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CONTACTLESS SPACE DEBRIS REMOVAL FROM GEOSTATIONARY ORBIT USING A HYBRID SCHEME BASED ON ION BEAM AND ELECTROSTATIC EFFECT

Abstract

The creation of safe and reliable space debris removal systems is an important scientific and technical task facing modern astronautics. To date, many different space debris removal methods have been proposed. Contactless space debris removal systems look promising as they are secure, since there is no direct mechanical contact between the space debris and an active spacecraft. In addition, contactless methods allow to transport rapidly rotating objects. This study examines an Ion Beam Shepherd approach that uses an ion engine plume (ion beam) to impact space debris. The generation of useful force is carried out by transferring a momentum of the ions that make up the plume to the space debris object. Irradiating an object with positively charged ions causes its charging. Since the Debye length in geostationary orbit exceeds one hundred meters, and the active spacecraft is located at a distance of about ten meters, charged space debris can have an electrostatic effect on the active spacecraft and vice versa. The purpose of the study is assessment of the influence of the electrostatic effect on the dynamics of space debris during its ion beam-assisted transportation from geostationary orbit into disposal orbit.

The motion of a mechanical system consisting of a cylindrical space debris object and an active spacecraft is considered. The Lagrange formalism is used to obtain the equations of motion. A simplified self-similar model of ion propagation and the hypothesis of fully diffused reflection of ions from the space debris surface are used to calculate the generated ion force and torque. A Multi-Sphere Method approach is used to model the electrostatic forces and torques. It is shown that without measures to additionally charge the space debris object and the spacecraft, the magnitude of the electrostatic force is small compared to the ion force and can be considered as a small disturbance. The results of numerical simulation showed that a change in the electrostatic torque as a result of changes in the charges of the spacecraft and space debris when they passing through the Earth shadow region leads to chaotization of the space debris attitude motion. The control law for the active spacecraft charge ensuring the detumbling of space debris during its contactless transportation is developed. The results can be used in the development of contactless space debris removal systems based on ion beam and electrostatic effects.