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OPTIMAL LOW THRUST DEORBITING OF PASSIVELY STABILIZED LEO SATELLITES

Abstract

Space debris mitigation requires all artificial satellites to be removed from orbit after completing a mission. The standard 25-year deorbit requirement is often a challenge for small satellites with a simplified attitude and orbit control system unless the aerodynamic drag mechanism is sufficient enough for quick spacecraft disposal. Of specific interest is the deorbiting problem for the densely populated low Earth orbit altitudes of about 700-1200 km. In this case, a thruster or some drag enhancing actuator is needed. The objective of the present work is to investigate the feasibility of designing a low thrust deorbit control for passively stabilized satellites in those orbits.

Most of passive stabilization techniques allow only one spacecraft axis to be stabilized. Consequently, one can install at most two opposite directed thrusters aligned with that stabilized axis—the orientation of any other spacecraft axis is poorly identifiable, which is unacceptable from the viewpoint of a continuous low thrust orbit control. As a result, the problem can be formulated in the following way: to derive an optimal thrust magnitude control law ensuring the desired change of satellite orbital elements (either a decrease in the semimajor axis or an increase in the eccentricity). What concerns the thrust direction, it is determined at any instant of time by the orientation of stabilized axis. For spin-stabilized spacecraft, the stabilized axis is nearly fixed in absolute space. (To be precise, a slow precession occurs.) In the case of passive magnetic stabilization, the thrust vector is aligned—within a 10-15-degree tolerance of attitude stabilization—with a direction of the local geomagnetic field. Both these passive stabilization methods are considered.

The fuel-optimal deorbiting control problem is shown to be reduced to a nonlinear programming problem by using the Gauss variational equations averaged over one orbit. A standard linear quadratic regulator technique is then applied to improve the nominal control and trajectory (e.g., to account for attitude stabilization errors and small orbital perturbations neglected before). The results indicate the possibility of timely deorbiting a passively stabilized satellite equipped with typical cold gas or ion thrusters.