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FAST AND ACCURATE ESTIMATION OF FUEL-OPTIMAL TRAJECTORIES TO NEAR-EARTH ASTEROIDS

Abstract

In the proposed paper a novel method for the preliminary evaluation of minimum-propellant trajectories to Near-Earth Asteroids (NEAs) is presented. The method is applicable to missions from Earth to asteroids with small eccentricity and inclination. A preliminary method was presented in a recent paper. Several improvements are here introduced, which greatly increase the method accuracy.

The approach assumes that multiple burn arcs are performed in correspondence of the apses of the target asteroid in order to change the initial spacecraft orbit (i.e., Earth's orbit) into the target orbit. The number of arcs is established once the time of flight is given (2 burns per revolution, 1 revolution per year can be assumed). The length and propellant consumption of each arc to attain the required changes of semimajor axis and eccentricity are computed by a procedure based on Edelbaum's approximation, which is well-suited to the problem at hand, as eccentricity changes are expected to be small for feasible missions.

No numerical integration is required, but only the numerical solution of a three-unknown algebraic system is needed, making the procedure extremely fast. Inclination change modifies the results and a method to accurately evaluate its influence is here introduced. A constant out-of plane thrust angle is assumed during each burn. Its value is updated during the solution of the planar problem in order to attain a specific fraction of the total inclination change. The effect of out-of-plane thrusting is assumed to depend on the eccentricity change, the angle between the asteroid line of nodes and line of apsides, and the expected length of the arc. If fact, when the eccentricity is small, the thrust arc can be performed at the nodes where inclination is efficiently changed, with little penalty in the planar maneuver. An efficient plane change is also performed when the angle between the asteroid line of nodes and line of apsides is small and/or the length of the arc is large, as in this case the node is comprised in the apsidal burn. The new method shows great accuracy. The results comparison with solutions obtained with an indirect optimization method for a set of more than 60 NEAs shows a 0.95 correlation coefficient in the propellant masses. The estimation error is below 10% for 80% of the targets, below 15% for 95% of the targets, and always below 20%.