Protons, Electrons, and Neutrons

Protons and electrons are charged-particle components of the space environment that are capable of damaging most thermal-control materials and, together with solar UV, are responsible for spacecraft charging effects. Neutrons, as their name implies, are electrically neutral and have great penetrating power but do little or no damage to spacecraft thermal-control materials.

As illustrated by Fig. 1, highly energetic protons and electrons are concentrated in the inner and outer Van Allen radiation belts because of Earth's magnetic field. The Van Allen belts are two concentric doughnut-shaped rings situated above the equator. Geosynchronous orbit (GEO) is located in the outer Van Allen belt; consequently, external surfaces of spacecraft in GEO are subjected to large doses of ionizing radiation. The charged particles in the Van Allen belts are omnidirectional, so all external spacecraft surfaces are equally irradiated. Only the sun-facing surfaces are simultaneously irradiated with solar UV and charged particles.

The lower boundary of the inner Van Allen belt is located at an altitude of about 1000 km, so spacecraft in LEO are not normally exposed to significant amounts of ionizing radiation. Increases in solar absorptance in LEO are mainly the result of solar UV radiation. Materials on spacecraft in polar orbits and in orbits that intercept the South Atlantic Anomaly are subjected to an ionizing radiation dose in these regions of space, but the dose is usually less than several Mrads, which generally induces insignificant changes in solar absorptance.

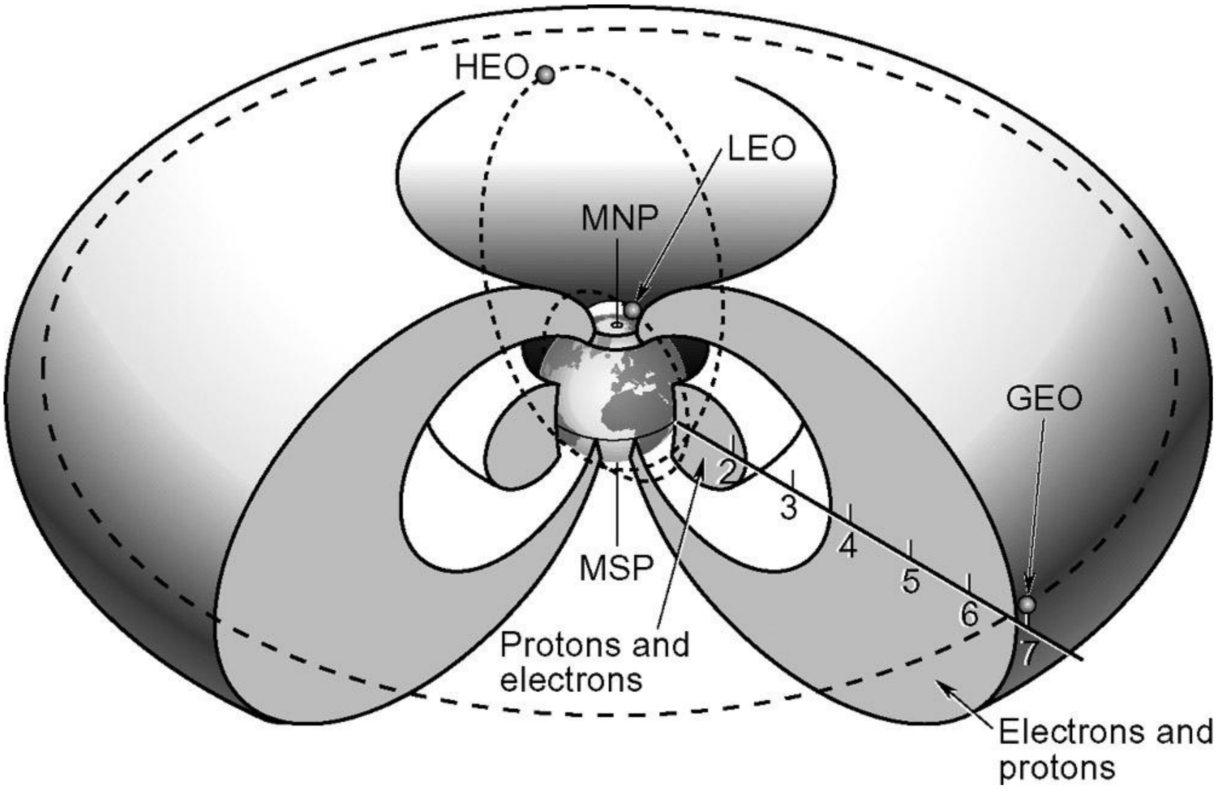

Figure 1: Earth's radiation belts.

The most damaging of the energetic charged particles are the 30-keV plasma-sheet protons and the 7-keV plasma-sheet electrons, which can deposit a very large dose of about 1011 rads to spacecraft outer surfaces during a 5-year mission in GEO. The 30-keV protons are capable of penetrating FEP Teflon to a depth of 0.01 mil. The 7-keV plasma-sheet electrons and 200-keV electrons of the Van Allen belts can penetrate Teflon to a depth of 0.06 and 10 mil, respectively. When energetic protons and electrons of the space environment penetrate a polymeric material, collisions between the relatively fast-moving charged particle and molecules of the solid produce ionization. The ionized molecules chemically react with neighboring molecules, forming larger polymeric molecules. These larger polymeric molecules generally have optical-absorption bands in the solar portion of the spectrum, which results in an increase in solar absorptance. Kapton, for example, experiences large increases in solar absorptance when used in geosynchronous orbits or other high-radiation environments. However, there are some transparent materials, such as fused silica, that do not darken as a result of exposure to ionizing radiation, partially because of the purity of the material.