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AIDA: ASTEROID IMPACT & DEFLECTION ASSESSMENT

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ABSTRACT

Abstract

To protect the Earth from a potential asteroid impact, various mitigation methods have been proposed, including deflection of the asteroid by a spacecraft impact. The Asteroid Impact & Deflection Assessment (AIDA) mission is a first demonstration of asteroid deflection and a characterization of the kinetic impact effects. AIDA consists of two independent but mutually supporting missions, one of which is the asteroid kinetic impactor and the other is the characterization spacecraft. These two missions are, respectively, DART and the European Space Agency's Asteroid Impact Monitoring (AIM) mission. DART will be the first ever space mission to deflect the trajectory of an asteroid and measure the deflection to within 10%. This will be done using a binary asteroid target with accurate determinations of orbital period by ground-based observations. AIDA will return vital data to determine the momentum transfer efficiency of the kinetic impact [1,2].

1. Introduction

DART follows the previous Don Quijote mission study performed by ESA in 2005 - 2007, whose objectives were to demonstrate the ability to modify the trajectory of an asteroid, to measure the trajectory change, and to characterize physical properties of the asteroid. Don Quijote involved an orbiter and an impactor spacecraft, with the orbiter arriving first, measuring the deflection, monitoring the impact and making additional characterization measurements. Unlike Don Quijote, DART envisions an impactor spacecraft to intercept the secondary member of a binary near-Earth asteroid, with ground-based observations to measure the deflection. In the joint AIDA mission, DART combines with the ESA AIM mission which will rendezvous with the asteroid. Each of these missions has independent value, with greatly increased return when combined. Both DART and AIM are low cost missions – for DART, under $150 million including launch; for AIM, in the 150 MEUR range.

2. DART Deflection Demonstration

The DART mission will use a single spacecraft to impact the smaller member of the binary Near-Earth asteroid [65803] Didymos in October, 2022. Didymos is an already well-observed radar and optical binary system. The impact of the >300 kg DART spacecraft at 6.25 km/s will change the mutual orbit of these two objects. By targeting the smaller, 150 m diameter member of a binary system, the DART mission produces an orbital deflection which is larger and easier to measure than would be the case if DART targeted a typical, single near-Earth asteroid so as to change its heliocentric orbit.

DART targets the asteroid Didymos in October, 2022, during a close approach to Earth. The DART impact will be observable by ground-based radar and optical telescopes around the world, providing exciting opportunities for international participation in this first asteroid deflection experiment. The DART mission will use ground-based observations to make the required measurements of the orbital deflection, by measuring the orbital period change of the binary asteroid. The DART impact will change the period by 0.5% – 1%, and this change can be determined to 10% accuracy within months of observations. The DART target is specifically chosen because it is an eclipsing binary [3], which enables accurate determination of small period changes by ground-based optical light curve measurements.

The DART payload is an imager based on New Horizons LORRI, a 20-cm aperture, CCD camera. Payload objectives are: to support autonomous guiding to impact the target body through its center, to determine the impact point within 1% of the target diameter, and to characterize the pre-impact surface morphology and geology of the target asteroid and the primary to <20 cm/px (goal).

The DART trajectory (Figure 1) remains near 1 AU from the Sun and has a maximum Earth distance <0.11 AU. The DART launch will use a Minotaur V launch vehicle. The impact velocity on Didymos is 6.25 km/s. A mono-propellant propulsion system is used for Δv burns and for attitude control.

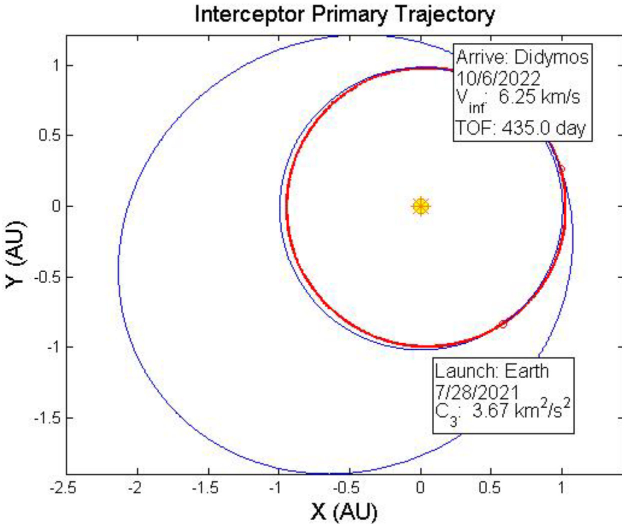

Figure 1. DART mission impacts Didymos in 2022 under excellent Earth-based viewing conditions.

3. Asteroid Impact Monitoring

The main objectives of ESA's Asteroid Impact Mission (AIM) mission are to: determine binary asteroid orbital and rotation state; analyze size, mass and shape of both binary components; analyze geology and surface properties; observe the impact crater and derive collision and impact properties (requires the DART mission). AIM will be a small spacecraft mission. The strawman payload for the characterization of the asteroid, which satisfies the minimum requirements, consists of a Narrow Angle Camera, a Micro laser Altimeter, a Thermal IR Imager and a NIR spectrometer.

The AIM rendezvous mission is designed to be compatible with the VEGA launch vehicle, which would require an additional "kick motor" (e.g., STAR-48) to perform the Earth escape burn. The baseline trajectory (Figure 2) involves an Earth swing-by and assumes a SNECMA PPS-1350 Hall-effect thruster, as demonstrated by ESA's SMART-1 lunar mission. On arrival, the spacecraft would perform continuous observations from a serious of "station points" fixed point relative to the asteroid inertial frame and at a safe distance, out of the sphere of influence of both Didymos components. In order to be able to image the two bodies for precise measurements of the orbital state, distances of 13.5 to 17 km were considered for the 1st characterization point. If the AIM spacecraft arrives at the target before the DART spacecraft, the impact of the DART spacecraft will be observed from a 2nd characterization point of 100 km to avoid any damage by impact debris.

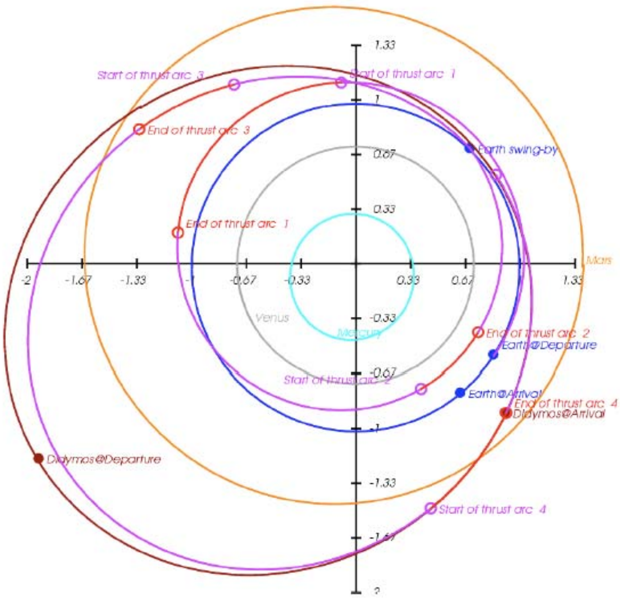

Figure 2. AIM electric propulsion trajectories.

4. Summary and Conclusions

DART will provide the first demonstration of asteroid deflection at low cost. Together with the AIM mission, the joint mission AIDA provides a full characterization and assessment of the kinetic impact. We thank numerous colleagues at APL, DLR, OCA, and NASA centers for generous and valuable support.

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