Lightening in Spacecraft: A Review of Internal Charging _ Environment, Effect, Prevention, and Mitigation

Authors: Wousik Kim, Insoo Jun, and many others

ABSTRACT: We provide a comprehensive overview of a radiation effect commonly encountered in space missions called inertial electrostatic discharge (IESD) or internal charging, deep dielectric charging, or bulk dielectric charging. IESD is a result of complex interplay of many different factors including particular mission design, mission's radiation environment associated with the mission design, material properties, material geometry, and shielding. Among these, the radiation environment is mostly relevant with space weather phenomena. Therefore, our review focuses on the space weather aspects of the relevant IESD radiation environment while we provide rather succinct (and short) descriptions on other factors. As a review paper, our intent is to provide a synopsis of the current state of the discipline and a summary of the gap analyses. We also describe approaches/methods frequently used to prevent and mitigate IESD.

1.0 Introduction

- What is IESD?
- Physics
    - Electron /proton energy vs. Penetration Depth (Range)
- Summary of the state of art for internal charging

2.0 History of Internal Charging

- History
- Why IESD is important?

3.0 Assessment Process

Block diagram
(In each subsection, describe gap and future works)

3.1 Material Properties

- Conductivity: Dark Conductivity, Radiation Induced Conductivity
- Dielectric Constant
- Dielectric Strength

3.2 Internal Charging Environment

- Environment measurements and models
- Spectrum: a few examples of environments
- Time duration (material property, trajectory)
- Safety Factor - Uncertainty
- space weather products desired for IESD assessment

3.3 Internal Charging Analysis

3.3.1 Two time-regimes of internal charging process

- Fast Dynamics: Charge deposition and Energy deposition
- Slow Dynamics: Charge Conduction

3.3.2 Internal charging simulation tools

- NUMIT (1D)
- DICTAT
- MCICT
- 3D NUMIT
- SPIS-IC

4.0 IESD Prevention/Mitigation Method

- Shielding
  - Decrease charging flux
- Ground all conductors. Add more grounded conductors
  - One-dimensional example: single side grounded vs. both sides grounded cases
- Limit the size of dielectrics
- Minimize exposed dielectric surface areas
  - Coat the dielectric surface with charge-dissipative layer
- Select less resistive material
- Harden the electronics affected by discharges
- Block the conducted discharges by filter

5.0 Summary and Conclusion

Future work

Appendix:

Standards and Guidelines

- NASA-HDBK-4002B (NASA)
- ECSS-E-ST-20-06C (Standard) and ECSS-E-HB-20-06A (Handbook) (ESA)
- E_JAXA-JERG-2-211A (JAXA)