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Ongoing and Upcoming Mission Highlights
Space Mission & Campaign Design

THE CHARACTER OF THE DART IMPACT SITE AND SHAPE OF DIMORPHOS

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ABSTRACT

The Double Asteroid Redirection Test (DART) is the first flight demonstration of kinetic impactor technology for planetary defense. On 26 September 2022 at 23:14:24.183 ±

0.004 UTC, the DART spacecraft intentionally collided with asteroid Dimorphos at a speed of 6.1449 ± 0.0003 km/s. The spacecraft streamed high-resolution images of Dimorphos in the minutes and seconds prior to impact, with the final complete image acquired 1.818 seconds before impact at a pixel scale of 5.5 cm. Scattered light from Didymos illuminated the dark side of Dimorphos and revealed the complete outline of the asteroid in images taken by the spacecraft.

We constructed a global shape model of Dimorphos and a digital terrain model of the impact site using stereophotoclinometry. We also reconstructed the spacecraft trajectory and orientation in the seconds leading to impact to accurately identify the impact site. This information is essential to determining the momentum enhancement from the DART impact and for interpreting the outcome of the impact.

This work shows that Dimorphos is an oblate spheroid with X, Y, and Z extents of 177 ± 2 m, 174 ± 4 m and 116 ± 2 m, respectively. The remarkably regular, oblate shape is unusual compared to the shapes of other near-Earth asteroids visited by spacecraft and is a key observable that models of Dimorphos' formation and evolution must explain.

The DART spacecraft hit Dimorphos 25 meters from the center of figure amid three boulders each larger than the spacecraft bus. The entire portion of asteroid imaged by DRACO is covered with boulders. The uncertainty in the impact site location is ±68 cm, which is smaller than the size of the spacecraft bus. The solar panels hit two of these three boulders (6.5 and 6.1 m-long, respectively.) The impact angle was 73 ± 7° degrees from local horizontal, where ± 7° is derived from the uncertainty in the impact location.

DART did not measure the mass of Dimorphos, but the total mass of the Didymos system is known from the orbit period and separation between the asteroids to be $(5.6 \pm 0.5) \times 10^{11}$ kg. If we assume that the densities of Didymos and Dimorphos are the same, then the density of Dimorphos is 2400 ± 300 kg/m^3. The assumption of equal densities cannot be rigorously tested using DART data alone, but is plausible given the similar densities of the primary and secondary asteroids in the few binary systems where density estimates exist for both objects. This density, combined with the volume of the Dimorphos shape model, implies that the mass of Dimorphos is 4.3×10^9 kg. This estimated density suggests a bulk porosity for Dimorphos on the order of 30% but with difficult-to-quantify uncertainties. The interior structure of Dimorphos remains ambiguous at this time. ESA's Hera mission will measure the mass, density, porosity, and interior structure when it arrives at the Didymos system in the late 2020s.

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Comments:

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