Designing the Next Generation Kinetic Impactors for Planetary Defense

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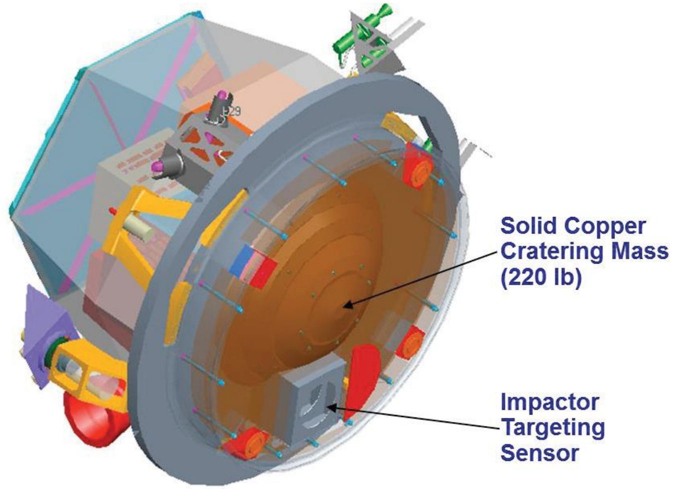
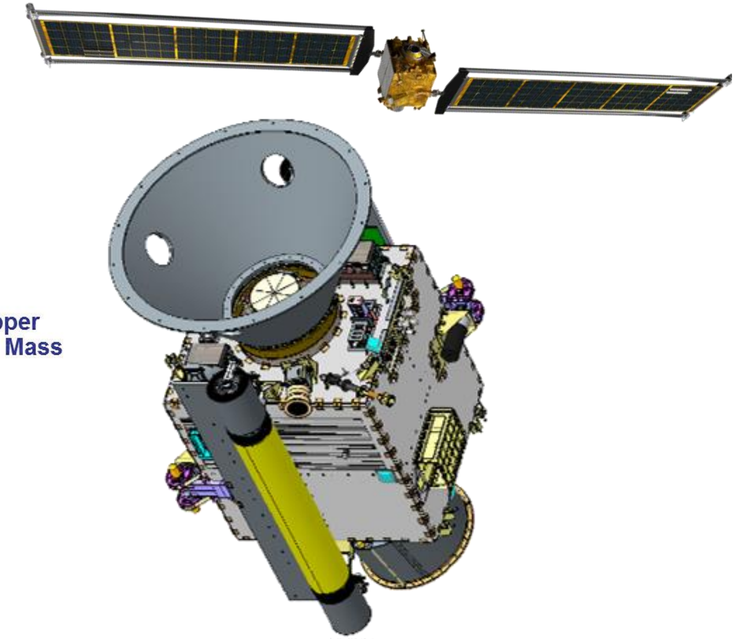
The objective of this investigation is to provide an understanding of how the next generation kinetic impactor for planetary defense can be designed to achieve the most efficient momentum enhancement.



Deep Impact Impactor
Spacecraft – 360 kg
Impact Velocity: 10 km/s

Illustration Credit: Henderson and Blume, Procedia Engineering 103 (2015)



