

✓ Hypothetical Asteroid Threat Exercise

DESIGN CONSTRAINTS FOR ASTEROID DEFLECTION CAMPAIGNS BASED ON DELTA-V ESTIMATION TIMELINES

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Thanks to the success of NASA's DART mission, the Kinetic Impact (KI) method is the only tested way of deflecting Near-Earth Asteroids (NEAs) away from the Earth [1]. However, one important consideration with KI deflections is the potential of disrupting the target while trying to deflect it. A disruption can happen if the NEA is small or if the relative impact momentum of the deflection spacecraft is too high. Recent studies indicate that unintended fragmentation of the asteroid can be avoided if the change in velocity (ΔV) of the asteroid due to a KI mission is less than 10% of its surface escape velocity [2]. Previous studies have proposed doing multiple, smaller deflections to avoid disrupting the target [3] and to increase the momentum transfer efficiency for targets with high curvature [4]. Campaigns with multiple KI spacecraft also offer redundancy in case one spacecraft fails to hit the target.

In order to safely conclude whether the threat from an impacting NEA has been mitigated (using one or more deflection spacecraft), we must estimate its ΔV as a result of the deflection. Doing so requires observations of the NEA both before and after the deflection event. The fastest method of acquiring these measurements is to have a reconnaissance spacecraft in orbit around the target. In this scenario, spacecraft tracking data can be converted to meter-level geocentric pseudo-range measurements, as was done by the OSIRIS-REx spacecraft at (101955) Bennu [5].

In this work, we provide timelines for estimating the ΔV for a deflection of the hypothetical asteroid 2024 PDC₂₅. We assume the presence of a reconnaissance spacecraft that can be tracked around the target NEA before and after deflection. Using this tracking data, we look to place constraints on the minimum time required to estimate the ΔV after a deflection. This is especially important for campaigns with multiple deflections because the uncertainties in the target's position compound after each deflection. Although we only apply this analysis to the hypothetical asteroid threat exercise based on asteroid 2024 PDC₂₅, we aim to generalize our results for any impacting asteroid.

Preliminary results show that the minimum time between deflections in a multiple KI campaign for 2024 PDC₂₅ needs to be at least a couple of weeks to confidently estimate the preceding ΔV before the next. Adhering to this constraint would enable decision-making ability between deflections and allow us to conclude whether the asteroid has been sufficiently deflected during the campaign. If this constraint is violated, our ability to reassess the asteroid's impact threat between deflections would be significantly affected. In this scenario, the campaign would have to follow a preset strategy without the ability to update it after each deflection. We would be able to conclude whether the impact threat from the NEA has been mitigated only after all the deflections were complete.

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Comments: *Oral Presentation; Eligible for Student Competition; The “Space Mission & Campaign Design” session would also be a viable alternative for this abstract.*

References

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