Spacecraft Charging Considerations for On-Orbit Servicing and Debris Mitigation in High Earth Orbit

Julian Hammerl[0000−0003−1296−7203] and Hanspeter Schaub[0000−0003−0002−6035]

University of Colorado Boulder, Boulder CO 80303, USA

Keywords: Servicing · Charged Astrodynamics · Spacecraft Charging.

1 Extended Abstract

Spacecraft build up electrostatic potentials in orbit due to various electric currents in the space environment. The incoming electromagnetic radiation from the Sun excites electrons and causes them to escape from the spacecraft if the craft is charged negatively, leading to a positive photoelectric current. The plasma environment in space results in both positive and negative currents due to the ions and electrons that impact objects in space. In Low Earth Orbit (LEO), the plasma environment is cold (low particle energies) and dense. Thus, spacecraft such as the International Space Station (ISS) tend to charge a few volts positive in sunlight and a few volts negative in eclipse. In Geostationary Earth Orbit (GEO) and cislunar space, however, the plasma is hot and tenuous, resulting in high spacecraft electric potentials that can reach tens of kilo-volts. The Applied Technology Satellite 6 (ATS-6), for example, experienced a record potential of -19 kV while in eclipse in geostationary orbit.

One consequence from spacecraft charging are the electrostatic forces that result from electric potentials and the corresponding electric charges (Fig. 1). Two charged objects in proximity are subject to electrostatic forces proportional to the charging levels of the two objects. While opposite signs of the charges result in attractive forces, equal signs cause repelling forces. This also leads to electrostatic torques if the center of charge of each object does not correspond to its center of mass. These electrostatic forces and torques can drastically influence the relative motion during rendezvous and proximity operations as well as docking. In order to dock, a servicing spacecraft needs to match the rotational rates imposed on an uncooperative target spacecraft, leading to an approach trajectory that is perturbed from the desired trajectory (Fig. 2). This can cause the servicer to fail critical tasks such as aligning its solar panels with the sun for power generation or pointing the antenna toward Earth for communication.

A controller was developed in prior work that feeds forward on the predicted electrostatic torques to reduce control effort and fuel consumption. The idea of using the expected torques in the controller can be extended to optimize the approach trajectory on the fly, as opposed to finding a pre-determined guidance solution as explained above. Novel remote sensing methods are being

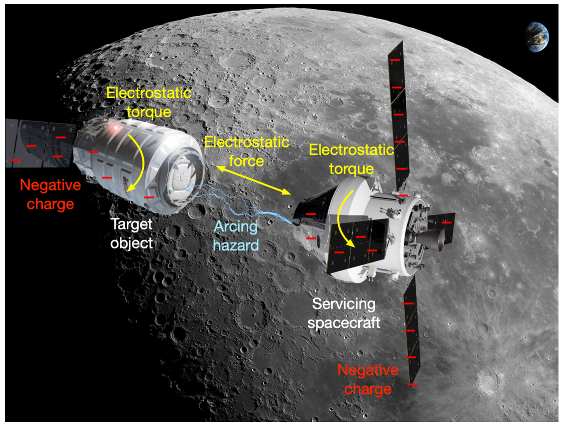

Fig. 1. Impact of spacecraft charging on rendezvous operations

developed that utilize an electron gun or the ambient plasma environment to estimate the electric potential of a nearby object by analyzing the generated secondary electrons and x-rays. These methods have been experimentally validated in our spacecraft charging research vacuum chamber at the University of Colorado Boulder. During rendezvous, these remote sensing techniques can be used to quickly update the estimated spacecraft potentials and compute the expected electrostatic torques with the Multi-Sphere Method (MSM). The remote electric potential sensing methods combined with rapid force and torque approximations using MSM enable new control strategies adapted to the electrostatic perturbations, which rely on quickly updated torque estimations.

In the oral presentation, we will review the fundamentals and prior work of on-orbit servicing, manufacturing and assembly (OSAM) operations subject to electrostatic perturbations and provide an update about current work in this field.

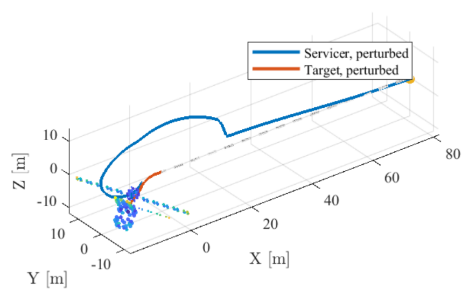

Fig. 2. Perturbed trajectory due to electrostatic torques