DART Impactor
Spacecraft – 550 kg
Impact Velocity: ~7 km/s

Illustration Credit: NASA

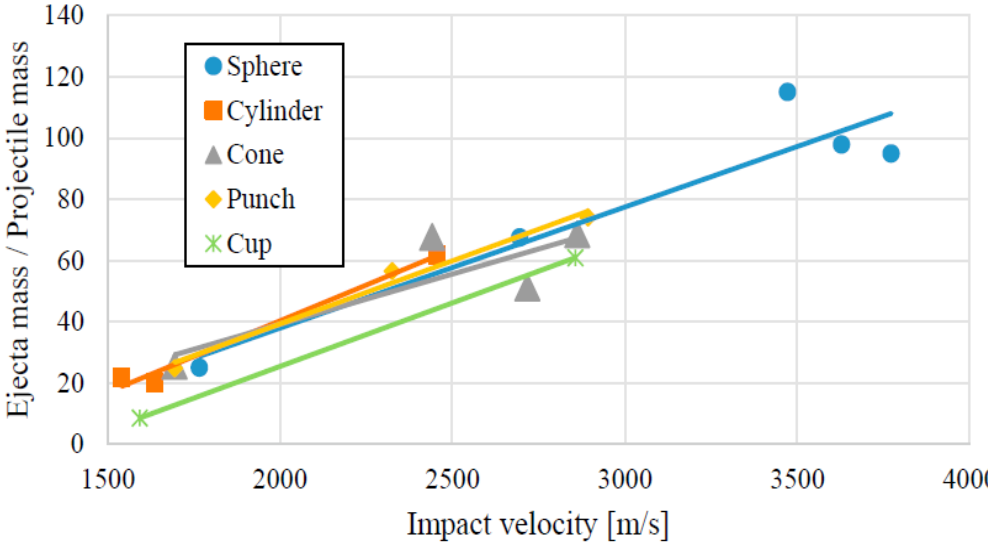
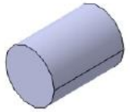


Fig. 1. Impact velocity vs. Normalized ejecta mass

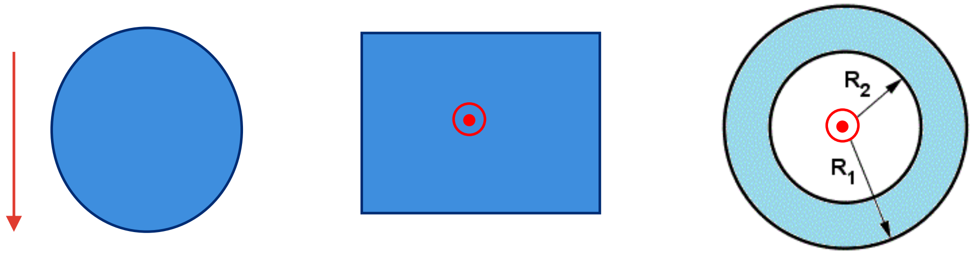
Table 1. Projectile

	Cylinder	Cone	Punch	Cup	Sphere
Shape					
Material	Al 2024-T4				Al 2017-T4

Ikeda *et al.*, Procedia Engineering 204 (2017) 138-145

The test matrix was designed to examine the effects of mass placement within the spacecraft on momentum enhancement.

Simple Impactor Geometries (2D)



Circle Plate Ring

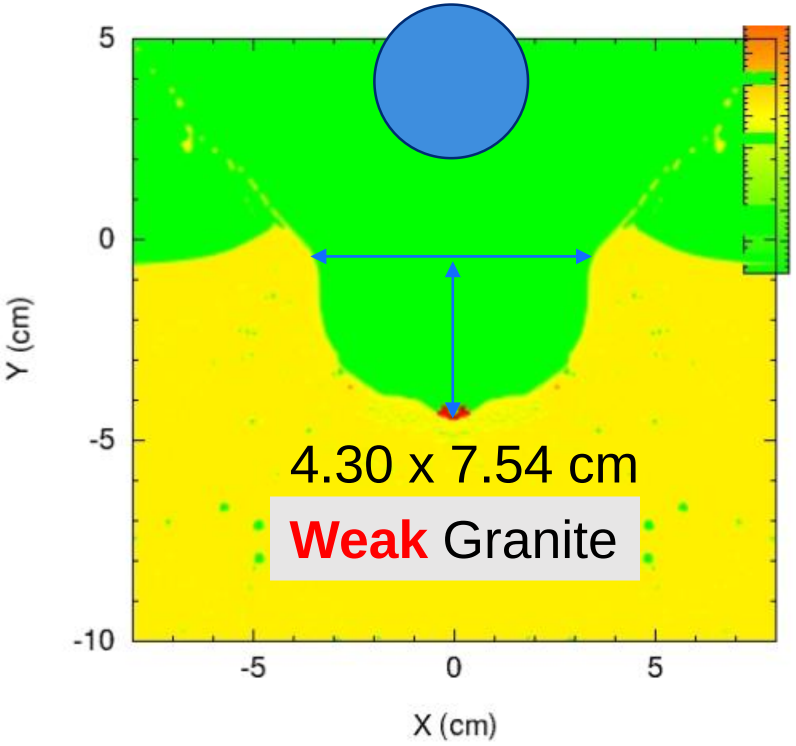
Complex Impactor Geometries (3D)

