The DART Impact – Testbed for Crater Scaling and Ejecta Simulation Models. N. Schmedemann[1], H. Hiesinger[1], [1]Institut für Planetologie, Westfälische Wilhelms Universität, Münster, Germany (nico.schmedemann@uni-muenster.de).

Introduction: On September 26 2022, 23:14 UTC the Double Asteroid Redirection Test (DART, [1]) projectile spacecraft hit the surface of Dimorphos, which is a satellite of 65803 Didymos, a near Earth asteroid (NEA). The aim of the DART mission was to test the effect of an artificial impact to manipulate the orbit of an asteroid as a potential way to deflect hazardous asteroids. Initial measurements indicate a significant reduction of the orbital period of Dimorphos around Didymos. Telescopic observation of the impact also showed a plume of impact ejecta erupting from the impact site and dispersing into space. In our work we want to test how close we can resample the telescopic observations by the application of NAIF SPICE [2] mission data as well as crater scaling [3] and ejecta scaling [4] models. For the best possible model of the ejecta plume it is important to know the exact time and location of the impact. Due to the small size of the target body of only 88.5 m × 87.0 m × 58.0 m (a×b×c axis radii) and a projectile impact speed of ~ 6 km/s, even a very small variance of the time of impact could result in significant offsets of the geographic position of the impact site, and thus, a different geometry of the resulting ejecta plume.

Methodology: For our approach we use reconstructed SPICE kernel data "d420a" provided on the mission website [5]. For analyzing the SPICE kernel data, we use the Matlab MICE Toolkit version N67 [6]. Our ejecta scaling model requires knowledge about the sizes of the projectile and the resulting crater. The projectile size (1.8 m × 1.9 m × 2.6 m) and mass (610 kg) is well known from mission data as a rectangular shaped object that, for model requirements, was converted into a sphere of 2.1 m diameter and a density of 125.8 kg/m³. With the scaling parameters listed in Table 1, we calculate a resulting impact crater of about 20.1 m diameter based on porous crater scaling.

Table 1: Scaling parameters for target body.

Parameter	Value
Target Density	2164.9 kg/m³
Projectile Density	125.8 kg/m³
Impact Velocity	6.145 km/s
Impact Angle	45°
Surface Gravity	4.9628×10^{-05} m/s²
Strength to Gravity Transition	100 km (all craters in strength regime)
Simple to Complex Transition	100 km (all craters are simple)
Projectile Diameter	2.1 m
Crater Diameter	20.1 m

For the ejecta scaling, we use a predefined set of parameters that is named "Sand" in [4]. For simplicity we let all particles eject at an 45° angle with the local surface. The exact time and location of impact is taken from SPICE kernel data (Fig.1). At split second resolution, Fig. 1 shows the importance of the exact time of impact, as values for longitude and latitude significantly change at the time of impact.

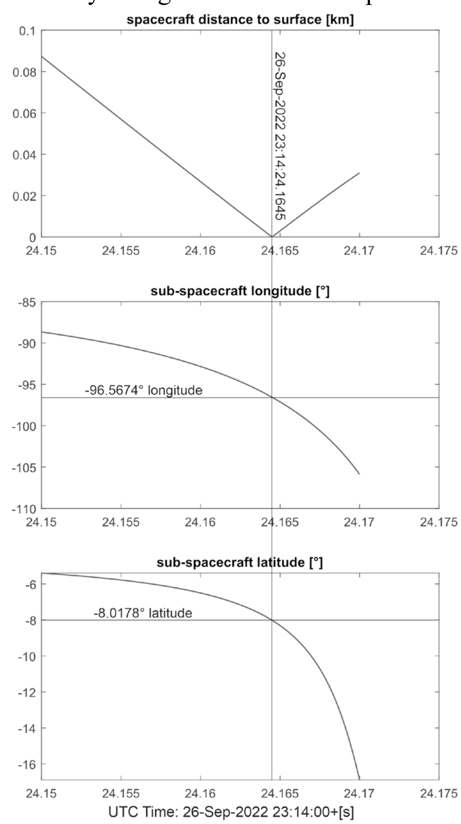

Fig. 1: Spacecraft location around the time of impact.

Results: In our crater scaling model we expect a crater diameter of 20.1 m. Even though it doesn't seem to be large, given the small dimensions of the target body that value equals about 12% of the target body diameter. The used ejecta scaling model provides information about how much mass was ejected at which velocity. Due to the low gravity of the target object its escape velocity is very low at about 0.09 m/s. Unfortunately, our model in its current form doesn't provide enough resolution at such low ejecta velocities. Thus, the slowest modeled particles are ejected at 0.8 m/s and all modeled ejecta particles are escaping the target body. Fig. 2 shows the mass-velocity distribution diagram of the impact.

