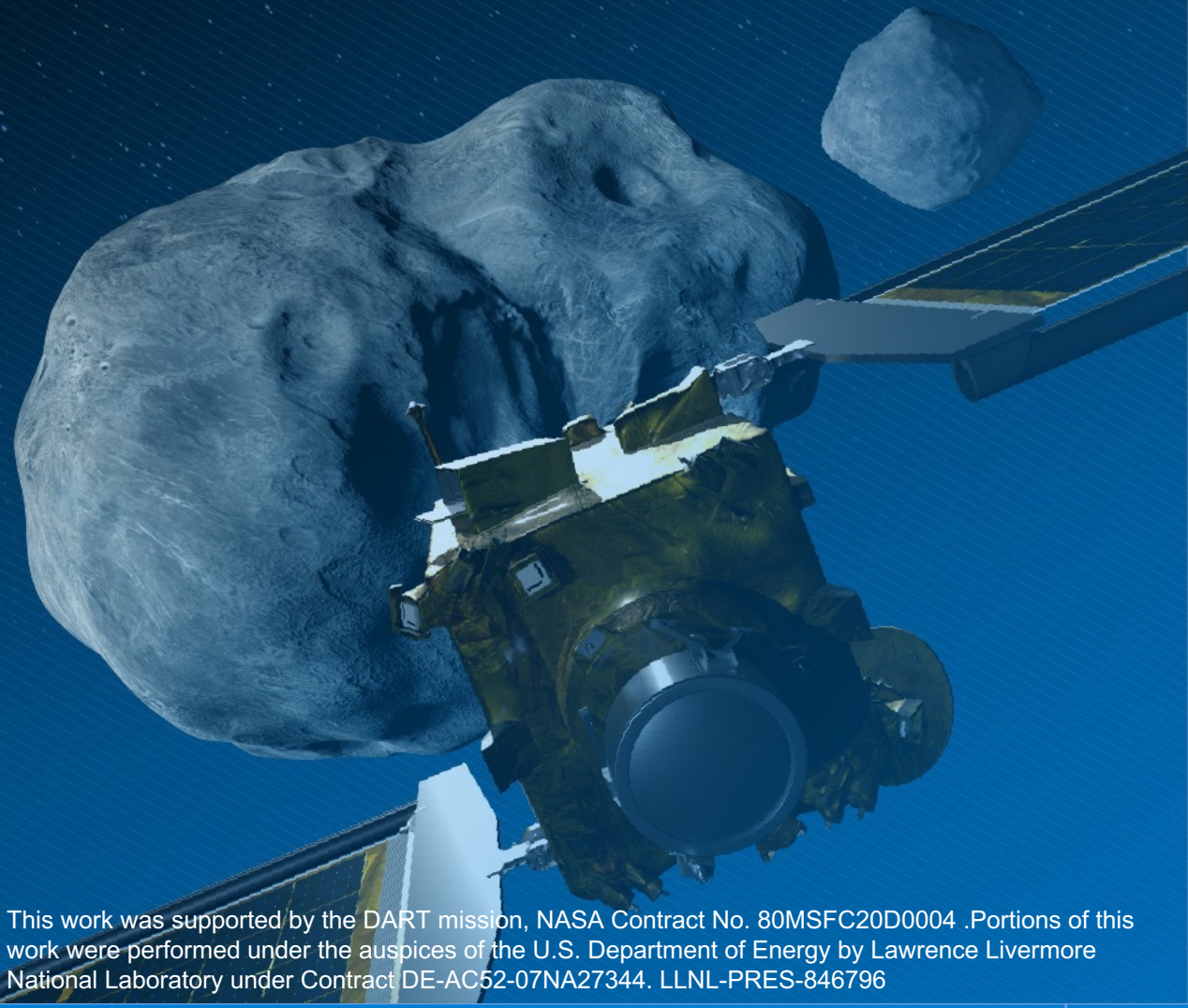
Spacecraft Geometry Effects for the DART Mission

Dawn Graninger
Johns Hopkins University Applied Physics Laboratory
Dawn.Graninger@jhuapl.edu

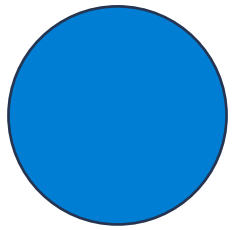
Coauthors: Mallory DeCoster, Katie Kumamoto, Mike Owen, Angela Stickle

PDC 2023 - April 5, 2023



This work was supported by the DART mission, NASA Contract No. 80MSFC20D0004 .Portions of this work were performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-846796

