

Abstract: The effects that solar proton events have on microelectronics and solar arrays are important considerations for spacecraft in geostationary and polar orbits and for interplanetary missions. Designers of spacecraft and mission planners are required to assess the performance of microelectronic systems under a variety of conditions. A number of useful approaches exist for predicting information about solar proton event fluences and, to a lesser extent, peak fluxes. This includes the cumulative fluence over the course of a mission, the fluence of a worst-case event during a mission, the frequency distribution of event fluences, and the frequency distribution of large peak fluxes. Naval Research Laboratory (NRL) and NASA Goddard Space Flight Center, under the sponsorship of NASA's Space Environments and Effects (SEE) Program, have developed a new model for predicting cumulative solar proton fluences and worst-case solar proton events as functions of mission duration and user confidence level. This model is called the Emission of Solar Protons (ESP) model.

J.W. Howard Jr.* and D.M. Hardage, **Spacecraft Environments Interactions: Space Radiation and its Effects on Electronic Systems**, **NASA/TP-1999-209373**, Systems Analysis and Integration Laboratory, Science and Engineering Directorate, NASA Marshall Space Flight Center, AL 35812, and *Computer Science Corporation, July 1999, pp. 32.

Keywords: radiation types, regions, environments, radiation effects categories, mitigation options, South Atlantic anomaly

Abstract: The natural space environment is characterized by complex and subtle phenomena hostile to spacecraft. Effects of these phenomena impact spacecraft design, development, and operation. Space systems become increasingly susceptible to the space environment as use of composite materials and smaller, faster electronics increases. This trend makes an understanding of space radiation and its effects on electronic systems essential to accomplish overall mission objectives, especially in the current climate of smaller/better/cheaper faster. This primer outlines the radiation environments encountered in space, discusses regions and types of radiation, applies the information to effects that these environments have on electronic systems, addresses design guidelines and system reliability, and stresses the importance of early involvement of radiation specialists in mission planning, system design, and design review (part-by-part verification).

S.L Huston and K.A. Pfitzer, **Space Environment Effects: Low-Altitude Trapped Radiation Model, NASA/CR-1998-208593**, NASA's Space Environments and Effects (SEE), NASA Marshall Space Flight Center, AL 35812, August 1998, pp. 63.

Abstract: Accurate models of the Earth's trapped energetic proton environment are required for both piloted and robotic space missions. For piloted missions, the concern is mainly total dose to the astronauts, particularly in long-duration missions and during extravehicular activity (EVA). As astronomical and remote sensing detectors become more sensitive, the proton flux can induce unwanted backgrounds in these instruments. Due to this unwanted backgrounds, the following description details the development of a new model for the low-trapped proton environment. The model is based on nearly 20 years of data from the TIRO/NOSS weather satellites.

The model, which has been designated NOAAPRO (for NOAA protons), predicts the integral omnidirectional proton flux in three energy ranges: >16, >36, and >80 MeV. It contains a true solar cycle variation and accounts for the secular variation in the Earth's magnetic field. It also extends to lower values of the magnetic L parameter than does AP8. Thus, the model addresses the major shortcomings of AP8.

B. L. Giles and M.A. McCook*, and M.W. McCook*, and G.P. Miller*, Compilers, **CRRES Combined Radiation and Release Effects Satellite Program George C. Marshall Space Flight Center, NASA TM-108494**, Space Sciences Laboratory, Science and Engineering Directorate NASA Marshall Space Flight Center, AL 35812, and *The University of Alabama in Huntsville, Huntsville, AL., June 1995, pp. 165.

Abstract: The various regions of the magnetosphere-ionosphere system are coupled by flows of charged particle beams and electromagnetic waves. This coupling gives rise to processes that affect both technical and non-technical aspects of life on Earth. The CRRES Program sponsored experiments which were designed to produce controlled and known input to the space environment and the effects were measured with arrays of diagnostic instruments. Large amounts of material were used to modify and perturb the environment in a controlled manner, and response to this was studied. The CRRES and PEGSAT satellites were dual-mission spacecraft with a NASA mission to perform active chemical-release experiments, grouped into categories of tracer, modification, and simulation experiments. Two sounding rocket chemical release campaigns completed the study. &K Plasma, Aurora, Magnetosphere, Ionosphere, Barium, Lithium, Active Experiment

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