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ASTEROID FLYBYS FROM THE L2 SUN-EARTH LAGRANGE POINT

Abstract

Over a mission lifespan there are several phases where a spacecraft may underspend its fuel budget, leaving a limited but non-negligible amount of propellant at the end of the nominal mission timeline, unlocking possibilities to perform an add-on mission with a profile contrastive to the nominal. The present research was prompted by example of the ESA GAIA mission, where remaining propellant generated discussion for such secondary science. One option explores Near-Earth Asteroid (NEA) encounters from the L2 Sun-Earth (SEL2) Lagrange Point within a 2-year departure window. Mission requirements including limitations on total delta-v (up to 150m/s), Time of Flight (TOF, up to 9 months), and relative flyby velocities (up to 5km/s) enhanced the realism of the trajectory design. Two mission scenarios were based on the direction of escape along the SEL2 unstable manifolds: Design 1 employed an exterior transfer towards the first perihelion point, whilst Design 2 considered an interior escape from SEL2 followed by an Earth-powered flyby to widen the range of initial heliocentric orbit elements available for the NEA transfer design. Initial searches evaluated target asteroid reachability by assessing the Minimum Orbital Intersection Distance between the spacecraft and the NEA against a threshold value calculated from delta-v limitations of this study. Across the two different mission scenarios, over 8000 preliminary candidates were retrieved. A second filter based upon desirable traits returned 162 asteroids total, out of which an initial batch of 20 were selected – 10 from each design. Pork chop plots were built to provide reliable starting guesses for the candidate flybys and pave the way for trajectory optimisation. The latter was achieved by means of a single shooting method aimed at minimizing delta-v cost of the overall transfer whilst satisfying inequality constraints driven by the aforementioned mission requirements (TOF and/or relative flyby velocity).

Of the 20 candidates evaluated, 7 asteroids met the delta-v constraint set out at the beginning of the study. Of these 7, 3 also had relative flyby velocities below 3km/s, and 1 met the additional TOF constraint. Generally, Design 1 returned higher candidate yield but was less flexible during optimisation than Design 2. From just the initial batch so far it was surmised that not only can asteroid flybys be done within this delta-v, but they can be done for significantly less fuel than 150 m/s if desired. Other topics under consideration for further analysis include additional powered-flybys, and L1 Earth-Moon parking orbits.