The Continuing Challenge of Spacecraft ESD

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The threat of spacecraft ESD arises primarily from the charged particles in the solar wind, especially the energetic electrons. Whether these electrons follow paths directly from the sun or whether they bypass the earth but are driven back again by plasma instabilities, the results are similar -- a large population of high-energy electrons at the altitudes of communications satellites, especially those in geo-synchronous orbit. These electrons become embedded in the many types of dielectric materials that are used for electrical or thermal reasons on the exterior or interior of the satellite, where they accumulate unless driven off by some physical process such as photoemission. Under the right circumstances, this charge accumulation continues until the dielectric breaks down electrically, producing effects such as material destruction, contamination of nearby surfaces, or electromagnetic interference which can be strong enough to damage semiconductor devices.

The dielectrics that are effective as electrical insulators or as thermal-control surfaces such an thermal blankets or second-surface mirrors, are also effective at storing electrical charge for periods as long as weeks. After a week or two of exposure to the elevated fluxes of multi-kilovolt or multi-megavolt electrons that occur during "magnetic storms", it is not uncommon for dielectric breakdown thresholds to be reached. If the resulting discharge is such as to mobilize a large quantity of charge, thus releasing an equally large quantity of energy, the results can be disastrous, disabling whole subsystems or even entire satellites. A particularly devastating scenario is a small discharge close to a high-current power source (such as a solar-cell array), triggering a self-sustaining arc with a current limited only by the small arc resistance and the capability of the power supply to continue functioning.

This paper describes the mechanisms of charge accumulation and discharge propagation, with examples of resulting damage. Test methods and mitigation techniques are discussed. The point is made that the space ESD threat has not gone away, and the relevant satellite specifications are becoming increasingly strict and hard to meet, constituting a continuing major challenge for spacecraft designers.

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