PDC 2025
Stellenbosch, Cape Town, South Africa

Please submit your abstract at `https://iaaspace.org/pdc`.

(please select the topic that best fits your abstract from the list below)
(you may also add a general comment - see end of this document)

- ○ **Ongoing and Upcoming Mission Highlights**
- ○ **Apophis T-4 Years**
- ○ **Hypothetical Asteroid Threat Exercise**
- ○ **Key International and Political Developments**
- ○ **Near-Earth Object (NEO) Discovery**
- ○ **NEO Characterization**
- ◉ **Deflection & Disruption Modeling and Testing**
- ○ **Space Mission & Campaign Design**
- ○ **Earth Impact Effects & Consequences**
- ○ **Disaster Management & Impact Response**
- ○ **Public Education and Communication**
- ○ **The Decision to Act: Political, Legal, Social, and Economic Aspects**

Optimizing Trajectories in Asteroid Defense Missions: Potential Gains from Eccentric Collision Approaches

Kinthong Lee[a], Zhaokui Wang[a,*]

[a]*School of Aerospace Engineering, Tsinghua University, 30 Shuangqing Rd, Haidian District, Beijing, 100160, China*

Keywords: Eccentric Collision, Kinetic Deflection, Planetary Defense, Trajectory Optimization, Ejecta

In asteroid kinetic deflection missions, the presence of ejecta leads to a phenomenon where the system's momentum appears to be "amplified" after impact. In our previous work, we leveraged this phenomenon and demonstrated, through simulations of kinetic deflection missions to 32 potentially hazardous asteroids (PHAs), that striking a point offset from the geometric center of the asteroid results in a greater deflection distance compared to collision at the geometric center with an average increase of 81.05%, while keeping all impact conditions unchanged [1]. In the work, the transfer trajectory is adopted using the simplest two-impulse transfer, also referred as Lambert transfer. One of the conclusions indicates that as the interception angle α increases, the advantage of the Best Impact Point (BIP) strategy over the Center of Geometry (COG) strategy becomes more pronounced.

Real space mission involving multi-impulse or continuous thrust transfer trajectories, the cost function is defined as the deflection distance, with the objective of maximizing it. Adoption of the COG strategy usually results in an interception angle α close to zero, aligning the spacecraft velocity vector nearly parallel to the asteroid velocity vector at the moment of impact. However, with the introduction of the BIP strategy, it is not always necessary to have a near-zero interception angle α to maximize the deflection distance. This raises essential questions about the influence on trajectory optimization design. Does incorporating the BIP strategy lead to a notable improvement in deflection distance compared to designs that only consider the COG strategy? These questions drive the deeper investigation presented in this paper.

*Corresponding author
Email addresses: lijintan23@mails.tsinghua.edu.cn (Kinthong Lee), wangzk@mails.tsinghua.edu.cn (Zhaokui Wang)

This study aims to simulate the defense of 24 PHAs using both the BIP and COG strategies. A comparative analysis of the two approaches will be conducted to verify the feasibility of eccentric impact strategies in planetary defense missions. It is predicted that for each simulation of every PHA, there exists a transfer trajectory with a larger interception angle and strike at a best impact point, results in a deflection distance superior to that of the traditional approach with a near-zero interception angle and a strike at the geometric center.

References

[1] K. Lee, Z. Fang, Z. Wang, Investigation of the incremental benefits of eccentric collisions in kinetic deflection of potentially hazardous asteroids, Icarus 425 (2025) 116312.