Double Asteroid Redirection Test – Mission Design and Navigation

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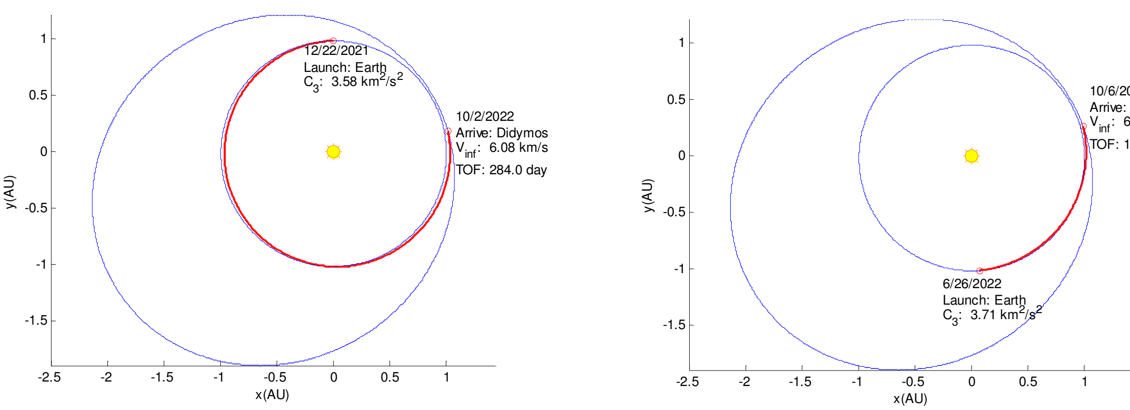
ABSTRACT

The Double Asteroid Redirection Test (DART) will be the first space experiment to demonstrate asteroid impact hazard mitigation by using a kinetic impactor to deflect an asteroid. DART is the interceptor element of the Asteroid Impact & Deflection Assessment (AIDA) mission, a joint NASA-ESA mission which also includes the ESA Asteroid Impact Monitor (AIM) rendezvous mission. The primary goal of AIDA is to measure and characterize deflection of an asteroid by a kinetic impactor. The results will have implications for planetary defense, human spaceflight, and near-Earth object (NEO) science and resource utilization.

The goal of the DART mission is to impact the smaller, secondary asteroid within a binary asteroid pair. Lambert-arc impact trajectories were generated to 38 binary pairs in the Near-Earth and Main-belt regions of the solar system. Each target and trajectory was evaluated on the basis of the impact geometry relative to the binary system's orbit plane, which is not necessarily coincident with the ecliptic plane. Given launch constraints, approach lighting conditions, and Earth-relative distances, the binary system Didymos was selected as a target. The baseline and backup trajectories are shown in Figure 1. In each case, there are no deterministic Δv's required, only statistical targeting burns.



a.) b.)

Figure 1. a.) Primary and b.) Backup trajectories to the Didymos binary pair.

DART will impact the 150 m diameter target with a closing velocity of roughly 6 km/s. The vehicle has a narrow field-of-view (5 mrad) camera as an optical payload, and uses chemical propellant for attitude control and delta-v maneuvers.

The navigation concept-of-operations is to divide the trajectory into three distinct modes: coast, primary-targeting, and terminal guidance. During the coast-mode, the vehicle is guided using ground-based measurements and commands. When the asteroid system is detectable using the on-board camera, navigation transitions to primary-targeting mode and uses optical navigation for updates. Finally, approximately one hour prior to impact, when the primary and secondary asteroids can be reliably differentiated, the system transitions to autonomous terminal-guidance mode. This mode employs high-rate sensing and on-board guidance algorithms to maneuver autonomously to target the secondary asteroid, without help from the ground. This approach is in contrast to traditional methods that use ground-based software to perform few carefully-targeted maneuvers, and would represent a new capability for deep-space missions. In this case, the high closing velocity, small target, and round-trip light time do not offer sufficient processing time for humans-in-the-loop.

When in terminal-guidance mode, the vehicle repeatedly images the target scene (Figure 2), removes any stars, identifies the primary and secondary asteroids, computes their respective centroids, estimates the linearized zero effort miss distance, and executes a targeting maneuver. Using an approach derived from proportional navigation, the vehicle performs maneuvers to minimize the final distance to the image centroid of the asteroid while maintaining sufficient fuel for future divert maneuvers. Initial simulations (Figure 3) of this process show robust, consistent targeting accuracy in the presence of high uncertainties.

a.) b.) c.)

Figure 2. Simulated images of the encounter at a.)10, b.)2.5, and c.)1.0 minute to impact.

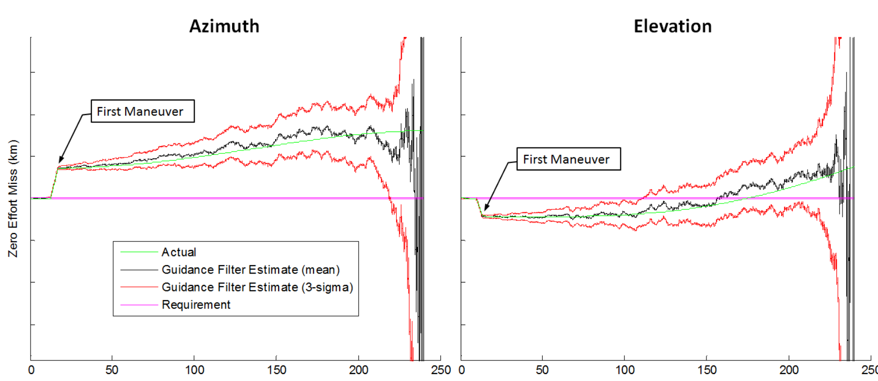


Figure 3. Sample results for the closed-loop guidance simulations.