Paper ID: 84994
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IAF SYMPOSIUM ON PLANETARY DEFENSE AND NEAR-EARTH OBJECTS (E10)
Interactive Presentations - IAF SYMPOSIUM ON PLANETARY DEFENSE AND NEAR-EARTH OBJECTS (IP)

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TRAJECTORY OPTIMIZATION AND PRELIMINARY PERFORMANCE EVALUATION OF KINETIC IMPACT DEFLECTION TEST MISSION AGAINST 30 DIAMETER SINGLE ASTEROID

Abstract

Near-Earth Asteroids (NEAs) poses a major potential impact threat to Earth, and kinetic impact (KI) is currently the most mature and feasible means of planetary defense. The deflection effect of kinetic impact is closely related to the asteroid's orbit, structure, material composition, mechanical properties, impact velocity, and other factors. Implementing an in-orbit demonstration mission to understand the laws of momentum transfer and orbital deflection is crucial to an actual asteroid defense mission. The Double Asteroid Redirection Test (DART) Mission has been launched and successfully impacted the Dimorphos whose diameter is 160m. The majority of currently discovered Potentially Hazardous Asteroids (PHAs) are single asteroids. Compared to binary asteroids, assessing the deflection effect of a single asteroid solely through ground observations is challenging. Deploying observer to rendezvous the asteroid in advance enables the determination of its precise orbit, physical characteristics, and morphology before impact. Besides, the distribution of ejecta could be observed during the impact process and the effectiveness of the deflection can be evaluated after impact. This paper proposes a scheme where a rocket simultaneously launches an observer and an impactor. First, we introduced the criteria of target selection and designed the mission scenario according to the mission cost and the way to evaluate the deflection distance. Then the trajectories of observer and impactor were decoupled and the deflection distance was optimized under a high-precision orbital dynamics model of the solar system. The Venus's gravity assist for observer was used to resolve the contradiction between the need for the observer to rendezvous with the asteroid at a low relative velocity and the requirement for the impactor to impact with the asteroid at a higher relative velocity. Next, in order to launch the spacecrafts using one rocket and overcome the launch site constraint, we employed phasing maneuver in highly elliptical orbit for both spacecrafts. Finally, we evaluated the performance of kinetic impact asteroid deflection missions. Considering uncertain factors such as the momentum enhancement factor, we calculated the range of deflection distance and evaluated the risk of the asteroid impacting the Earth after the mission. We also analyzed the fragmentation possibility of the asteroid. This study can serve as a reference for in-orbit kinetic impact test mission against 20-50m diameter single asteroid.