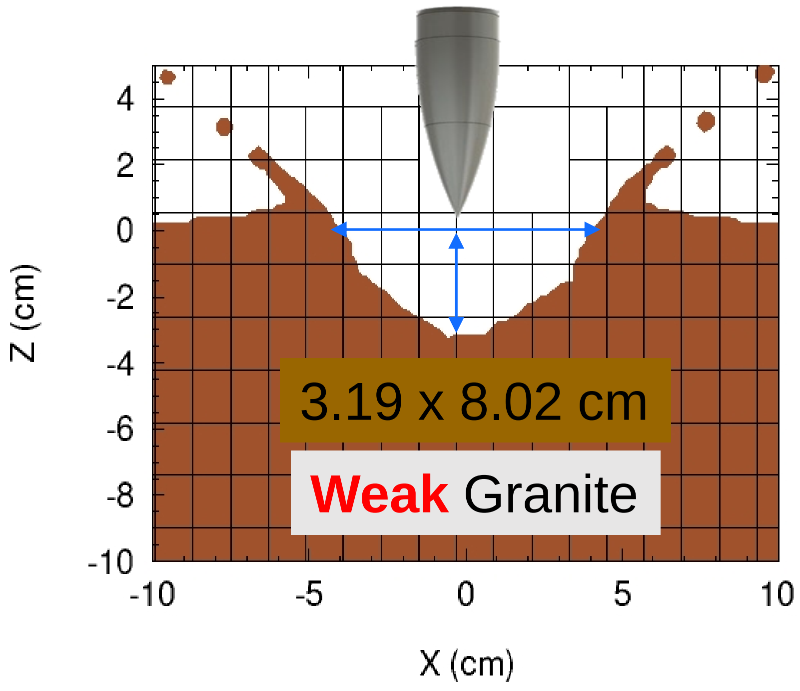
Ogive

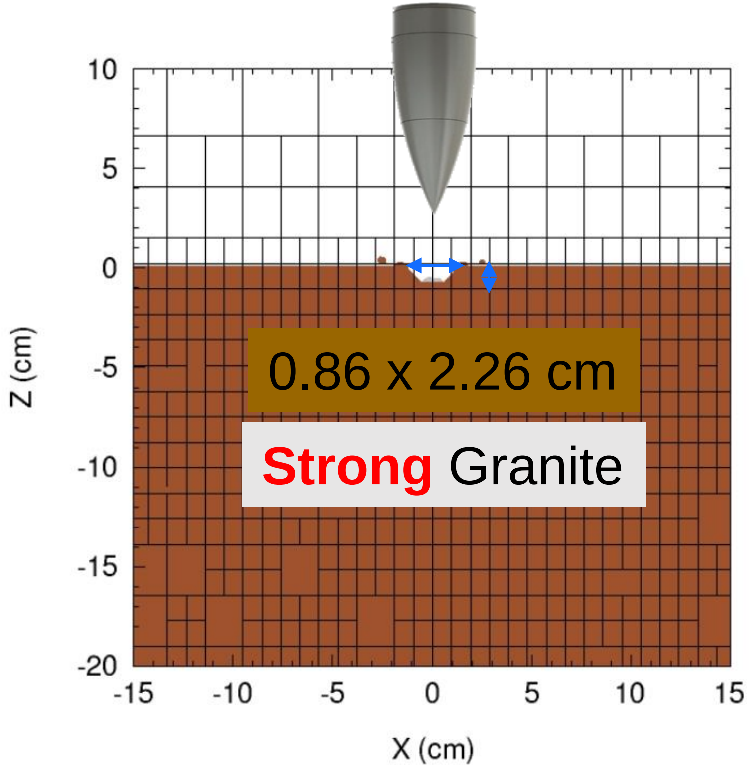
Variables	Value
Projectile Mass (g)	1, 500000
Projectile Material (density g/cc)	Al (2.69), Cu (8.96)
Impact Velocity (m/s)	500, 5000
Target: Strength	Granite Plate: **Strong**, **Medium**, **Weak**

