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Ongoing and Upcoming Mission Highlights
Deflection / Disruption Modeling & Testing

Simulating the DART impact: Effects of spacecraft and boulder geometry on ejecta

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ABSTRACT

In NASA's Double Asteroid Redirection Test (DART) mission, the DART spacecraft impacted Dimorphos, the secondary asteroid of the (65803) Didymos binary asteroid system. This collision changed the trajectory of Dimorphos in its orbit around Didymos and released large streams of material from the impact site. In this study, we explore what material parameters are consistent with observations of the DART impact, including the boulder strewn surface observed by DRACO, the change in the asteroid's velocity, and the morphology of the ejecta cone observed by the Light Italian Cubesat for Imaging of Asteroids (LICIACube) as well as telescopic observations.

We examine a wide variety of material properties with 3D hydrocode simulations (example simulation setup shown in Figure 1). To model the impactor, we use a CAD model of the DART spacecraft (Owen et al., 2022), with the mass adjusted to match the estimated final mass of the spacecraft at impact. Additional runs using a simple spherical impactor as well as the three-sphere impactor analog described in Owen et al. (2022) are also performed for comparison. For Dimorphos, we use a best-fit ellipsoid constructed from DRACO observations and filled with a mix of matrix and boulders. The Tillotson equation of state for the asteroid material and Weibull parameters describing damage behavior were set to match deformation experiments on the Aba Panu meteorite (Rabbi et al., 2021). In addition to porosity (and thus asteroid mass), varied material properties included yield strength, shear modulus, and coefficient of friction for both intact and damaged material.

Simulations are defined either manually or by using a random forest regressor, an ensemble machine learning algorithm built on a series of decision trees. Manually defined sets of simulations allow us to easily explore the effects of a few variables by systematically varying them, while the simulations directed by the random forest regressor help us fill out the simulation space and identify other possible combinations of parameters that reproduce observations. Here, we focus on the uncertainties associated with the properties and arrangement of boulders and how these unknowns could affect the ejecta production and morphology.

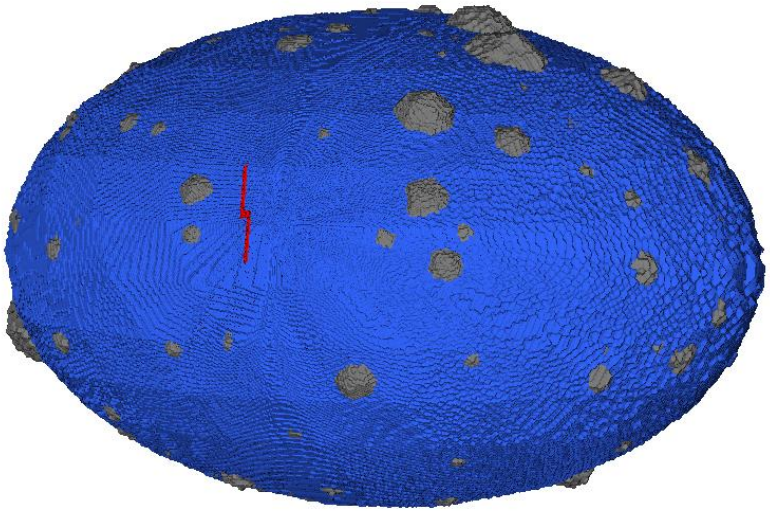

Figure 1: An example of a simulation setup with 50% matrix and 50% boulders. The DART spacecraft is shown in red, the matrix material in blue, and the boulders in grey.

References:
Owen et al. (2022), PSJ, doi: 10.3847/PSJ/ac8932
Rabbi et al. (2021), MPS, doi: 10.1111/maps.13761

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