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Interactive Presentations - 56th IAA SYMPOSIUM ON SAFETY, QUALITY AND KNOWLEDGE MANAGEMENT IN SPACE ACTIVITIES (IP)

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DIFFERENTIAL SPACECRAFT CHARGING IN LOW EARTH ORBIT DURING EXTREME CONDITIONS

Abstract

Telecommunication satellites are increasingly being placed in Low Earth Orbit (LEO) due to the lower amount of energy required for launches, power-requirements, and latency of communications. Compared to Geosynchronous Earth Orbits, plasma in LEO is expected to have a minor impact on satellite charging in typical conditions.

Nevertheless, significant charging events have been observed in the polar regions, a potential of -2000 V was measured on the satellite DMSP F12 in June 1995 [1]. This study aims therefore to model significant spacecraft charging events of hundreds to thousands of volts, and deduce the cause of extreme potentials and extreme differential potentials which are associated with electrostatic arcing and breakdowns.

Particle-In-Cell simulations were conducted using the Electro-Magnetic Spacecraft Environment Simulator (EMSES) [2]. They were first run for a generic satellite architecture, consisting of two conducting bodies in a Sun-Synchronous Orbit. Embedded in typical conditions, the absolute difference of potential between bodies would not exceed 1 V, thus leading to the inclusion of high-energy auroral electrons. These auroral electrons consist of field-aligned injections propagating at high speeds of 10104 km/s, with temperatures of 10^2 10^4 eV. Within our simulations, this second population of electrons was able to induce overall charging down to 120 V, with a clear dependence on their density. Moreover, a linear differential charging relationship is observed with particle velocity, when the two spacecraft bodies are oriented such that the auroral electrons strike one specific body head on but the other is shielded from this additional current. Worst-case scenarios were then simulated with a representative spacecraft, the Jason-3 satellite, which experienced extreme charging events in the polar regions, induced by 10 keV electron populations [3]. Including a high energy population at 10 keV and a flux of 2.5×10^7 $cm^{-2}s^{-1}sr^{-1}$, the

differences between electrically separated regions of the spacecraft reached 15 V. When simulating higher densities, potential differences rose up to 300 V for a flux five times the original, which was identified as a potentially critical scenario that might damage a satellite permanently. These simulated scenarios show how differential charging is sensitive to the spacecraft shape, orientation, photo- and electron-emission characteristics and is induced by auroral electron injections, whose energy and density are required to accurately predict and mitigate extreme charging events and satellite malfunctions in LEO.

[1] Anderson et al., (2012) https://www.researchgate.net/publication/336889086

[2] Miyake Usui (2009), https://doi.org/10.1063/1.3147922

[3] Enengl et al. (2022), https://doi.org/10.1109/TPS.2022.3157958