	Tillotson EOS with BDL Strength		
Target Strength Parameters	Strong	Medium	Weak
Young's modulus (GPa)	35	35	35
Poisson ratio	0.25	0.25	0.25
Tensile Strength (MPa)	-10	-10	-10
Compressive Strength (MPa)	280	280	280
Cohesion (MPa)	90	45	0.1

The crater profiles for endmembers resulting from different 1g projectiles with an impact velocity of 500 m/s show that the target material properties are far more important than the impactor geometry for enhanced crater excavation.

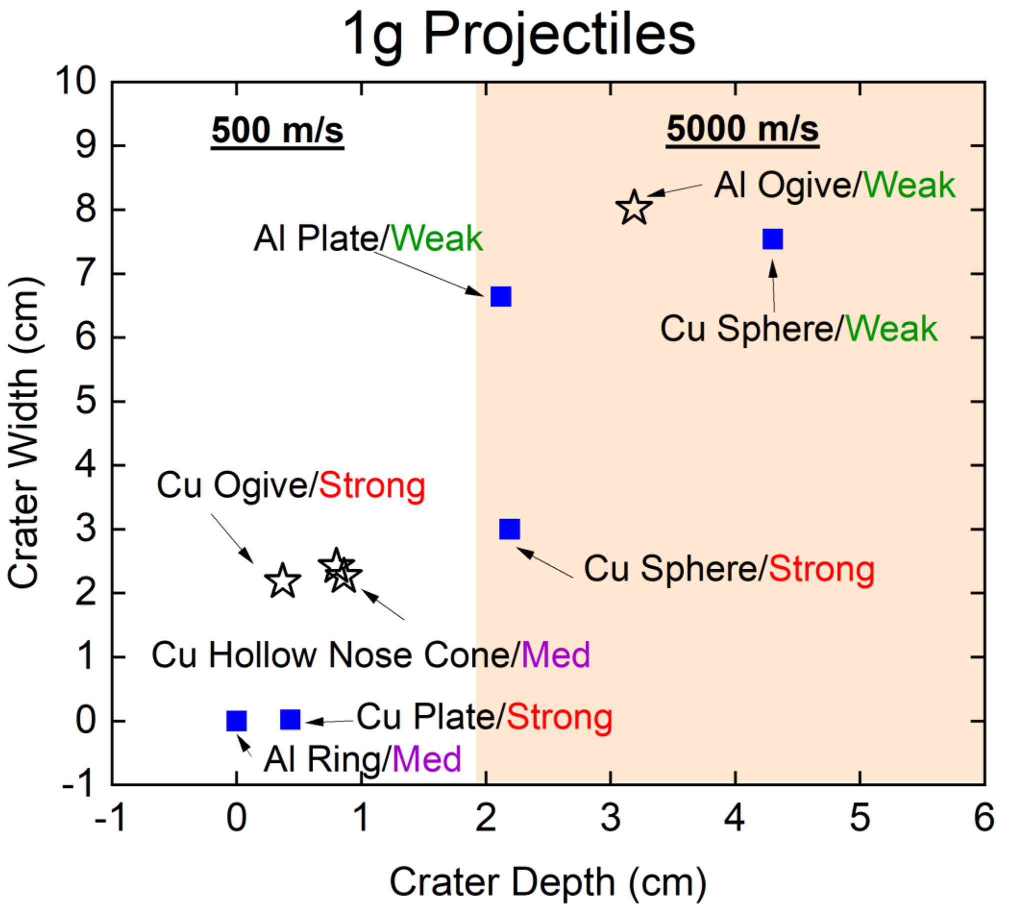


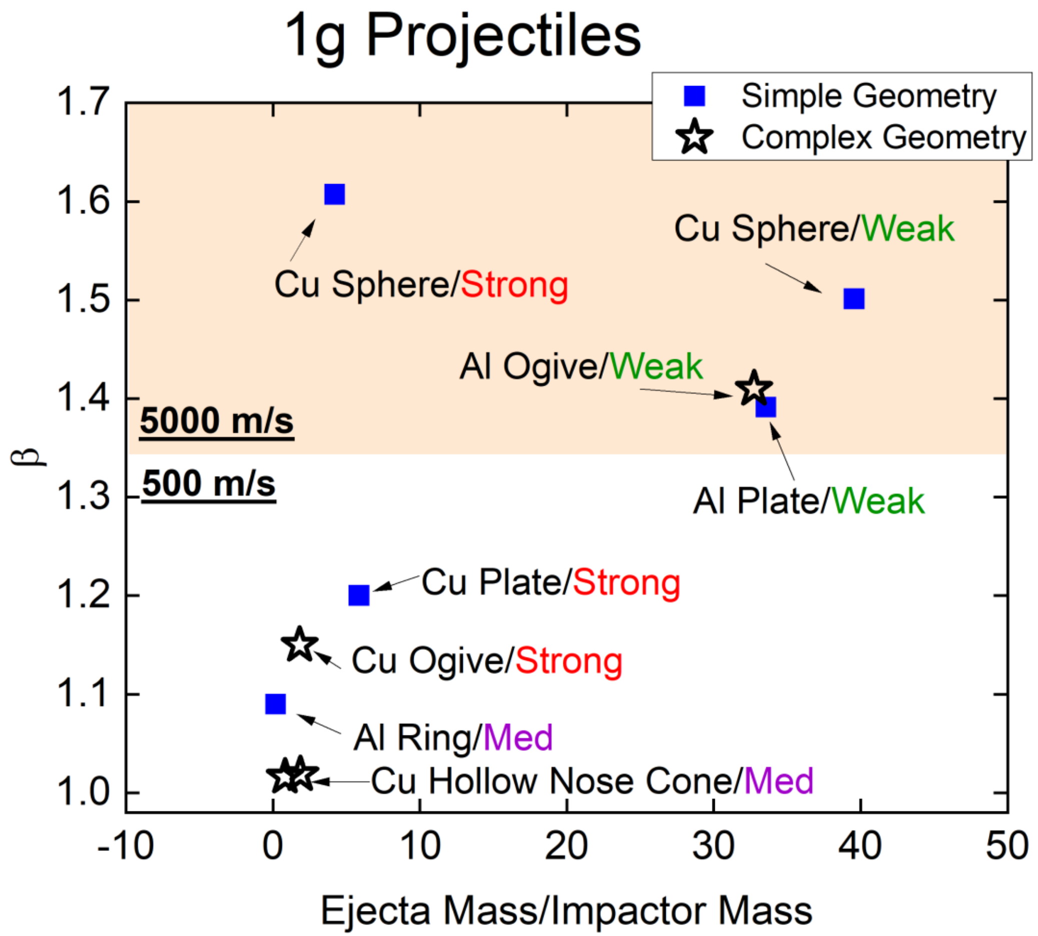




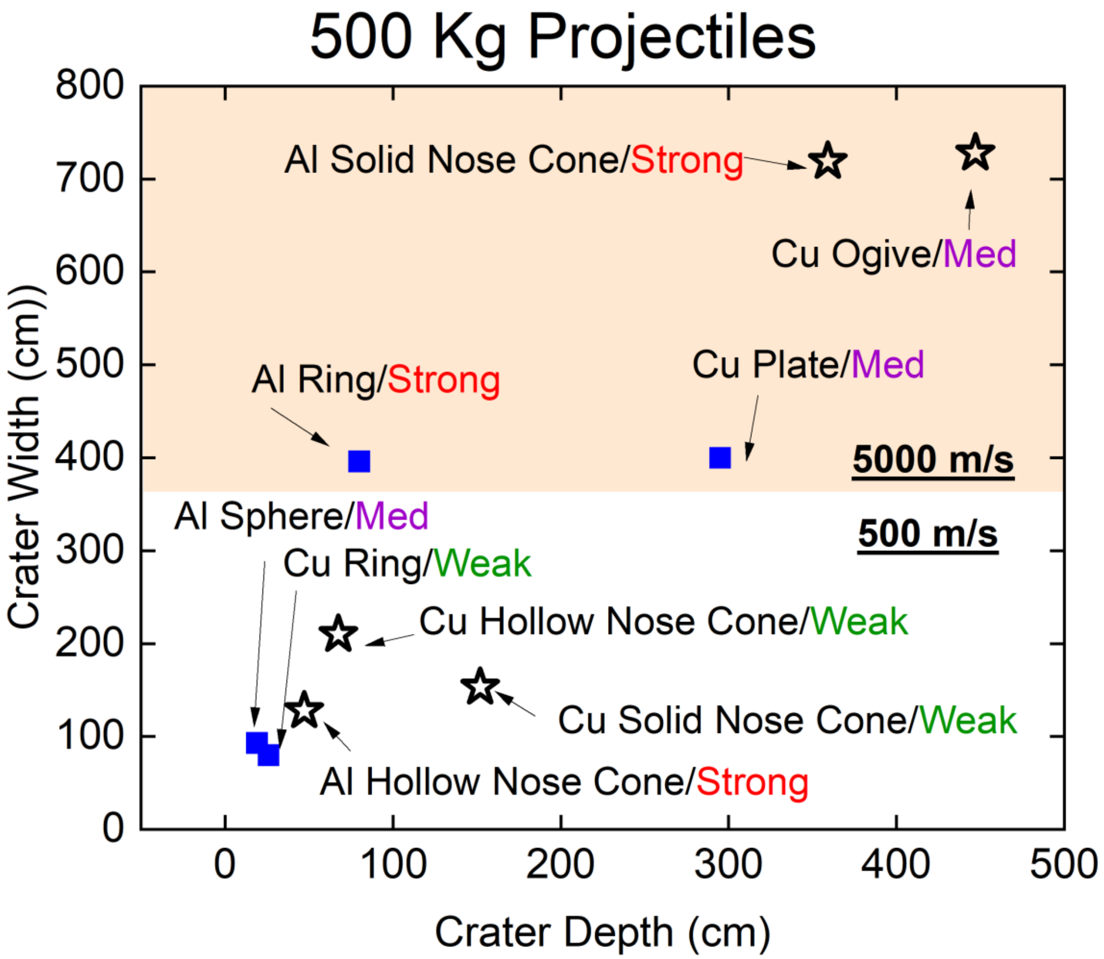
$m_{projectile}$=1 g V_{impact}=500 m/s

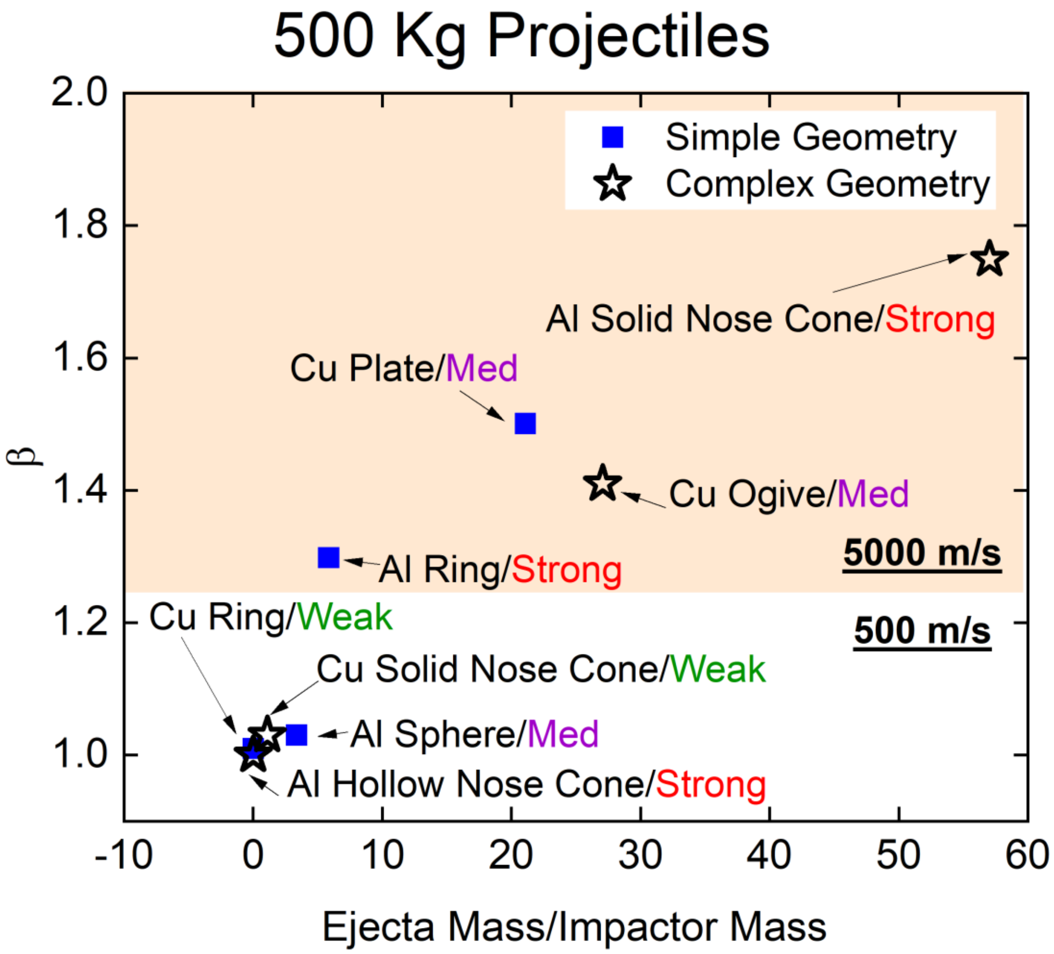
