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NEAR-EARTH OBJECTS DEFLECTION STRATEGIES: A MULTICRITERIA COMPARISON FOR THE TARGET ASTEROID 2023 PDC

Abstract

The Solar System is populated by many asteroids and comets which orbit around the Sun. Some of these objects' trajectories can cross Earth's orbit, causing a collision. In particular Near Earth Objects (NEOs) can represent a collision threat to our planet. Historically, asteroids and comets have been impacting our planet, as the Chelyabinsk event, in 2013. This has motivated space agencies to set planetary defence programs, with the aim of selecting and developing different technologies for the deflection of potentially lethal asteroids and protect Earth from their resulting impact.

Continuing and extending the work of Sanchez et al. (2009), in this paper all the deflection strategies discussed in literature are described and compared, considering asteroid 2023 PDC as a target, a fictitious asteroid presented by NASA as an exercise in the Planetary Defence Conference (PDC). In the proposed solution by NASA in B. Barbee et al. (PDC 2023 simulated impact threat scenario, April 2023), only two strategies, kinetic impactor and nuclear standoff explosion were considered, and it was concluded that only the second one is useful for the deflection of 2023 PDC.

In addition to these two, in this article more strategies are considered, namely: multiple kinetic impactor, gravity, electrostatic and magnetic tractor, mass driver, ion beam shepherd, tugboat, laser ablation, tether ballast system and deviation through exploitation of the Yarkovsky effect. Based on a trade-off considering TRL, Δv provided to the asteroid to deflect it, effectiveness of the strategy, warning time, mission complexity and sensitivity to asteroid properties uncertainties of each technology, four of the listed strategies are considered for the following analysis: kinetic impactor, nuclear explosion, gravity tractor and laser ablation. A genetic algorithm based multi-objective optimisation process is used to maximise the deviation and to minimise the probability of collision. The results in terms of deflection are shown in Pareto fronts, using the deviation at Minimum Orbital Interception Distance (MOID), the initial spacecraft mass and the warning time as variables for the optimisation.

The paper concludes that, in addition to nuclear explosion, as suggested by NASA, also a multiple kinetic impactor missions, exploiting deep-space manoeuvres, with seven spacecraft with mass of 5700 kg, and a multiple gravity tractor strategy consisting of eight satellites (each one with mass of 11000 kg) disposed in two artificial Halo orbit, and laser ablation can be used to completely deviate the trajectory of asteroid 2023 PDC and avoid collision with Earth.