CHARACTERIZATION OF THE DART IMPACT SITE ON DIMORPHOS.

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Introduction: The Double Asteroid Redirection Test (DART) spacecraft impacted Dimorphos, the moon of the (65803) Didymos asteroid system, on 26 September 2022 at 23:14:24.183 UTC [1]. The spacecraft mass at the time of impact was 579.4 ± 0.7 kg, and the impact velocity was 6.1449 ± 0.0003 km/s, resulting in an impact energy of 10.94 ± 0.01 GJ [1]. The impact changed the orbital period of Dimorphos relative to Didymos by -33.0 ± 1.0 minutes [2], and the initial estimate of the resulting momentum enhancement factor, β, is between 2.2 and 4.9, depending on Dimorphos's mass [3].

Determining a value for β is not sufficient to understand the implications of the DART impact for planetary defense. The properties of the impact site affect the behavior of the excavated ejecta, thereby influencing β. The impact site must be characterized to understand the processes controlling the momentum enhancement and to provide key information for numerical impact models [e.g., 4]. Those results can be compared with measurements obtained from telescopes, LICIACube, and ultimately the Hera mission [5].

High-resolution images returned by DRACO, the onboard imager [6], revealed a boulder-strewn surface (Fig. 1) resembling other small near-Earth asteroids such as the S-type (25143) Itokawa [7], and carbonaceous asteroids (101955) Bennu [8], and (162173) Ryugu [9], suggesting a rubble-pile structure for Dimorphos. DRACO streamed images back to Earth every second in the four hours leading to impact; these images allow us to determine the location and surface characteristics of the spacecraft impact site. The final fully transmitted DRACO image was acquired ~1.818 seconds before impact and has a pixel scale of 5.5 cm.

Impact Location: The impact site was identified based on a reconstructed spacecraft trajectory (Fig. 1) and is known to ± 68 cm [1] (by comparison, the main spacecraft bus was approximately 1.2 x 1.3 x 1.31 m). This location corresponds to 8.84 ± 0.45ºS, 264.30 ± 0.47ºE on the preliminary shape model [1]. The impact occurred 25 ± 1 m from the center of figure of the asteroid. The spacecraft bus (~88% of the spacecraft mass at impact) hit between two large boulders (6.5 m and 6.1 m long, labeled in Fig. 2).

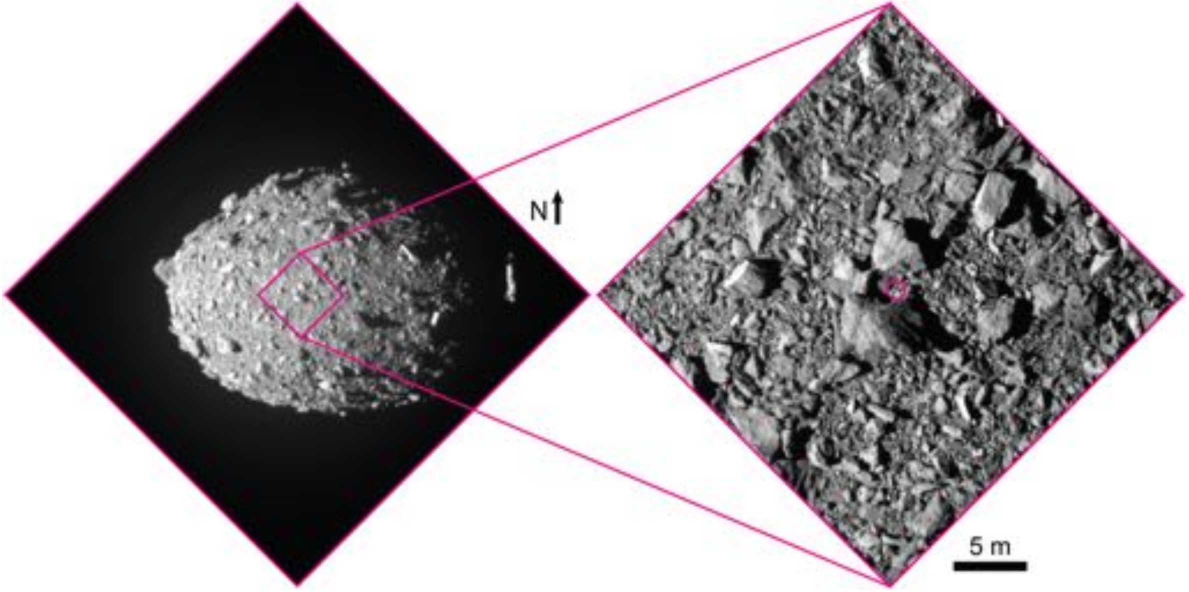

Figure 1. Left: The final DRACO image to contain all of Dimorphos (dart_0401930049_14119_01). The footprint of the final full image is shown. Right: The final full DRACO image transmitted back to Earth (dart_0401930049_43695_01). This image was acquired 1.818 seconds before impact and has a pixel scale of 5.5 cm. The impact site is indicated by a magenta circle.

