THICK DIELECTRIC CHARGING / INTERNAL ELECTROSTATIC DISCHARGE (IESD)

Practice:

Dielectric compositions used in such spacecraft materials as circuit boards, cable insulation and thermal blankets will build up an imbedded charge when exposed to a natural space environment featuring energetic electrons. If the electric field resulting from the imbedded charge exceeds the breakdown threshold for the dielectric, an arc will occur, damaging the dielectric and producing an electromagnetic pulse which can couple into subsystem electronics.

Enhance hardware reliability in an energetic electron environment by conducting a materials inventory, resistivity analysis, and shielding assessment. Ascertain material susceptibility to deep dielectric charging and explosive discharge when the material:

1. Is exposed to an energetic electron flux exceeding 2×10^5 electrons/(cm^2-s), and

2. Achieves an imbedded charge density greater than a threshold of 10^{11} electrons/cm^2.

Benefit:

Materials and design structures which represent possible internal electrostatic discharge (IESD) sources can be identified early in the program. Risk to hardware may be reduced through design changes which substitute materials having sufficient conductivity to permit charge bleed-off. Sensitive cable runs may be rerouted or shielded to reduce exposure to energetic electrons. Grounding schemes may be changed to ensure that otherwise isolated conductors are grounded and that grounds are designed to maximize the opportunity to bleed-off the charge from dielectric materials.

Programs that Certified Usage:

Voyager, Galileo, Spacecraft Charging at High Altitudes (SCATHA), Chemical Release & Radiation Effects Satellite (CRRES)

Center to Contact for Information:

Jet Propulsion Laboratory (JPL)

Implementation Method:

Utilize the electron environment specified for the mission and a transport code (such as NOVICE) to estimate the electron flux at interior locations where dielectric materials pose an IESD problem. When the electron flux exceeds the guideline values, apply ameliorating strategies:

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1. Replace dielectric with a more conductive material,

2. Relocate the dielectric structure to a more suitable location within the spacecraft, and

3. Review the grounding scheme to maximize charge bleed-off.

Good design practices can minimize IESD risk by optimizing the spacecraft structure to provide shielding for otherwise exposed cable runs and highly resistive materials. Shielding reduces the ability of incident energetic electrons to cause IESD by shifting the flux spectra to lower energies, resulting in fewer high energy particles. Providing a shield thickness of 400 mg/cm^2 has been found sufficient to reduce most electron environments below the IESD threshold.

Technical Rationale:

IESD is caused by electron flux present in the earth's magnetosphere which is sufficiently energetic to penetrate the spacecraft skin and imbed in cable insulation, thermal blankets, circuit boards, and other non-conductors. Ungrounded islands of metalization can also develop a charge. When the charge build-up results in an electric field sufficient to break down the dielectric, an arc to an adjacent material at a lower potential will occur. Material damage (burn-out) and an electromagnetic pulse occurs which can couple into the subsystem electronics with the possibility of undesirable anomalous subsystem behavior.

Electrons responsible for bulk dielectric charging are more energetic than those responsible for surface charging. The IESD threshold current density is approximately $2x10^5$ electrons/(cm^2-s) for integral electron flux above approximately 100keV. The frequency of IESD increases as the electron flux increases above threshold. Dielectric breakdown begins to occur when the concentration of electrons exceeds approximately 10^{11} electrons/cm^2.

Impact of Non-Practice:

Non-compliance with the IESD practice will result in increased risk of deep dielectric charging when energetic electrons are encountered. Internal discharges result from severe electron environments; they produce electromagnetic pulses that can couple into subsystem electronics, resulting in anomalous spacecraft behavior. Dielectric breakdown and material failure also occurs.

Related Practices:

1. *Design Practice to Control Interference From Electrostatic Discharge (ESD)*, Practice No. PD-ED-1244

2. *Surface Charging / ESD Analysis*, Practice No. PD-AP-1301

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References:

1. Vampola, A.L. (1987), "Thick Dielectric Charging on High-Altitude Spacecraft", Journal of Electrostatics, 20, pp 21-30.

2. Fredericks,A.R., Holeman, E.G, Mullem, E.G. (Dec. 1992)," Characteristics of Spontaneous Electrical Discharging of Various Insulators in Space Radiations", IEEE Trans. on Nucl. Sci., 39, 6.

3. Purvis, C.K., Garrett, H.B., Whittlesey, A., Stevens, N.J. (Sept. 1984), "Handbook of Design Guidelines for Assessing and Controlling Spacecraft Charging Effects", NASA Technical Paper 2361.

4. Mizera, P.F., Fennell, J.F., Hall, D.F., Koons, H.C., and Vampola, A.L., "Spacecraft Charging Handbook", SD-TR-85-26, 1985.

5. Rudie, N.J., "Electron Caused Electromagnetic Pulse", DS&E Magazine, pp58-59, June 1987.