Results for 1g Projectiles: The largest craters were generated for the sphere, ogive, and plate. However crater size appears to be more dependent on the target material strength than the impactor geometry. Within similar target material parameters, the sphere emerges as the most efficient impactor geometry for optimizing beta.





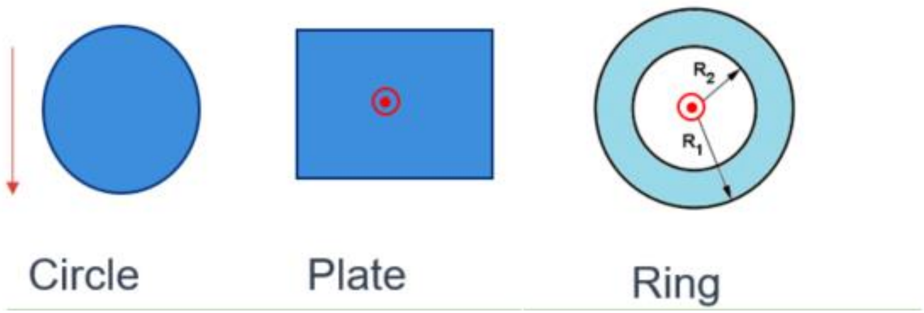
Results for 500 Kg Projectiles: When the projectile momentum is constant, the more complex projectiles produce the largest craters. However a larger crater is not always associated with a larger beta, indicating the differences in ejecta velocity distributions may play a significant role.