The DART Impact – A complex impactor



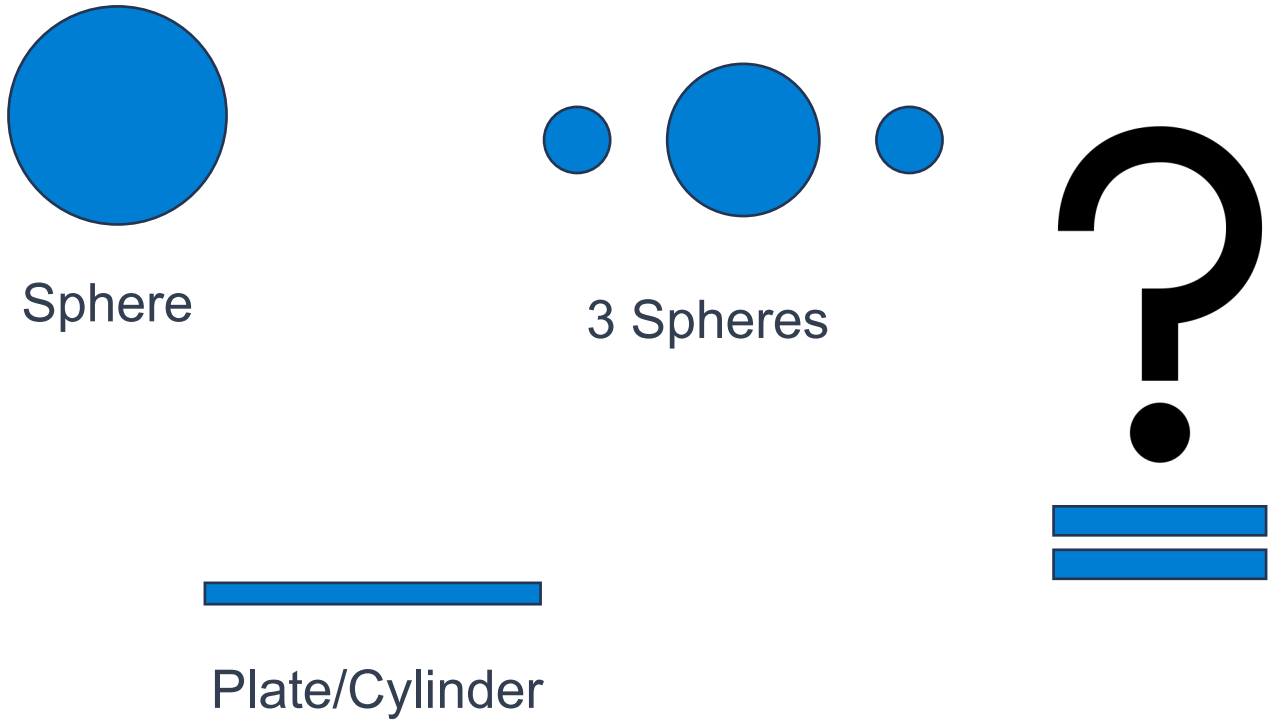
Sphere

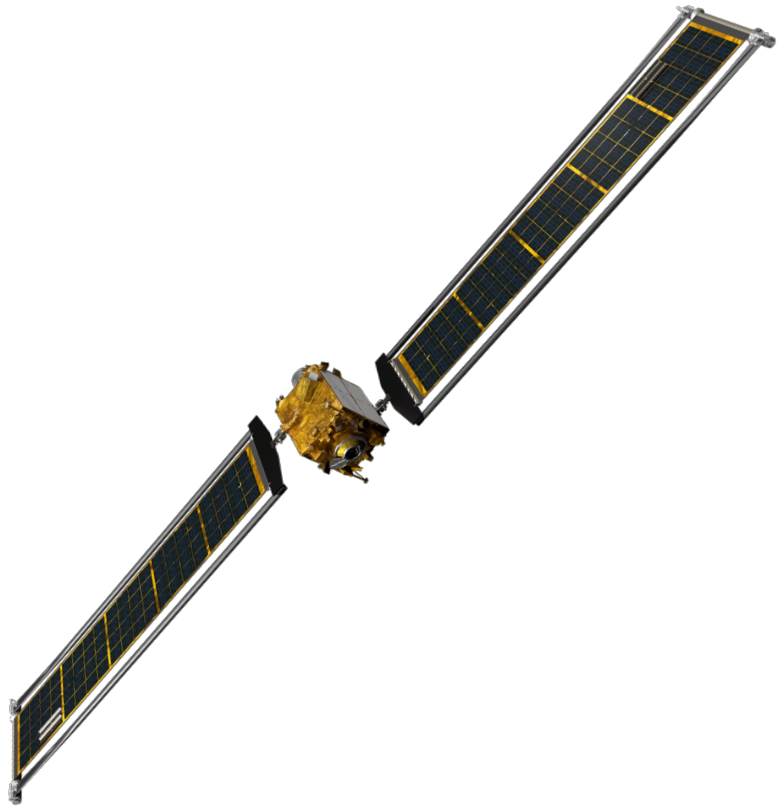
3 Spheres

Plate/Cylinder

Typically used in Models…

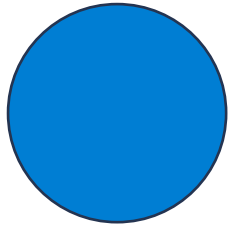
The DART Impact – A complex impactor





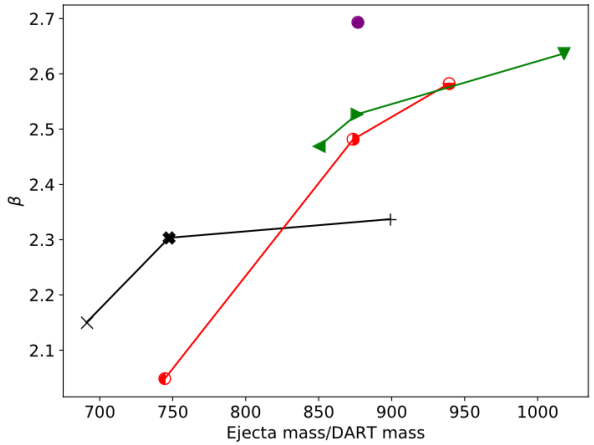
Typically used in Models…

What did pre-impact simulations suggest?

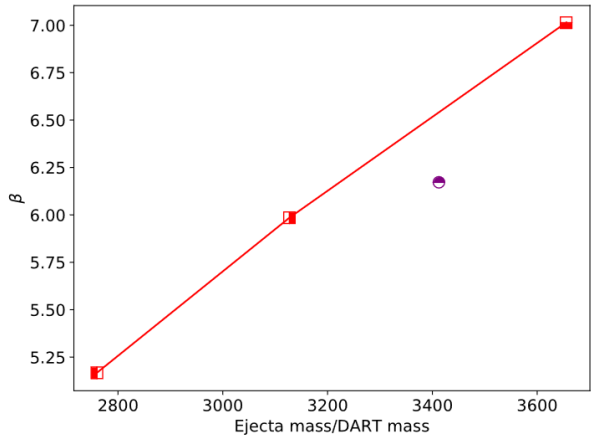


A sphere can overestimate the value of β by 10 – 20% compared to the DART spacecraft geometry

3 spheres better approximates DART spacecraft geometry, but still is an overestimate…



(a) Weak target (Spheral)



(b) Weak target (iSALE)

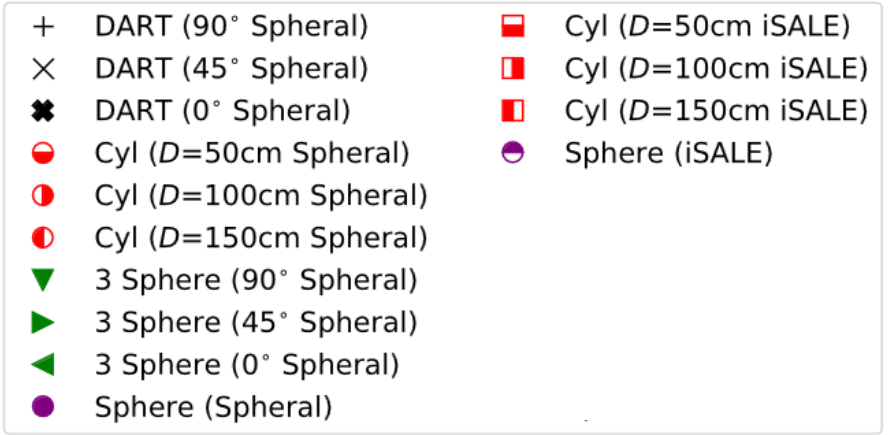
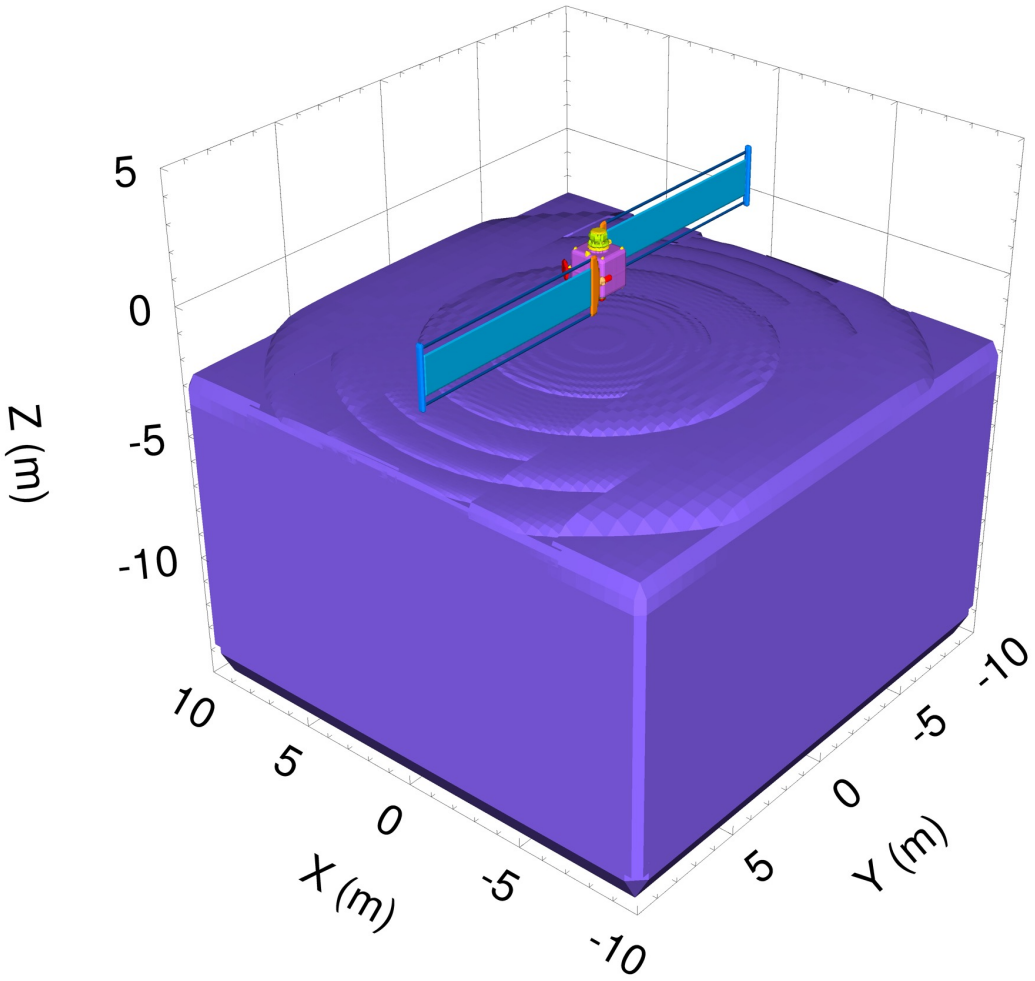


