Study on active mitigation of spacecraft charging in the Earth's polar region via three-dimensional particle-in-cell simulations

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We studied the active mitigation of spacecraft charging in the Earth's polar region by performing three-dimensional Particle-In-Cell (PIC) simulations. In the Polar Earth Orbit (PEO), spacecraft charging occurs due to the aurora electrons impinging to the spacecraft surface along the magnetic field line. In such a situation, differential charging can occur between the solar panels made of dielectric materials and the conducting part of spacecraft. If this differential charging exceeds a threshold, discharge can occur and cause anomalies of spacecraft power system. In order to mitigate the spacecraft charging, active plasma emission from a plasma contactor device onboard spacecraft is one of the effective methods. However, the mitigation process has not been clearly understood in terms of spacecraft-plasma interaction. We investigated the mitigation process of the spacecraft charging in PEO by performing three-dimensional electrostatic PIC simulations. We first investigated the spacecraft charging process in the PEO environment. The floating potential of spacecraft becomes negative with respect to the plasma potential and the potential is determined when the amount of aurora electron flux and that of the background ion flux becomes equal. We also confirmed that the charging of the conducting part of spacecraft depends on the energy of aurora electrons while the differential charging at the solar panels depends on the direction of aurora electron flow.

We next investigated the charging mitigation of spacecraft in PEO by means of plasma release. In the case of electron release, negative potential of spacecraft surface including dielectric part basically increases up to the plasma potential. However, the electron release from the conducting surface cannot reduce the amount of the charge accumulated on the solar panel. To mitigate the negative charging on the solar panel, we performed ion release along with electrons from the contactor. In addition to the mitigation of conducting part of spacecraft by electron release, it turned out that negative charges on the solar panel are neutralized by the released ions. We also examined the dynamics of released plasma in terms of acceleration by sheath electric field and the influence of geomagnetic field. By considering the results obtained in the simulations, we discussed the effective condition of plasma release for the charging mitigation. We found that release of electrons with low energy and high-density along the geomagnetic field is the most effective for the charging mitigation in PEO. The analysis and discussion in the present research will be beneficial for the future design of plasma contactor device.

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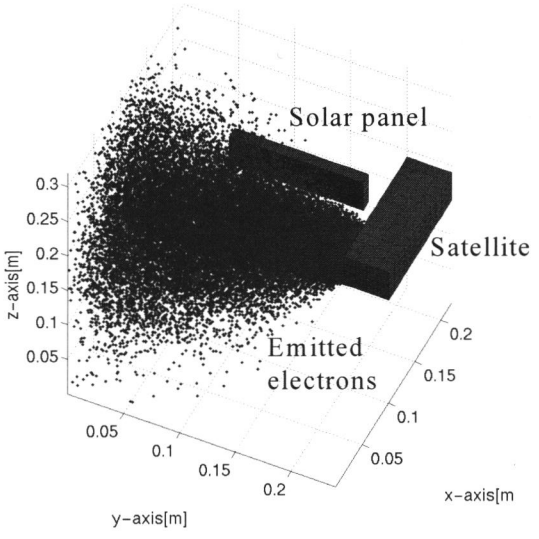

A snapshot of spatial distribution of electrons emitted from the satellite