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DART: Double Asteroid Redirection Test

A.F. Cheng [1], P. Michel [2], C. Reed [1], A. Galvez [3], I. Carnelli [3]
[1] Johns Hopkins University Applied Physics Laboratory, (email: andrew.cheng@jhuapl.edu, phone: 1-240-228-5415), [2] University of Nice-Sophia Antipolis, CNRS, Côte d'Azur Observatory, [3] ESA Headquarters, Paris

Abstract

The Double Asteroid Redirection Test (DART) study has been undertaken by the Johns Hopkins Applied Physics Laboratory with support from members of NASA centers including the Goddard Space Flight Center, the Johnson Space Center, and the Jet Propulsion Laboratory, as one of two elements of a joint mission named Asteroid Impact & Deflection Assessment (AIDA), which 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. DART 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 – in the case of DART, under $150 million including launch.

1.1 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, which enables accurate determination of small period changes by ground-based optical light curve measurements. In an eclipsing binary [3], 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 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).

2. DART Mission

The DART trajectory 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.

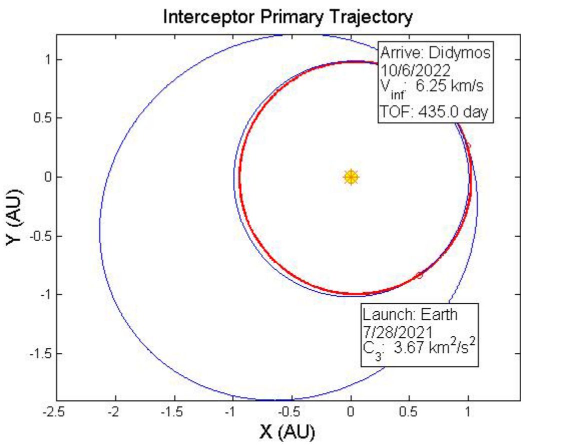

Figure 1. DART mission impacts Didymos in 2022 under excellent Earth-based viewing conditions.

3. DART Spacecraft

The DART mission uses a simple, high-technology-readiness, and low-cost spacecraft to intercept Didymos. DART hosts no scientific payload other than an imager for targeting and data acquisition as described above. The spacecraft is single string, and most of the components are either rebuilds of previous APL designs or commercial off-the-shelf equipment. Terminal guidance to the target asteroid is accomplished using the imager for optical navigation and using autonomous guidance algorithms based on APL experience in development of the Standard Missile used on US Navy ships for air defense. A mono-propellant propulsion system is used for all Δv burns. Three-axis attitude control is performed using thrusters.

The spacecraft wet mass is estimated to be 235 kg with 30% dry mass margin and with Δv capability of 100 m/s. Ballast mass would be added to reach the launch capability of 330 kg. Power is estimated at 202 W. The spacecraft has a fixed 1-meter high gain antenna with X-band telemetry. The mechanical layout of the spacecraft is optimized for the terminal navigation phase, with fixed geometries for the imager, high gain antenna, and solar arrays.

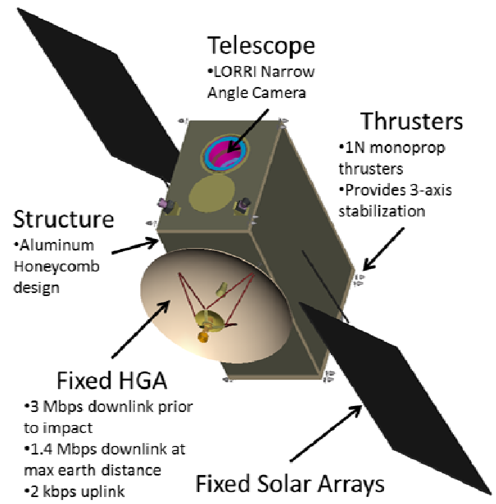

Figure 2. DART: simple spacecraft design.

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.

Acknowledgements

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References

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