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Asteroid Impact and Deflection Assessment mission: the Double Asteroid Redirection Test (DART)

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Abstract

The Asteroid Impact & Deflection Assessment (AIDA) mission will be the first space experiment to demonstrate asteroid impact hazard mitigation by using a kinetic impactor. AIDA is a joint ESA-NASA cooperative project, which includes the ESA Asteroid Impact Mission (AIM) rendezvous spacecraft and the NASA Double Asteroid Redirection Test (DART) mission. The AIDA target is the near-Earth binary asteroid 65803 Didymos, which will make an unusually close approach to Earth in October, 2022. The ~300-kg DART spacecraft is designed to impact the Didymos secondary at 6.5 km/s and demonstrate the ability to modify its trajectory through momentum transfer. The primary goals of AIDA are (i) to investigate the binary near-Earth asteroid (65803) Didymos, (ii) to demonstrate asteroid deflection by kinetic impact and to characterize the deflection. The primary DART objectives are to demonstrate a hypervelocity impact on the Didymos moon and to determine the resulting deflection from ground-based observatories. The DART impact on the Didymos secondary will cause a measurable change in the orbital period of the binary.

1. Introduction

AIDA is a joint ESA-NASA cooperative project, which includes the ESA Asteroid Impact Mission (AIM) rendezvous spacecraft and the NASA Double Asteroid Redirection Test (DART) mission. AIM is in Phase A/B1 study at ESA as of early 2015 and continues until summer 2016. DART entered Phase A study at NASA in late spring 2015 until fall 2016.

The target of AIDA is the secondary member of the binary near-Earth asteroid (65803) Didymos, with the deflection experiment to occur in October, 2022. The DART impact on the secondary at ~6.5 km/s will alter the binary orbit period, which can be measured by Earth-based observatories. The AIM spacecraft will be launched in 2020 and arrive at Didymos in spring 2022. AIM will characterize the Didymos binary system by means of remote sensing and in-situ instruments both before and after the DART impact. The asteroid deflection will be measured to higher accuracy, and additional results of the DART impact, like the impact crater, will be studied in great detail by the AIM mission.

The joint mission AIDA will return vital data to determine the momentum transfer efficiency of the kinetic impact and key physical properties of the target asteroid.

2.AIDA/DART Science

The main objectives of the DART mission are to:

- Impact the secondary member of the Didymos binary system during its close approach to Earth in September-October, 2022
- Demonstrate asteroid deflection by kinetic impact and measure the period change of the binary orbit resulting from the impact, by ground-based observations
- Determine the impact location on the target asteroid, the local surface topography and the geologic context
- Develop and validate models for momentum transfer efficiency of kinetic impacts on an asteroid

DART will demonstrate a hypervelocity spacecraft impact deflection of a small near-Earth asteroid (NEA) and then measure the deflection caused by the impact. The DART mission includes ground-based optical and radar-observing campaigns of Didymos both before and after the kinetic impact, as well as modeling and simulation programs, in order to determine and understand the amount of deflection, as well as to develop and validate models for momentum transfer in asteroid impacts. In this way, DART helps us learn how to mitigate an asteroid threat by kinetic impact. AIM will further make detailed measurements of the DART impact and its outcome. AIDA will thus be the first fully documented impact experiment at real asteroid scale, allowing numerical codes to be tested and used for similar and other scientific applications at those scales.

DART is targeted to impact the smaller secondary component of the binary system [65803] Didymos, which has an 800 m primary and a 150 m secondary in an 11.9 hour orbit, from radar and optical observations [1,2]. The impact of the ~300 kg DART spacecraft at 6.5 km/s will produce a velocity change on the order of 0.4 mm/s, if the momentum is simply transferred to the target. However, production of crater ejecta, released back towards the incident direction, increases the momentum transferred to the target above that brought in by the incident projectile.

The momentum transfer efficiency of the spacecraft impact is characterized by the factor β, defined as the ratio of momentum transferred to the target to the incident momentum. The momentum transfer has been calculated using either well-known point source scaling relationships or numerical simulations [3-6]. Laboratory experiments have also measured the momentum transfer efficiency versus incident velocity in various target materials [7]. These studies predict β typically in the range 1.1 to 2.5 for a variety of target material properties, with lower β for low strength, porous targets, but higher values, even $\beta > 4$, are predicted for very strong, non-porous targets.

The DART impact leads to a significant change in the mutual orbit of the binary, but only a minimal change in the heliocentric orbit of the system, because the target's velocity change from the impact is significant compared to its orbital speed ~17 cm/s, although it is quite small compared to the heliocentric orbit speed ~23 km/s. Thus the change in the binary orbit is relatively easy to measure compared with the change in the heliocentric orbit.

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 is expected to change the period by ~0.5%, 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, which enables accurate determination of small period changes by ground-based optical light curve measurements. In an eclipsing binary, the two objects pass in front of each other (occultations), or one object creates solar eclipses seen by the other, so there are sharp features in the lightcurves which can be timed accurately.

The DART payload consists of a high-resolution visible imager to support the primary mission objective of impacting the target body through its center. The DART imager is required to support optical navigation on approach and autonomous navigation in the terminal phase. The imager is derived from the New Horizons LORRI instrument [8] which used a 20 cm aperture Ritchey-Chretien telescope to obtain images at 1 arc sec resolution. The DART imager will determine the impact point within 1% of the target diameter, and it will characterize the pre-impact surface morphology and geology of the target asteroid and the primary to <20 cm/px.

3. Summary and Conclusions

DART will be the first full-scale demonstration of asteroid deflection by a spacecraft kinetic impact.

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References

[1] Pravec, P. et al. (2003), (65803) 1996 GT, IAU Circular 8244.
[2] Scheirich, P., and P. Pravec, 2009, Modeling of lightcurves of binary asteroids, Icarus, 200:531-547.
[3] Holsapple, K. A., and K. R. Housen (2012), Momentum transfer in asteroid impacts. I. Theory and scaling, Icarus, 221(2), 875–887.
[4] Holsapple, K. A. (1993), The scaling of impact processes in planetary sciences, Annual Review of Earth and Planetary Sciences, 21, 333–373.
[5] Jutzi, M., and P. Michel (2014), Hypervelocity impacts on asteroids and momentum transfer. I. Numerical simulations using porous targets. Icarus 229, 247-253.
[6] Cheng, A. F. (2013) AIDA: Test of Asteroid Deflection by Spacecraft Impact. 44th LPSC 2013, paper 2985
[7] Housen, K. R. and K. Holsapple (2012) Deflecting asteroids by impacts: what is beta? 43rd LPSC 2012, paper 2539
[8] Cheng A. F. et al., (2008), Long-Range Reconnaissance Imager on New Horizons, Space Science Reviews, 140, 189, doi:10.1007/s11214-007-9271-6.