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VALIDATION OF A NOVEL COUPLED ORBIT-ATTITUDE PROPAGATOR BY COMPARISON TO SLR DATA AND LIGHT CURVES

Abstract

Large space debris, mostly defunct satellites and upper stages, populate the near-Earth environment and represent a significant risk to active and future space missions. Active Debris Removal (ADR) has been proposed as a solution to this problem, where a removal spacecraft would be launched, rendezvous with a target, stabilize and capture it, and finally remove it from orbit. However, precise knowledge of the target's rotational parameters ahead of time is key for the stabilization and capture of the debris, especially since current techniques could become dangerous for debris spinning at high angular velocities. Many external torques affect the spin characteristics of uncontrolled objects and the long-term, cumulative effect of these have only recently started to be studied.

A comprehensive coupled orbit/attitude propagation model is therefore developed in order to determine, to the highest degree of accuracy possible, the evolution of the rotational parameters of uncontrolled space objects over a time scale of years. This model would benefit the space debris community by being able to predict the future attitude state of ADR targets long before mission launch. The developed model includes a widespread list of external gravitational and non-gravitational perturbations. It includes a high order gravitational potential used to calculate the gravitational acceleration and the gravity-gradient torque, as well as third-body perturbations from the Moon and the Sun. It also includes the effect the solar radiation pressure and torque, the aerodynamic drag and torque calculated using atmospheric densities from multiple empirical thermosphere models (DTM-2013, JB-2008, and NRLMSISE-00), and the eddy-current torque making use of two models for Earth's magnetic field (IGRF-2012 and WMM). Hypervelocity impacts and the transfer of linear and angular momentum from bombardment of small debris and micrometeoroids can also be included.

The developed model is tested against past observations of the evolution of the angular motion of uncontrolled space objects. Simulation results are compared to estimates of the subject's rotational parameters obtained from SLR residuals and photometric measurements. Multiple case studies are performed, covering a large set of orbit types and spacecraft properties, in order to validate the propagation model. These include defunct satellites such as TOPEX/Poseidon and Cbers-2B, inoperative SL-16 upper stages, and uncontrolled spacecraft such as Ajisai, LAGEOS and LARES.