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Numerical simulation of active spacecraft charging in interplanetary space

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It is well known that spacecraft is charged by the background plasma in space. Since spacecraft charging is a cause of the discharge and malfunction of electric equipment, spacecraft are usually designed to mitigate their surface charging.

However, a new concept of spacecraft orbital control using electromagnetic forces such as the Lorentz force and the Coulomb force has been recently proposed. Spacecraft controls their orbit by controlling their potential using a charged-particle emitter. Various applications of electromagnetic force as the primary means of spacecraft propulsion have been studied.

This orbital control method may provide propellantless orbital control and a very lightweight propulsion system compared with conventional chemical and electric propulsion systems.

Moreover, the system's lifetime is not limited by propellant, so it can extend the spacecraft's orbital lifetime.

To control the electromagnetic force that acts on the spacecraft, it is necessary to actively control the spacecraft's electrical potential.

In this paper, we investigate charging characteristics of active spacecraft charging in interplanetary space. by using 3D Full Particle-in-cell simulation.

We particularly evaluate the effects of the solar wind velocity, beam-emission angle, and photoelectron emission on the spacecraft's electric potential.

Additionally, we also investigate the charging characteristics of an electric solar wind sail, which is proposed as an application of electromagnetic orbital control in interplanetary space.

An electric solar wind sail consists of several-kilometer long, thin, conducting tethers.

Tethers are kept at a high positive potential on the order several kilo-volts by an electron gun.

The positively charged tethers deflect the momentum of solar wind protons which result in a propulsive force.

We analyze the dependency of the electric potential on the length and diameter of charged tethers, and evaluate the effect on thrust characteristics.

Keywords: Spacecraft Charing, Solar Wind, Electric Sail