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An Investigation of Low Earth Orbit Internal Charging

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Low Earth orbit is usually considered a relatively benign environment for internal charging threats due to the low flux of penetrating electrons with energies of a few MeV that are encountered over an orbit. There are configurations, however, where insulators and ungrounded conductors used on the outside of a spacecraft hull may charge when exposed to much lower energy electrons of some 100's keV in a process that is better characterized as internal charging than surface charging. For example, the minimal radiation shielding afforded by thin thermal control materials such as metalized polymer sheets (e.g., aluminized Kapton or Mylar) and multilayer insulation may allow electrons of 100's of keV to charge underlying materials. Yet these same thermal control materials protect the underlying insulators and ungrounded conductors from surface charging currents due to electrons and ions at energies less than a few keV as well as suppress the photoemission, secondary electron, and backscattered electron processes associated with surface charging.

We investigate the conditions required for this low Earth orbit "internal charging" to occur and evaluate the environments for which the process may be a threat to spacecraft. First, we describe a simple one-dimensional internal charging model that is used to compute the charge accumulation on materials under thin shielding. Only the electron flux that penetrates exposed surface shielding material is considered and we treat the charge balance in underlying insulation as a parallel plate capacitor accumulating charge from the penetrating electron flux and losing charge due to conduction to a ground plane. Charge dissipation due to conduction can be neglected to consider the effects of charging an ungrounded conductor. In both cases, the potential and electric field is computed as a function of time. An additional charge loss process is introduced due to an electrostatic discharge current when the electric field reaches a prescribed breakdown strength. For simplicity, the amount of charge lost in the discharge is treated as a random percentage of the total charge between a set maximum and minimum amount so a user can consider partial discharges of insulating materials (small loss of charge) or arcing from a conductor (large loss of charge). We apply the model to electron flux measurements from the NOAA-19 spacecraft to demonstrate that charging can reach levels where electrostatic discharges occur and estimate the magnitude of the discharge