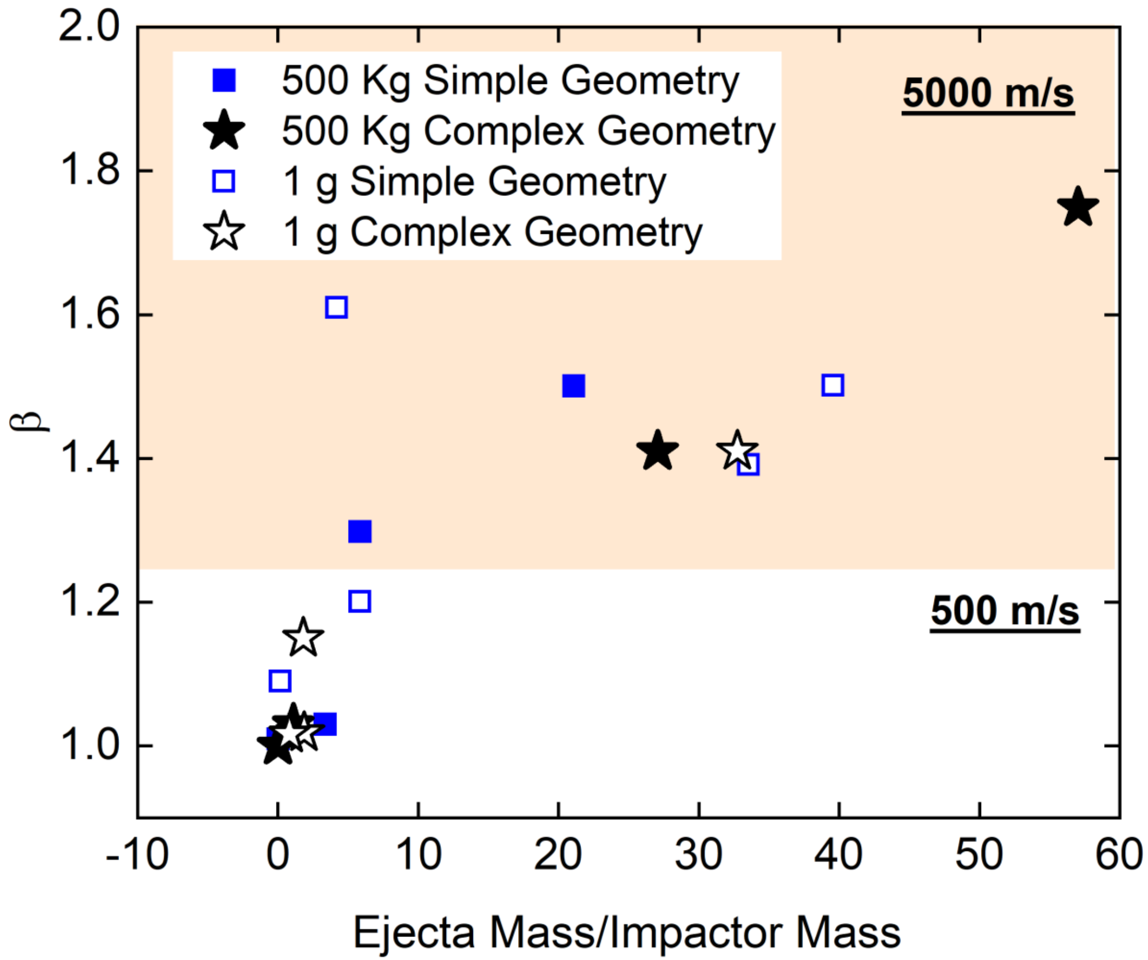


Summary: When the impactor momentum is held constant, different projectile geometries produce varying degrees of ejecta mass resulting in ~ 38% variation in the measured momentum enhancement factor (β).

Simple Impactor Geometries (2D)



Complex Impactor Geometries (3D)



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