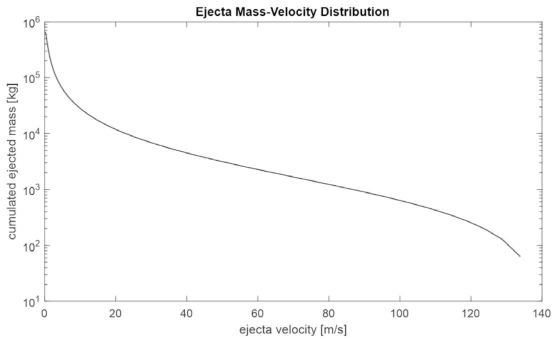

Fig. 2: The ejecta mass-velocity distribution shows how much mass has been ejected above any given velocity.

In Fig. 3 we show actual telescopic post-impact images [7] of the Hubble WFC3 instrument and for comparison the modeled ejecta plume as it would look like in the Hubble WFC3 field of view and at the same time slices after impact. The telescopic images show more fine structure, that is probably caused by a large number of very small particles for which the resolution of our ejecta model is insufficient. The Hubble data shows a few ejecta jets East (left) of Didymos, where the model has no dense particle accumulations. However, the main ejecta plume extending to the bottom (South, shorter extend) of the images and to the upper right image corners (North West, wider extend), appear similar, although more straight in the telescope image data. Note, that the telescopic images also show a cross-like artifact caused by refraction effects of the secondary mirror mount, tilted by 45°.

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[4] K. R. Housen and K. A. Holsapple, *Icarus*, 211, 856 (2011).

[5] https://dart.jhuapl.edu/SPICE_kernels/

[6] https://naif.jpl.nasa.gov/pub/naif/toolkit_docs/MATLAB/info/dscriptn.html#Toolkit%20Contents%20Description

[7] https://esawebb.org/images/weic2215b/

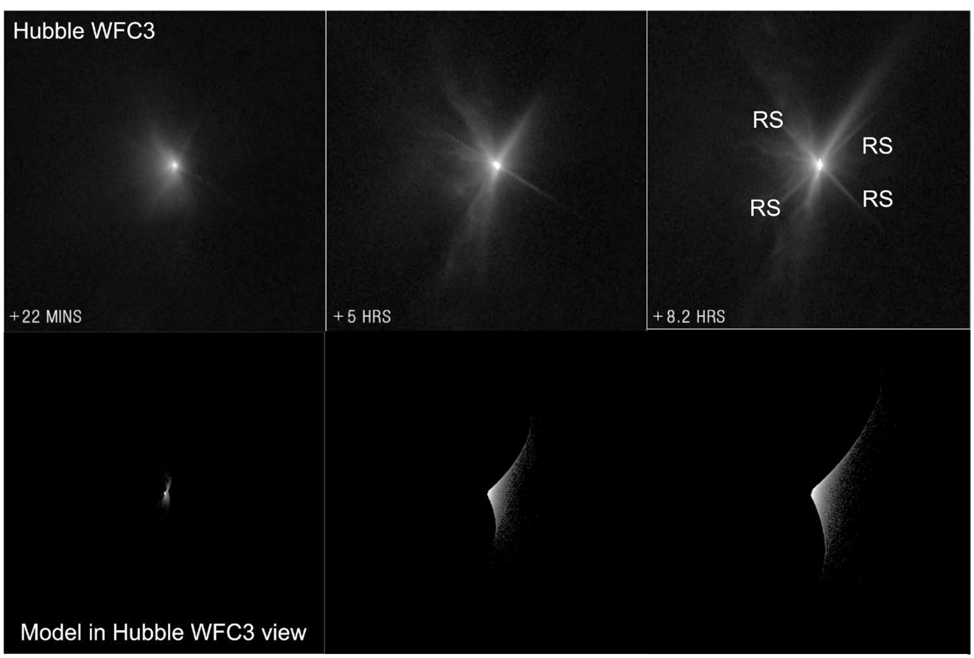

Fig.3: Comparison of Hubble WFC3 post-impact imagery [7] with model ejecta data at the same time slices and image geometry. The Hubble images show artifacts, which are refraction spikes (RS) of the telescope secondary mirror mount.