Figure adapted from Owen et al. 2022

Impact using the DART Spacecraft Geometry



Full Spacecraft CAD Model with 580 kg mass – does not model Xe and hydrazine

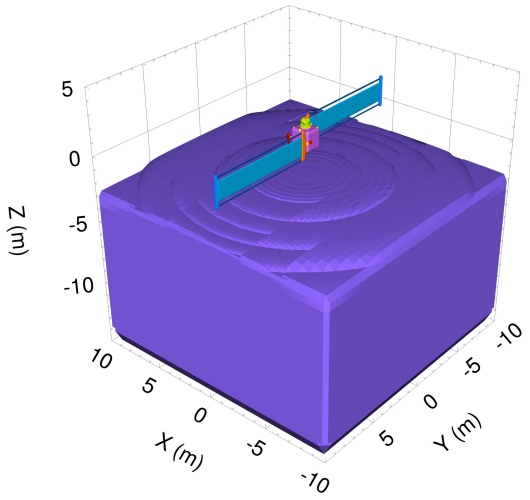
Highest resolution = 7 cm

Dimorphos Density = 2.3 g/cc

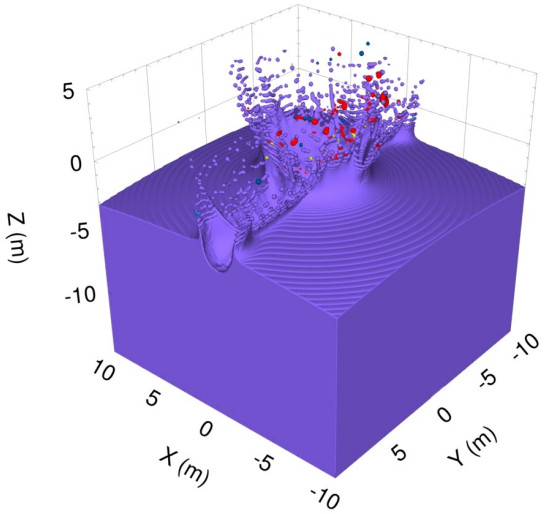
Granular Material with 1 kPa cohesive and tensile strength (using GEO model in CTH) with Johnson-Cook Damage and coefficient of internal friction of 0.7

