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Environmentally Induced Spacecraft Anomalies

IN the November-December 1989 issue of *Journal of Spacecraft and Rockets*, A. L. Vampola was the Guest Editor for a collection of papers on the Solar Cycle Effects on Space Systems. The environmental variations that were detailed as stemming from the solar cycle and impacting the operation of space systems fit into the genesis of events that are responsible for spacecraft anomalies. There is a general consensus that the solar output of radiation, solar wind, and energetic particles depends on the solar magnetic cycle. Although these outputs have a pronounced influence on the near-Earth space environments as well as interplanetary ones, the theory is only good to the first order. Historical records that have been started fairly recently on the near-Earth environments indicate that there are elements interacting not unlike weather on the surface of Earth. These elements become unstable and cause havoc with satellites when energy is unleashed as an avalanche of charged particles on a path that can cause anomalous behavior of varying degrees. From experience we know that just having a substorm in progress and just having a satellite on the dawn side aren't enough to charge the vehicle; and just charging the vehicle isn't enough to cause discharge. It follows from the qualitative theory of solar cycles that the evolutionary processes that follow can only be even more unpredictable. The papers that have been collected in this special section are focused on the issue of trying to help engineers and scientists design and build better spacecraft that will last longer by providing alternative ways for dealing with the uncertainty of these events that hopefully will be considered. Because of the statistical nature of the risk, apathy reigns among some of the spacecraft community, with the exception of total dose analysis from the trapped particle models. As our skills improve in the prediction of events, interest is bound to increase.

The 1990 AIAA Aerospace Sciences Meeting included a session on environmentally induced spacecraft anomalies at which the following six invited papers were presented. There was a seventh paper by S. Daughtridge et al. on "Environmentally Induced Spacecraft Anomalies on TDRSS" that was published in the May-June 1990 issue of *JSR*. The first paper, intended to be a tutorial on anomalies, "Analysis of Environmentally Induced Spacecraft Anomalies," describes a general decision tree for diagnosing the anomalies by resorting to a process of elimination to isolate the cause. Anomaly is defined as the entire spectrum from the initial design to operations. The second section elaborates on the classes of environmentally induced anomalies and provides an intelligence on the relevance of orbital and environmental parameters, magnetic activity, and particle environments. The final analysis is a tally of the most likely type of anomalies for particular orbits.

The second paper, "National Oceanic and Atmospheric Administration's Spacecraft Anomaly Data Base and Examples of Solar Activity Affecting Spacecraft," is a fine example of how a catastrophic failure of a satellite instrument, which coincided with the arrival of high energy protons from an X3 solar flare, initiated the start of statistical data collection to determine its cause. It is hoped that such data would help answer questions about future failures. Examples are given showing the correlations that were found with the environmental variations such as magnetic storms, proton events, seasonal variations, and daily variations from eclipse to daytime.

The third paper, "Anomalies due to Single Event Upsets," describes the methodology for making engineering estimates for the rate of single event upsets (SEUs) based on ground testing. However, as technology pushes toward faster and lower power devices, the sensitivity to high energy particles increases. A simple diagram is given to show the ranking of susceptibility to SEUs based on material technology.

The fourth paper is on the genealogy of NASA standard AE-8 and AP-8 trapped radiation models. These calculate the integral and differential electron and proton flux for given values of particle energy E, drift shell parameter L, and magnetic field strength normalized to the equatorial/minimum value on the field line B/B_o for either solar max or min conditions. The importance of these models lies in the influence that radiation environment has on measurements, instruments, materials, and humans. In the absence of a consensus in the early days of space research, analysis was very individualistic so that final products were prohibitively different, typically by a factor of 100. These static models are empirical based on in situ measurements of fluxes of trapped particles. A consensus was used to treat the portions of the model that were based on soft data or had inconsistencies. Except where gradients are steep, models are estimated to typically represent observed data within a factor of 2. An error to avoid is to use an epoch for the models that is more current. The models are based on measurements in the 1960s and 1970s and as they were adjusted for the epoch during those years these are the epochs that must be used in order to use the models correctly. The need for dynamic models is obvious as the old theories are modified and new theories are developed and validated.

The fifth paper, "Spacecraft Environmental Anomalies Expert System," is a rules- and facts-based system developed for use in the diagnosis of satellite anomalies caused by interaction of the space environment. Software technology has advanced to such an extent that, today, expert system programs are feasible. This program involves knowledge-based concepts based on the personal knowledge of "experts" and allows the novices to take advantage of the expert's experience. This expert system is a tool in the research state of development beyond prototype, where it has been shown to produce useful answers. It still needs a continual addition of rules and frames. Ultimately, when the expert system has achieved a state of utility, it should be an effective tool for convincing managers of spacecraft that the environment is a problem, and for training of new spacecraft operators in the military and civilian sector, as well as quick and fast analysis for spacecraft controllers themselves.

The sixth paper, "On-Line Spacecraft Environment Interactions Information System," describes the prominent features of a computerized text type of data base on a variety of space environments that also has facilities for running interactive models of interest for diagnosing anomalies. A description is given of an on-line version of the PC-based expert system by Koons and Gorney, which has been developed using NASA's CLIPS software.

M. Lauriente and J. Gaudet
Guest Editors