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MOID-INCREASING DISPOSAL STRATEGIES FOR LPO MISSIONS

Abstract

Sun-Earth Libration Point Orbits are commonly chosen to place space observatories and, though their neighborhood will not be densely populated any time soon, the issue on the final fate of such missions has recently drawn the attention of ESA. So far, the only disposal concepts implemented at the end-of-life consist in heliocentric graveyard orbits: interior to the Earth's orbit in the case of the L1 NASA ISEE-3 mission or exterior in the cases of the L2 ESA Herschel and Planck missions. Other strategies can be considered, e.g., Earth re-entry, but in general they are more demanding in terms of operations and risk.

For the graveyard orbit design, it is required that the spacecraft will never return to Earth after leaving its operational orbit. A naïve approach to fulfill this constraint is to close the zero velocity curves, in such a way that no physical motion is possible between the geocentric orbital regime and the heliocentric one. We propose here an alternative approach, requiring less energy and thus propellant: the disposal orbit is such that, despite the fact that the given bottleneck passage may remain open, it always has an increasing Minimum Orbit Intersection Distance (MOID) evolution.

Two numerical procedures have been developed to this end, one considers the application of optimization techniques onto the Two-Body Problem equations, the other a Newton's method with the Circular Restricted Three-Body model. Both methodologies aim at designing resonant spacecraft-Earth encounters, which ensure that the variation in semi-major axis, eccentricity and inclination are such that the MOID will increase. The angle of encounter is the critical parameter in this approach: it can be defined either in terms of osculating orbital elements at a given epoch or synodical coordinates, according to the algorithm considered. The evolution of the orbital elements as a function of this parameter is first analyzed by means of a semi-analytical 3D extension of the energy kick function (Ross and Scheeres, 2007), which provides a first guess solution to the numerical procedures.

Emphasis will be put in showing how the resonant ratio can affect the outcome of the energy kick function, and also that the 3D nature of the problem cannot be disregarded, despite the low inclination of the orbits considered. Considering Herschel as a test case scenario, a comparative analysis with the strategy based on the closure of the zero velocity curves will be given in terms of Δv budget and time.