Impact Speed = 6.15 km/s

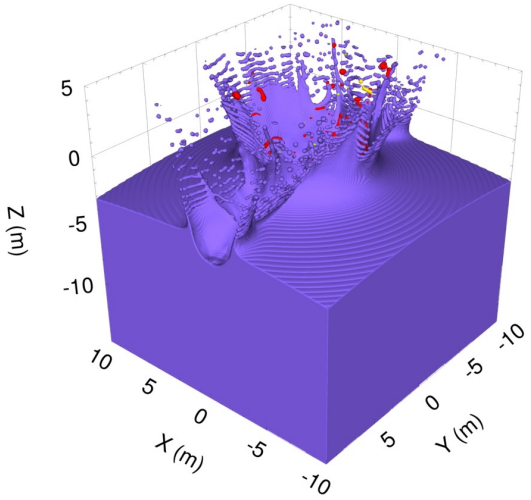
Impact Timeline in Simulations



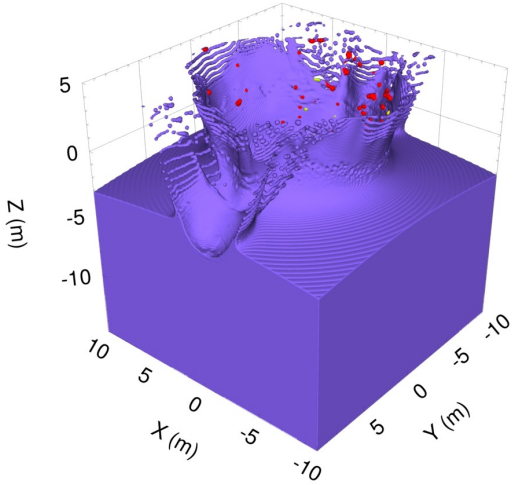
t = 0 sec



t = 0.025 sec



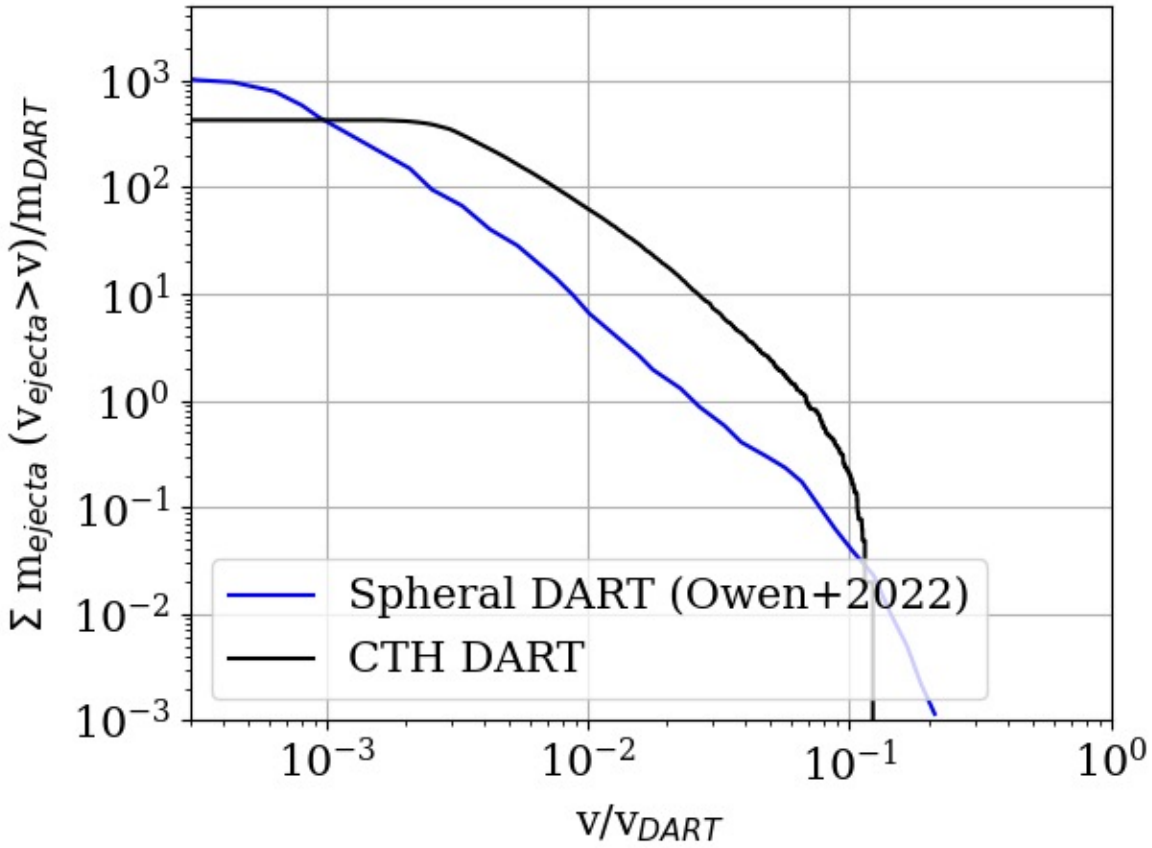
t = 0.05 sec

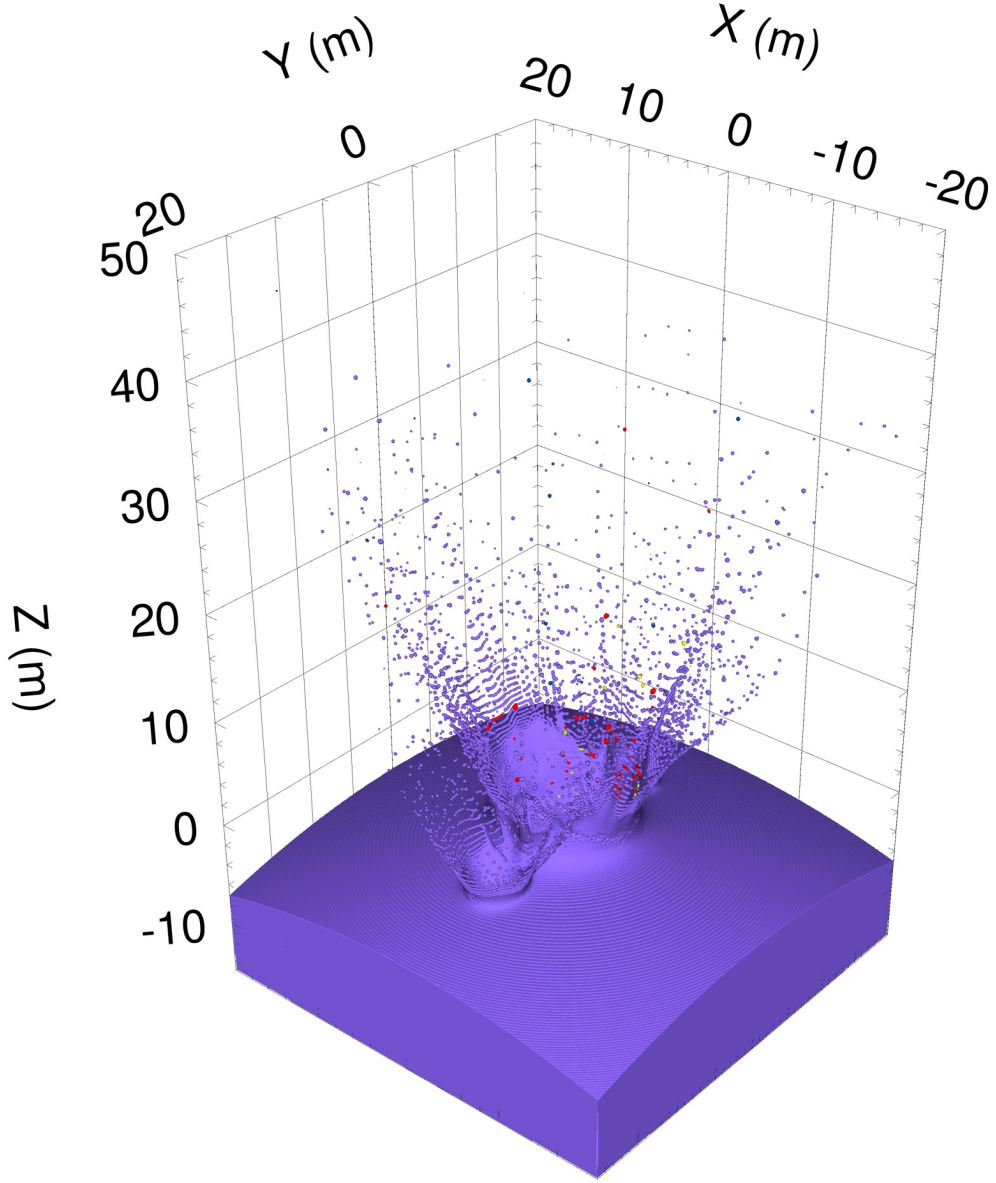


t = 0.1 sec

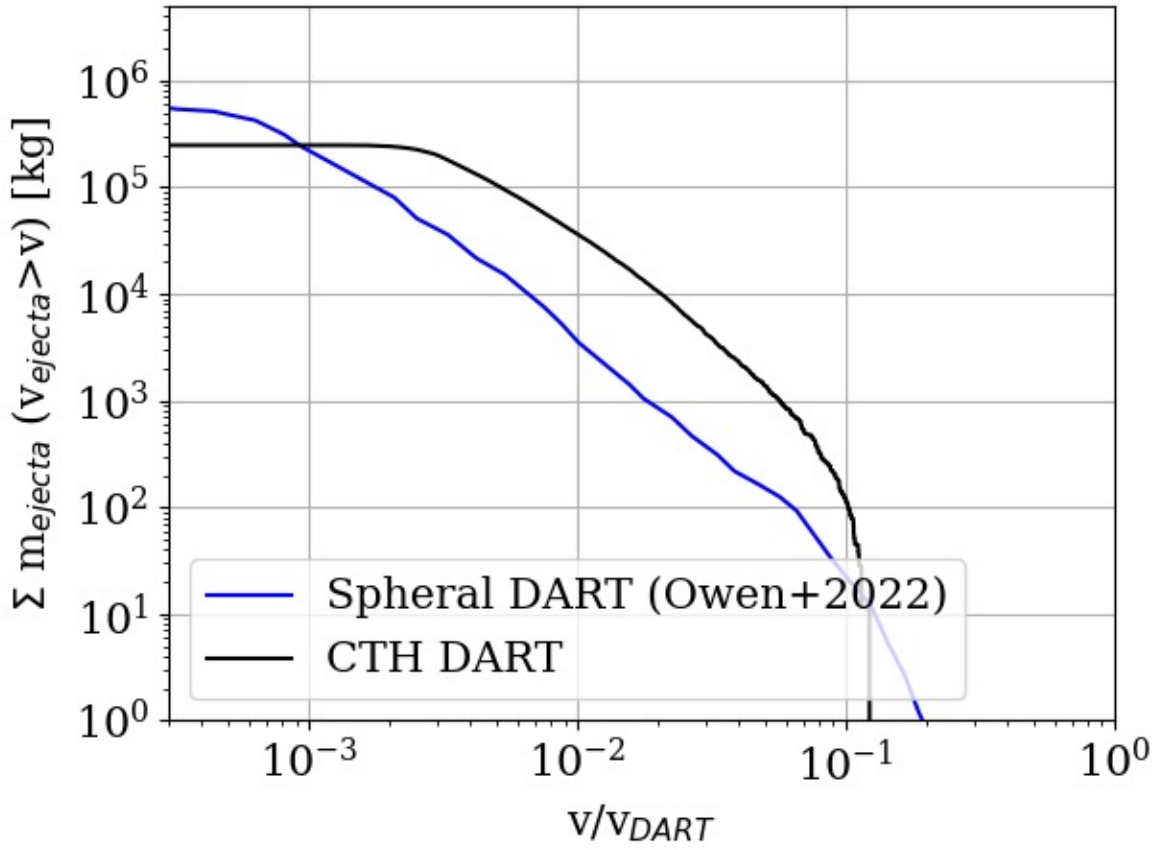
The evolution of the crater and the ejecta is influenced by the spacecraft shape

