A Review of a Multi-Spacecraft Strategy for the Capture of Near-Earth Asteroids

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Near-Earth asteroids could be an important source of materials for future space missions or terrestrial markets. In order for these materials to be better accessible from Earth, asteroids can be captured into orbits in the vicinity of the Earth. These materials could then be used for in-space manufacturing, propellant, or life support [1].

A new strategy to capture near-Earth asteroids has been investigated using a 'pitcher' and a 'catcher' spacecraft. In this case, the pitcher hops from asteroid to asteroid and deflects them towards the vicinity of the Earth, while the catcher is stationed at the Earth and captures the incoming asteroids. A schematic of this two-spacecraft strategy is shown in Fig. 1, for the capture of one asteroid.

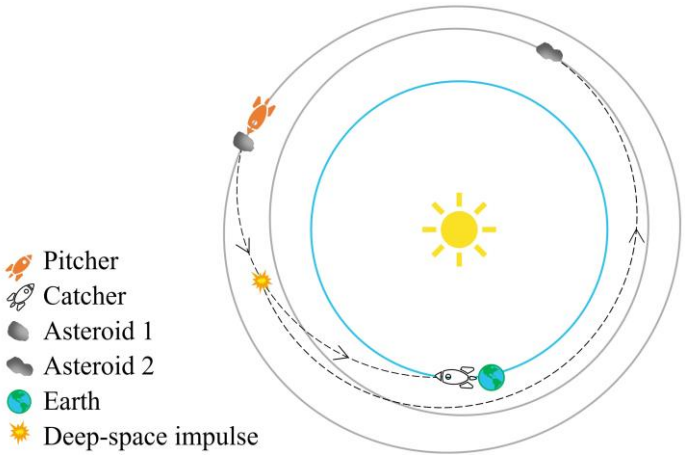

Fig. 1. Schematic of the capture of one asteroid with the two-spacecraft strategy.

At first, a scenario is investigated where the asteroids are deflected from their orbit and directly captured into Earth's heliocentric orbit, assuming impulsive maneuvers and two-body Keplerian dynamics [2]. A mass model is derived to estimate the quantity of asteroid mass that can be retrieved from a capture mission. The strategy using two spacecraft is compared to a strategy with a single spacecraft. It is assumed that both strategies launch the same mass. Thus, the masses of the pitcher and catcher together are equal to the mass of the single spacecraft. In a statistical analysis, where phasing is not taken into account yet and fictitious asteroids are targeted, it is found that the two-

spacecraft strategy is able to retrieve more asteroid mass than the one-spacecraft strategy. Furthermore, a larger number of asteroids can be retrieved using the two-spacecraft strategy. Since the initial spacecraft mass is distributed between the pitcher and the catcher for the two-spacecraft strategy, a staging effect is observed, such that more propellant is available for the deflection of the asteroids.

In addition, capture missions aimed at retrieving three asteroids have been analysed, where a subset of near-Earth asteroids from the JPL database has been used as potential targets. The phasing of the asteroids was considered in this case, which also made the comparison of mission durations possible. Similar to the statistical analysis, using the two-spacecraft strategy resulted in a larger retrieved mass than the one-spacecraft strategy. Moreover, mission durations were often shorter. Both the retrieved asteroid mass and the mission duration have an influence on the potential commercial revenue, where a larger retrieved mass and a shorter mission duration are favourable [3].

Subsequently, the use of Earth fly-bys was investigated to enhance the mass retrieval of the two-spacecraft strategy [4]. In this scenario, the pitcher performs a fly-by of the Earth before transferring to the next asteroid. The catcher is stationed in a circular Earth-centred orbit. A two-dimensional, patched-conic Keplerian model was assumed for all orbits. A comparison in terms of retrieved mass and mission duration was made among four strategies: a two-spacecraft strategy with a powered fly-by, a two-spacecraft strategy with an unpowered fly-by, a two-spacecraft strategy without a fly-by and a one-spacecraft strategy. Results showed that the two-spacecraft strategy with an unpowered fly-by was able to retrieve the largest amount of mass on average, but also had the longest mission durations on average. The two-spacecraft strategy without a fly-by performed best in terms of mission duration, since for this strategy, the pitcher does not have to intercept the Earth for the fly-by before transferring to the next asteroid. The pitcher had the least flexibility for the two-spacecraft strategy with a powered fly-by, where it applied an impulse during the fly-by at Earth. All two-spacecraft strategies performed better than the one-spacecraft strategy.

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