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ASTEROID RETRIEVAL MISSIONS ENABLED BY INVARIANT MANIFOLD DYNAMICS

Abstract

Near Earth Objects (NEOs), i.e., asteroids and comets whose orbits come close to that of the Earth, are attractive targets for new space missions. This is mainly because of their scientific importance to understand the formation, evolution and composition of the Solar System, but also because of their impact threat, as well as the possibility to exploit their resources. The asteroid retrieval mission concept has thus arisen as a synergistic approach to tackle these three facets of interest in one single mission. This paper reviews the methodology used by the authors (2013) in a previous search for objects that could be transported from accessible heliocentric orbits into the Earth's neighbourhood at affordable costs. These objects were referred to as Easily Retrievable Objects (EROs). The methodology to search for EROs consists of a heuristic pruning of the complete NEO population (>12,000 objects) to obtain a manageable number of likely retrievable candidates. The latter group undergoes a global trajectory optimization procedure, where optimal lambert arcs are found to link the asteroid's orbit with a stable hyperbolic invariant manifold trajectory leading to a periodic libration point orbit near one of the collinear equilibrium points in the Sun-Earth system. However, the result of this optimization is a catalogue of impulsive retrieval opportunities. Low thrust propulsion on the other hand clearly enables the transportation of much larger objects due to its much higher specific impulse. Hence, low thrust retrieval transfers were sought using the previous lambert arc trajectory as first guesses to solve the optimal control problem required for low thrust trajectories. GPOPS-II (Patterson and Rao 2014) is then used to transcribe the continuous-time optimal control problem to a nonlinear programming problem (NLP). The latter was solved by IPOPT (Wächter and Biegler 2006), an open source software package for large-scale NLPs. Finally, a continuation procedure that increases the asteroid mass allows then to find out which is the largest objects that could be retrieved from a given asteroid orbit. If this retrievable mass is larger than the actual mass of the asteroid, the asteroid retrieval mission for this particular object is said to be feasible. The paper concludes with an updated list of 15 EROs, as of January 2015, with their maximum retrievable masses by means of low thrust propulsion. This ranges from 2,000 tonnes for the easiest object to be retrieved to 300 tonnes for the least accessible of them.