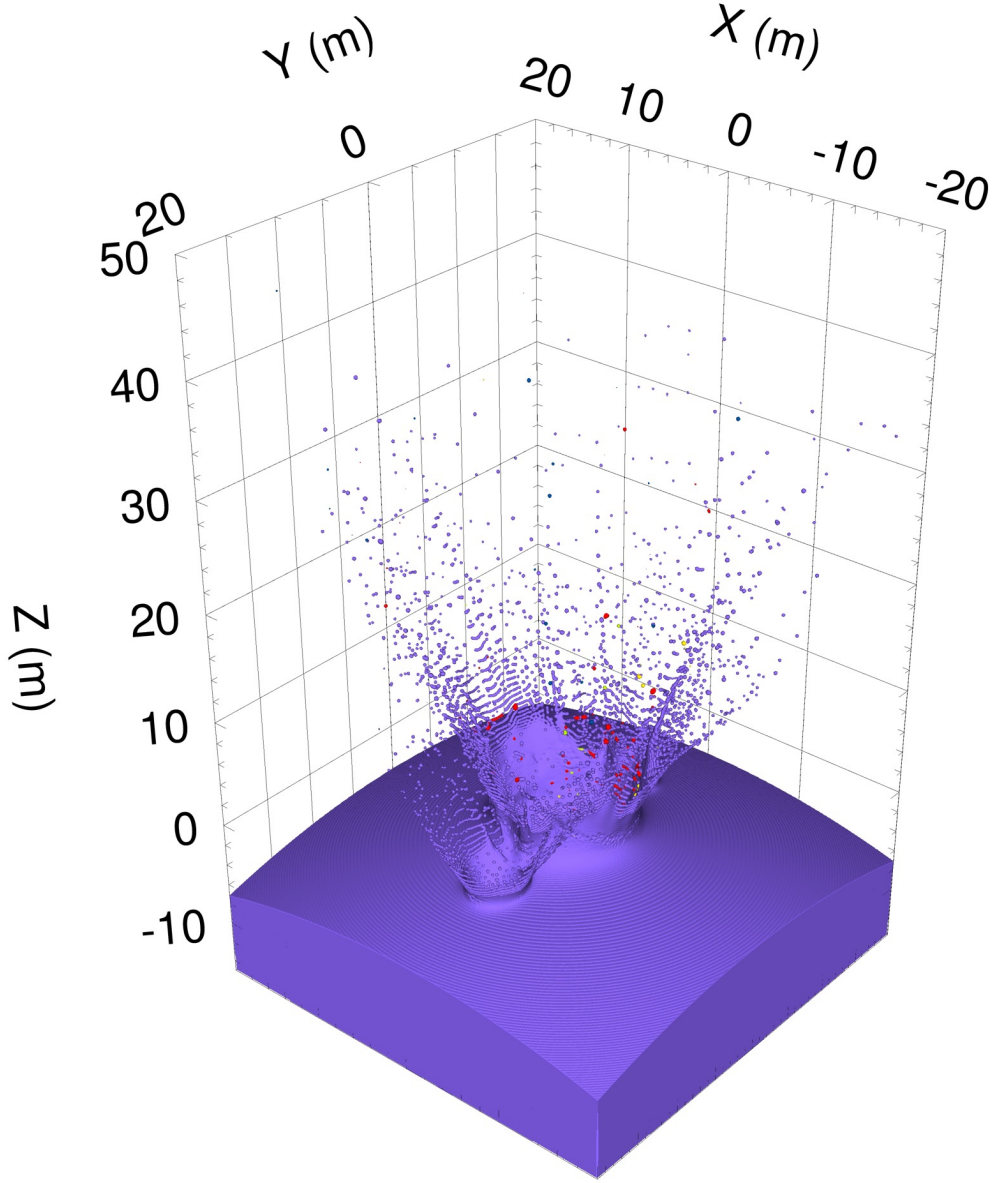
Ejecta Cone and Properties





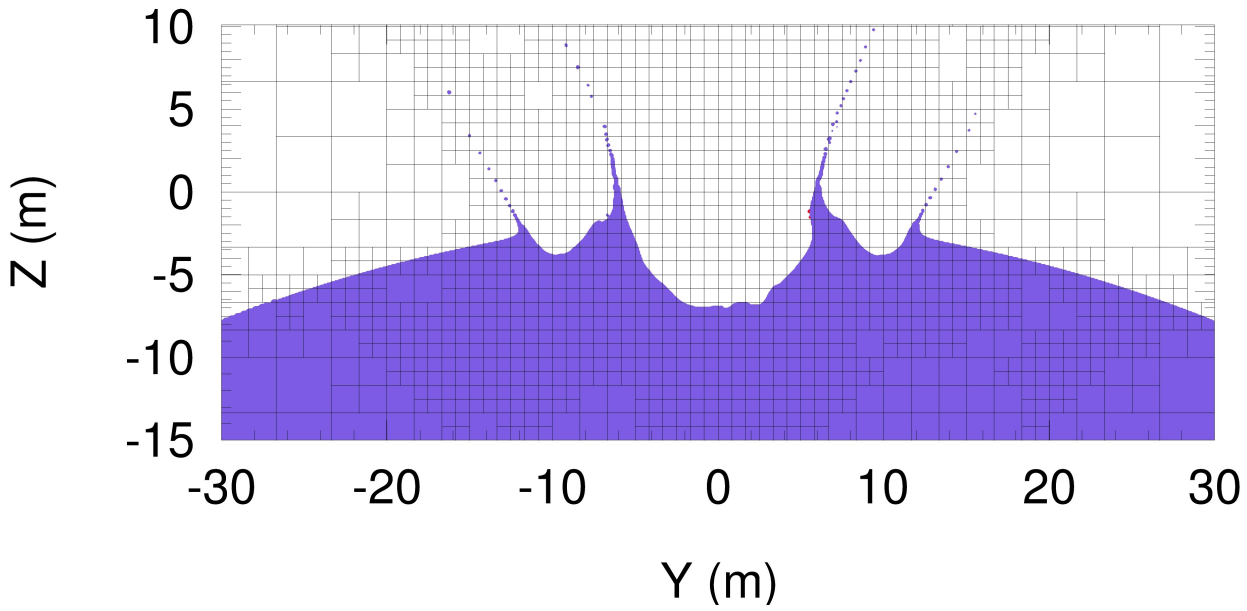
Ejecta Cone and Properties





Ejecta is still being produced at these early times…

Crater Properties at 100msec

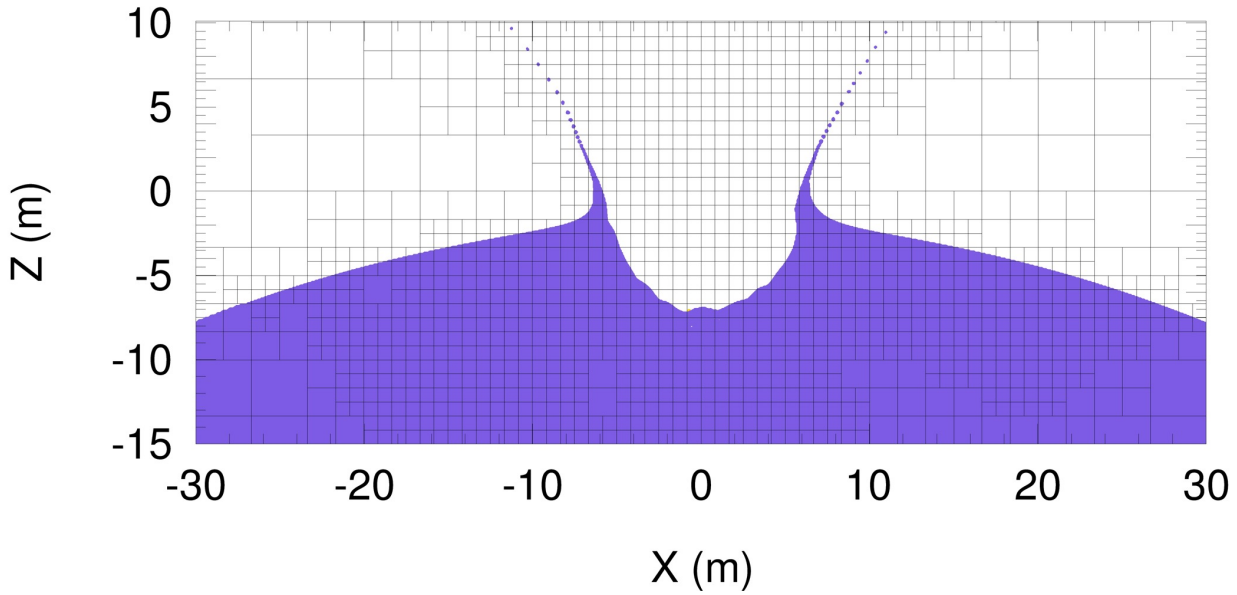


At these times, the crater is still growing…

