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DEVELOPMENT OF A 3D ASTEROID CHARGING MODEL BASED ON FINITE ELEMENT METHODS FOR THE ELECTROSTATIC TRACTOR METHOD

Abstract

Several mitigation methods have been studied to various degree of accuracy in the literature to deflect an asteroid from its collision course with the Earth. With the gravity tractor method, the gravitational attraction between the asteroid and a massive spacecraft is used to exert a small force remotely to tow the asteroid in the required direction to avoid an impact. One of the drawbacks of this method is the lack of control over the force produced as it only depends on the mass of the spacecraft and its distance from the asteroid. To overcome this, a new method was introduced: the electrostatic tractor. With this strategy, the deflection force is exerted by means of the electrostatic force produced by artificially charging both a spacecraft and the asteroid, which allows improving the achievable deflection.

Our paper discusses a new computation model to investigate the asteroid charging mechanism produced by a plasma contactor placed on the surface of the asteroid. Unlike a simple estimation assuming a cohesive, conductive, and spherical asteroid, our model can handle the case of asteroids with an arbitrary complex shape by solving the Maxwell equations on a 3D mesh. Assuming a quasi-steady condition and an asteroid composed of an Ohmic material, it can be shown that solving the Maxwell equations on the 3D domain is equivalent to solving a Laplace equation for the potential field inside the asteroid. The boundary conditions are introduced by considering the interaction between the charged asteroid and the ambient plasma. This interaction is modeled by equivalent current sources into the surface elements, accounting for the contribution of free electrons, protons, secondary electrons, and photoelectrons, and constitutes a non-linear function of the potential V of the surface elements. Using a finite element approach provides a way to discretize this problem and reformulate it as an equivalent electric network. In this network, adjacent vertices in the mesh are connected via equivalent resistances, which depend on the geometry and the local material properties. Finally, a Newton method is employed to solve the non-linear boundary problem.

Analysis for several asteroids are performed with our model and the results of the parametric study about the material, shape, and ambient plasma conditions are provided in the paper.