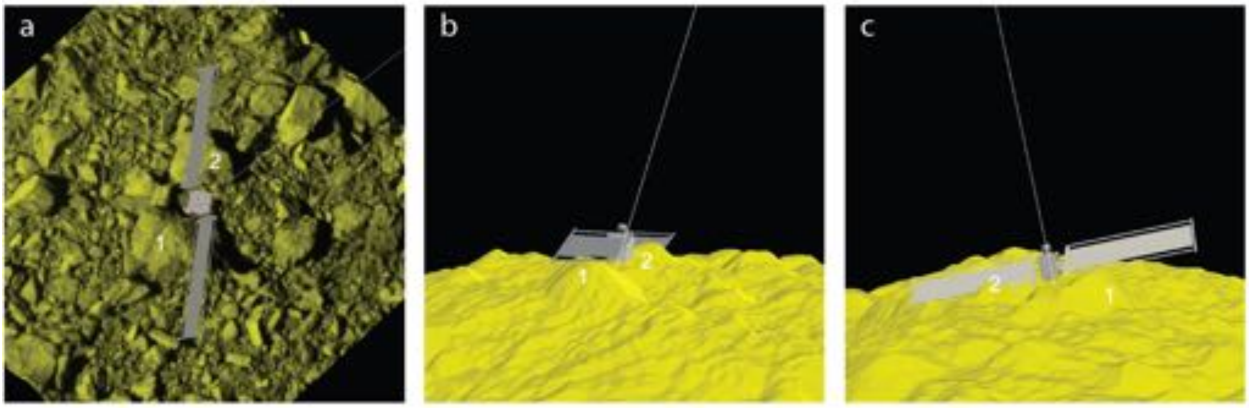

Figure 2. Views of the DART trajectory and orientation of the spacecraft just before impact. The two largest boulders are labeled in each pane; 1 is 6.5 m long, 2 is 6.1 m long. a) A view from above with final full DRACO image overlain on a local digital terrain model (DTM) of the impact site; b, c) Views from two sides of the spacecraft with respect to the DTM. The two large solar panels (each 8.5 m long) interacted with the two large boulders just before the bus impacted the surface between them.

Impact Angle: The impact angle was 73 ± 7º from local horizontal [1], determined using the preliminary shape model from tilts averaged over a 1.5-m radius. The uncertainty accounts for the distribution of angles that the spacecraft could have encountered given the ±68-cm uncertainty in impact site location.

Spacecraft-Surface Interaction: Fig. 2 illustrates the DART trajectory and orientation of the spacecraft moments before impact. The view from above suggests that the large solar arrays may have interacted with the two large boulders surrounding the point of impact. Side views indicate that one of the solar arrays made first contact with boulder 2, followed shortly by the other solar array with boulder 1, and finally the spacecraft bus between them.

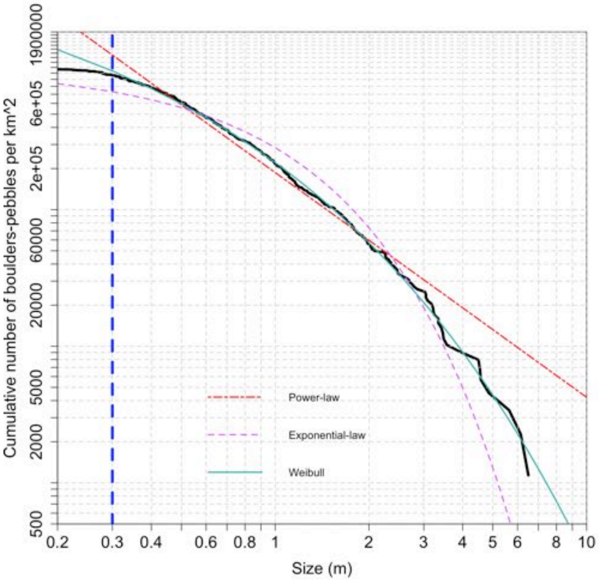

Figure 3. Cumulative size frequency distribution of 953 boulders measured within the final full DRACO image, surrounding the impact site. The data are best fit as a Weibull distribution. The blue dashed line is the lower limit used for the fit, assuming ≥5-pixel sampling.

Impact Site Characteristics: The impact site was covered in boulders and unconsolidated material that was easily mobilized. The blocky nature of the impact site likely influenced crater formation, ejecta, and momentum enhancement, and will be important to consider in impact simulations.

Boulders. The impact site, like Dimorphos's surface [10], is covered in boulders. A total of 953 boulders were identified and measured in the final full DRACO image (area 0.00088 km^2), the largest of which is the 6.5-m-long boulder just south of the DART impact site (boulder 1 in Fig. 2). The cumulative size-frequency distribution of these boulders is shown in Fig. 3; the data are best fit by a Weibull function [e.g., 11], as opposed to a power law that is often used to characterize boulder distributions on small bodies. There is evidence for cracks within boulders, "rocks on rocks", and partially buried boulders. There is no evidence for smooth deposits (grain size smaller than the image pixel scale) such as those seen on Itokawa.

Surface Motion. Broad scale surface displacements are not evident in light of local slope data. Initial analysis has identified many rocks on slopes <30º, but no rocks on slopes >30º, which may imply friction angle ~30º. Further investigation of the site may allow us to estimate key material properties important for modeling the impact.

References: [1] Daly, R.T. et al. (2023) *Nature*, in revision. [2] Thomas, C. et al. (2023) *Nature*, in revision. [3] Cheng, A.F. et al. (2023) *Nature*, submitted. [4] Stickle, A.M. et al. (2022) *PSJ* 3, 248. [5] Michel, P. et al. (2021) *PSJ* 3, 160. [6] Fletcher, Z.T., et al. (2022) SPIE, 121800E. [7] Fujiwara, A. et al. (2006) *Science* 312, 330–1334. [8] Lauretta, D. S. et al. (2019) *Nature* 568, 55–60. [9] Watanabe, S. et al. (2019) *Science* 364, 268–272. [10] Pajola, M. et al. (2023) this meeting. [11] Pajola, M. et al. (2019) *PSS* 165, 99–109.