Not clear from this analysis if the side lobes will merge into the central crater or not…

At this time using this method, approximate crater size is:

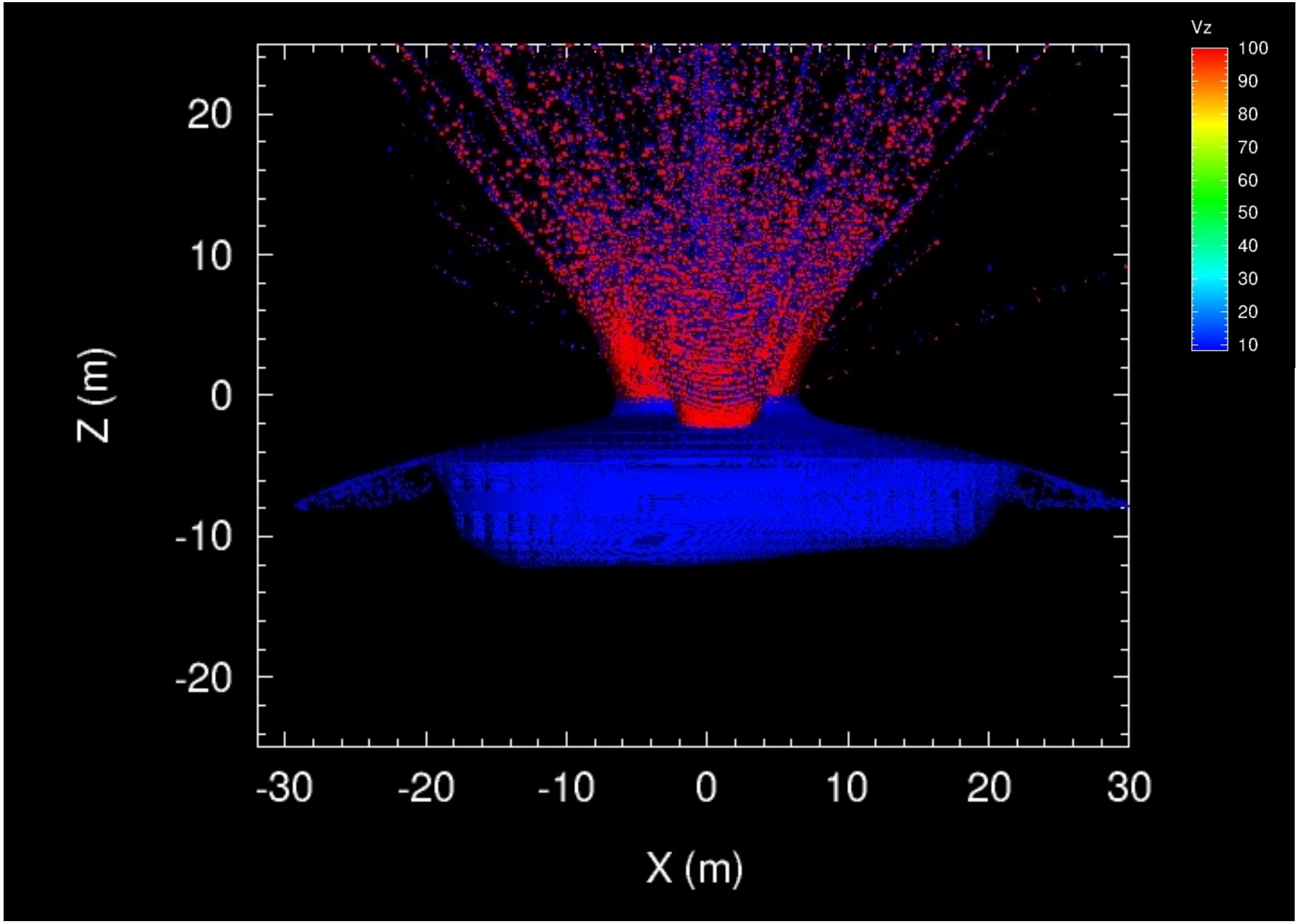
Side craters: ~ 4 meters
Central crater: ~ 10 meters
Total crater width ~ 20 meters



