SURFACE CHARGING / ESD ANALYSIS

Practice:

Considering the natural environment, perform spacecraft charging analyses to determine that the energy that can be stored by each nonconductive surface is less than 3 mJ. Determine the feasibility of occurrence of electrostatic discharges (ESD). ESD should not be allowed to occur on surfaces near receivers/antenna operating at less than 8 GHz or on surfaces near sensitive circuits. For this practice to be effective, a test program to demonstrate the spacecraft's immunity to a 3 mJ ESD is required.

Benefit:

Surfaces that are conceivable ESD sources can be identified early in the program. Design changes such as application of a conductive coating and use of alternate materials can be implemented to eliminate or reduce the ESD risk. Preventive measures such as the installation of RC filters on sensitive circuits also can be implemented to control the adverse ESD effects.

Programs That Certified Usage:

Voyager, Galileo

Center to Contact for Information:

Jet Propulsion Laboratory (JPL)

Implementation Method:

Use a validated computer code (NASCAP or other appropriate computer code) to determine the maximum differential charging (V) of each nonconductive surface. When differential charging occurs, an electric field is developed within the dielectric material. The magnitude of the electric field (E) is given by:

$$E = V/d$$

where d is the thickness of the dielectric material. Usually, when this electric field is greater than 2×10^5 V/cm, ESD is likely to occur.

To determine the charging level, electrical properties of the nonconductive material must be known.These properties include (but are not limited to) surface resistivity, bulk resistivity, secondary and backscatter electron emission coefficient, and photoelectron yield. For materials with unknown electrical properties, the charging level must be determined by a ground test. In the ground test, the nonconductive

SURFACE CHARGING / ESD ANALYSIS

surface is exposed to simulated charging environments (mission-dependent) and the resulting charging levels are measured.

ESD must not be allowed to occur on surfaces near sensitive radio frequency (RF) receivers and on surfaces near sensitive circuits. For other surfaces, the energy of an ESD should be limited to 3 mJ. The ESD energy can be determined with the following equation:

$$W = 1/2CV^2$$

where C is the capacitance of the nonconductive surface with respect to spacecraft ground. The value C depends on the geometry (area and thickness) of the nonconductive surface. The ESD energy as a function of capacitance and charging level is displayed in Figure 1. Usually, the best way to reduce the ESD energy is to limit the value of V. This usually implies the use of a more conductive material. Since the charging current available in the space environment is relatively low, material with resistivity of 10^9 Ohm-cm is considered adequate for effective charge control.

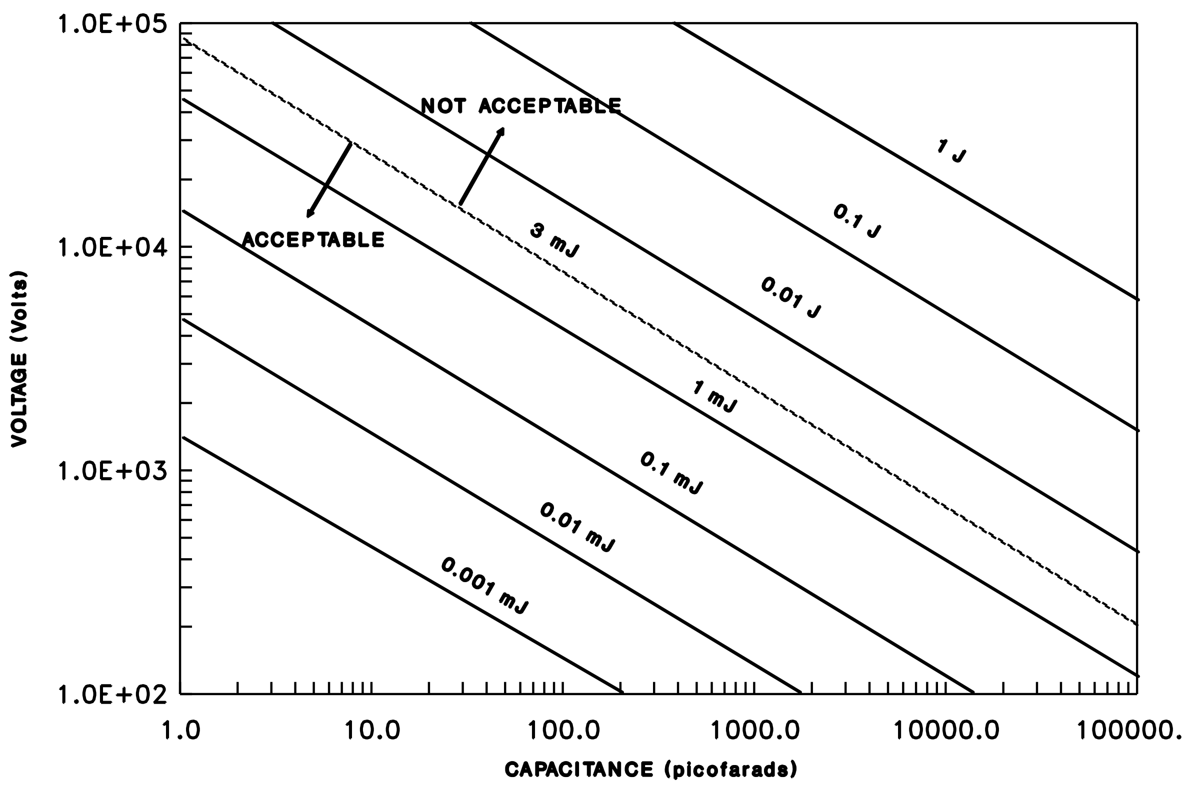

Figure 1. ESD Energy as a Function of Capacitance and Voltage

<u>Technical Rationale</u>:

In an environment of energetic electrons, spacecraft surface charging can occur. Due to their high resistivities, dielectric surfaces can be charged to different potentials than the metallic surfaces (which

SURFACE CHARGING / ESD ANALYSIS

should be at spacecraft ground potential). When the electric field that results from differential charging is sufficiently high, an ESD would occur.

ESD is an intense source of electromagnetic interference (EMI). The EMI energies that can be capacitively and inductively coupled to electronic circuits are proportional to both the magnitude and rate of increase (dI/dt) of the discharge current, respectively. Under most conditions, the discharge current (I) is directly related to the energy (W) of a discharge. By minimizing the ESD energy, the magnitude of discharge current and the magnitude of ESD-induced EMI on circuits can be reduced.

The typical energy required to damage a sensitive IC is an order of several µJ. The energy required to upset a circuit is approximately 10 times less. In a typical discharge, only a fraction of the stored electrostatic energy can be coupled to a circuit. The coupling efficiency is dependent on the shielding and geometry of the spacecraft. Restricting the energy of an ESD minimizes the amount of energy available for IC damage and circuit upset, resulting in a more reliable spacecraft. In the Voyager ESD system test program, a 30 mJ discharge did not disturb spacecraft operation. However, differences in spacecraft configurations and circuit protection devices (e.g., RC filters in sensitive circuits) means that the "safe" (maximum allowable) energy could be different for different spacecraft configurations. Thus, 3 mJ was chosen as the maximum allowable energy.

Impact of Nonpractice:

Unpredictable operational anomalies and electronic parts failure could be caused by in-flight ESD events. The consequences could be catastrophic.