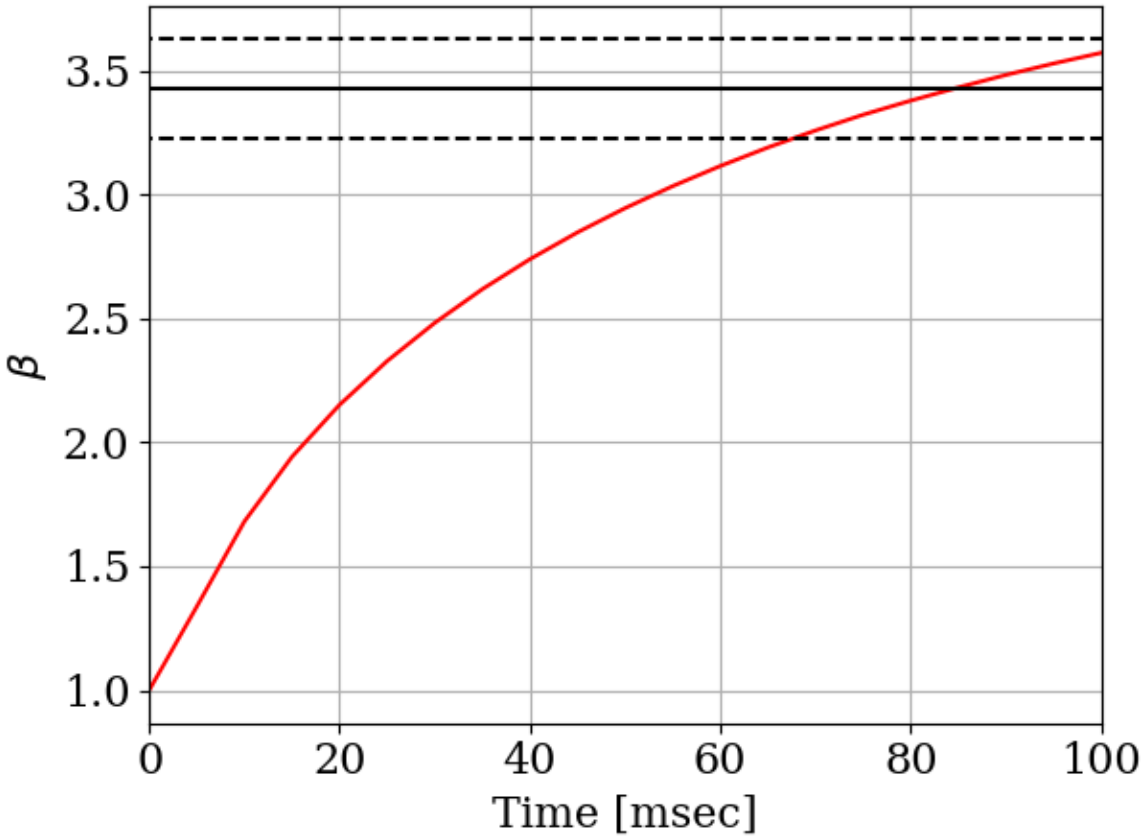
Crater Properties at 100msec

But we can use velocity thresholds using the escape velocity of the system as the threshold…

Expands the final crater size up to **~40 meter** diameter and the crater lobes have merged.

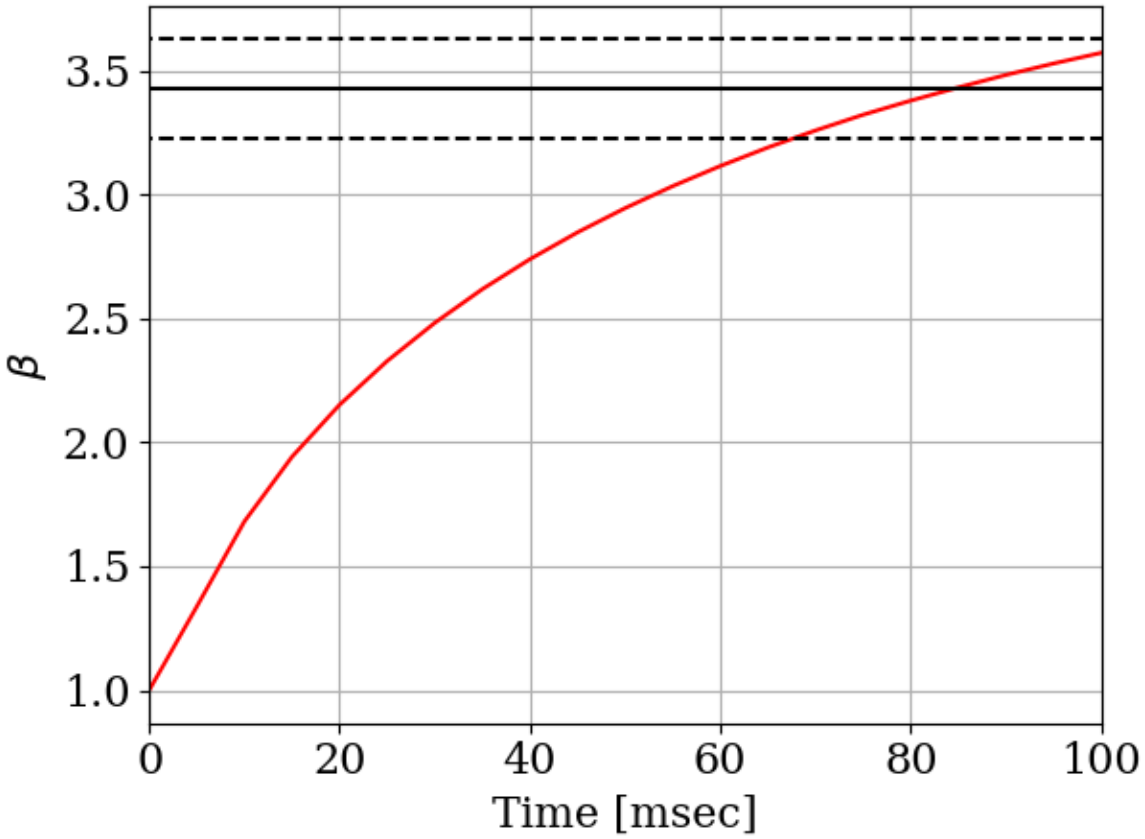


Momentum Transfer - β

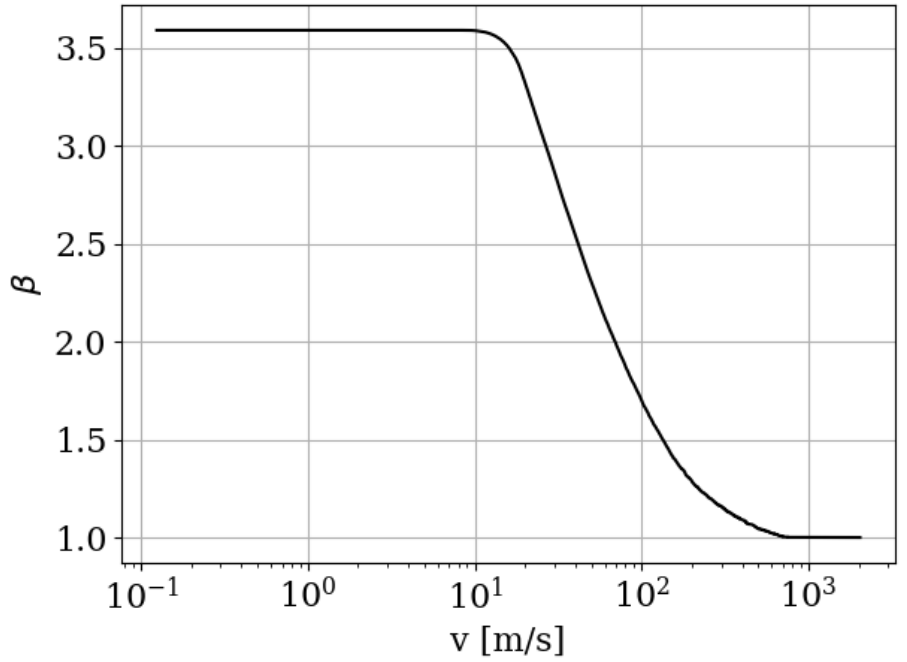


Adjusting β for density with the results in Cheng et al. 2023, we see that the spacecraft impacting into a 1kPa target produces too high of a β value…

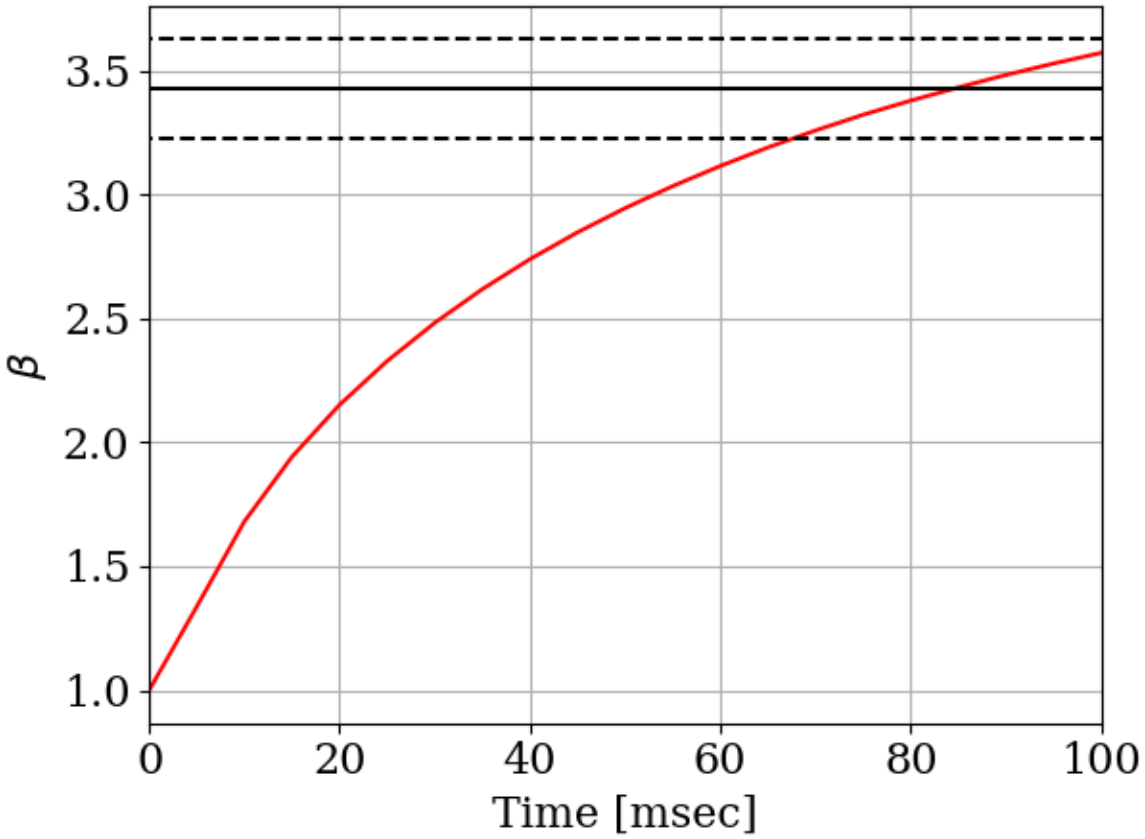
Momentum Transfer - β



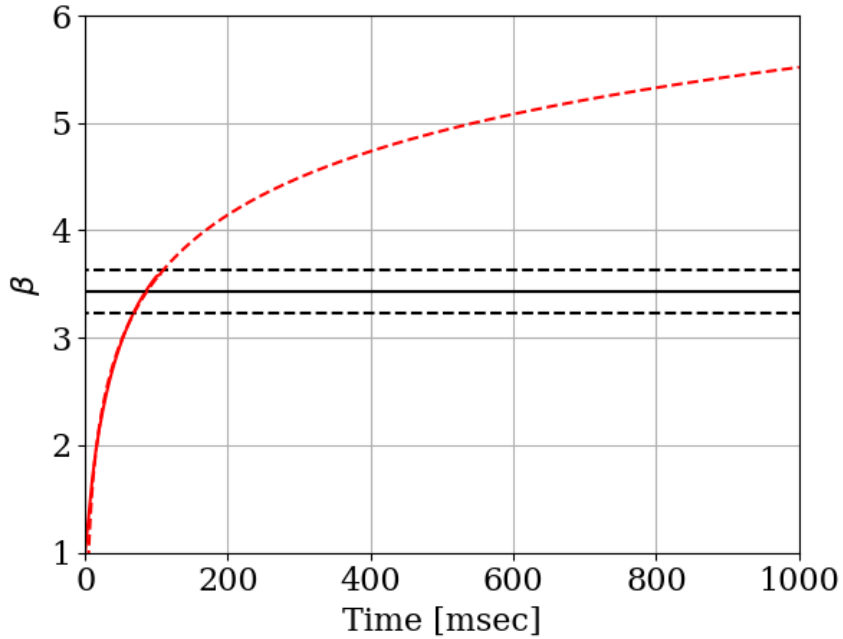
Adjusting β for density with the results in Cheng et al. 2023, we see that the spacecraft impacting into a 1kPa target produces too high of a β value…



Momentum Transfer - β



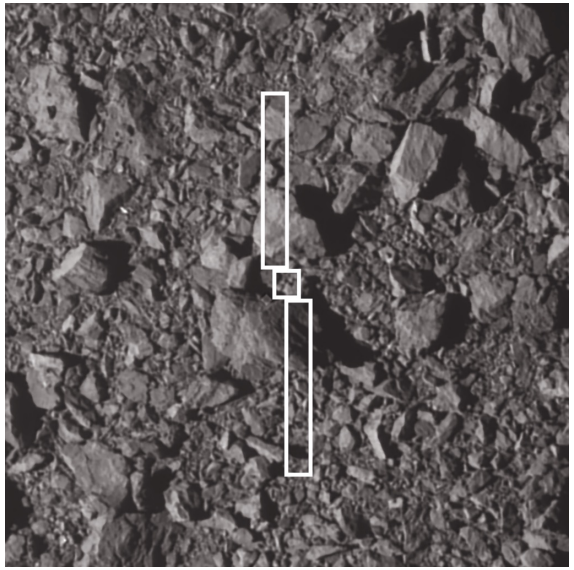
Adjusting β for density with the results in Cheng et al. 2023, we see that the spacecraft impacting into a 1kPa target produces too high of a β value…



General Takeaways & Future Work

Simulations using the spacecraft impacting into a moderately weak homogeneous 1kPa target result in β values in excess of what was observed with DART.

The inclusion of rubble pile structures will decrease the value of β, however it is unclear if that alone will be enough to reach the range of observed values without increasing strength.



Daly et al. *Nature* 2023

≠