The Evolution of Shape: Designing the Next Generation of Kinetic Impactors

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Overview

- *The Evolution of Shape: Designing the Next Generation Kinetic Impactor for Planetary Defense* (PI: Mallory DeCoster) is our currently funded YORPD grant to explore ways to optimize kinetic impactor design.

- We will present our latest numerical studies on the effects of projectile shape on effectiveness, as measured by the impact on β.

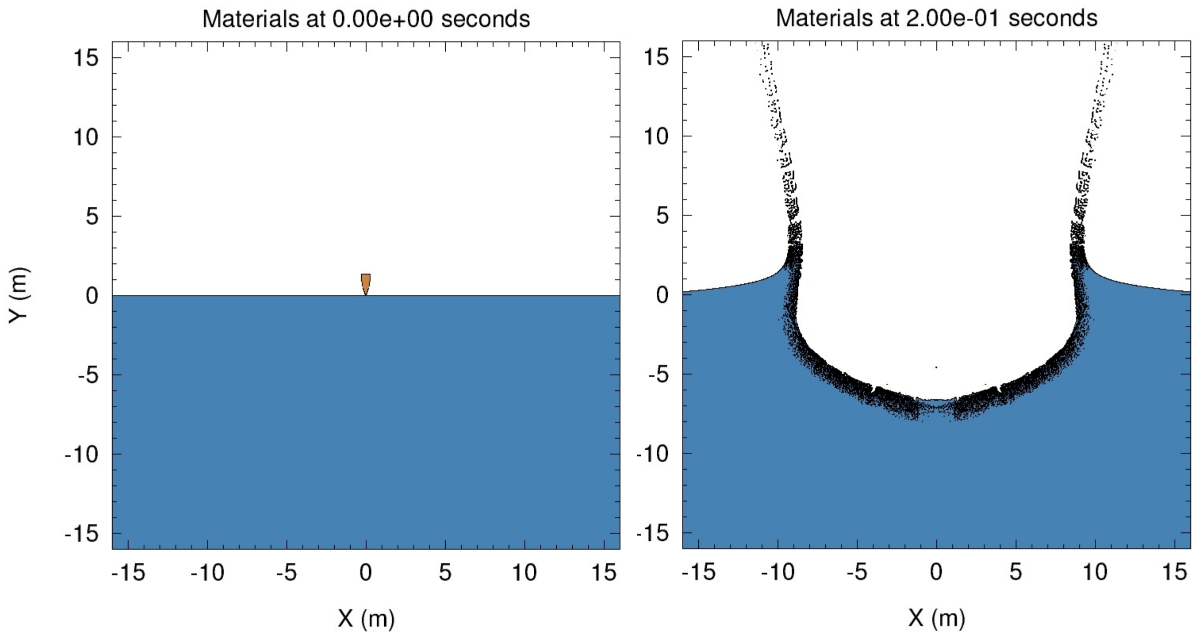
- We focus in this particular study on variations in a ballistic shape known as an ogive.

CTH Simulations

- For the current study, we focused on conducting 2D axisymmetric (2DC) impacts to maximize resolution and minimize runtime and storage requirements.

- 20 meter wide, 20 meter deep target with 40 meters above for ejecta to travel; 5 levels of AMR refinement to a minimum resolution of ~1 cm (minimum CPPR width-wise of 25 depending on target shape)
  - Standard refinement criteria are chosen (refining on shock and interfaces)

- The projectiles are all 500 kg aluminum ogives and the target is either a weak or strong basalt target (described later)
  - SESAME tables for aluminum and dry_sand
  - A single discard criterion (10% density) is used to eliminate badly behaved expanded zones



Example material plot (target blue, impactor orange) for the RL02, 6.65 km/s, Weak target case (described later) at 0 and 0.2 seconds

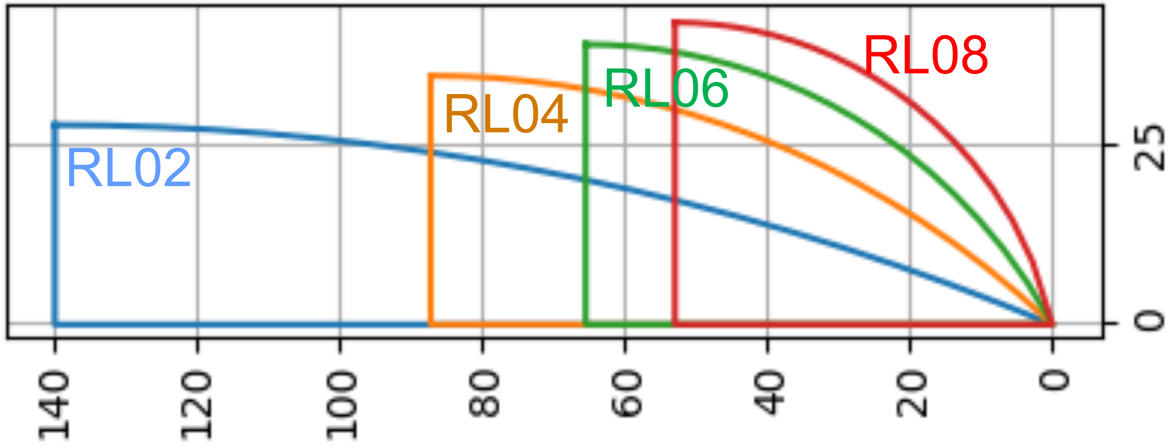
Exploring Impactor Shape: the Ogive

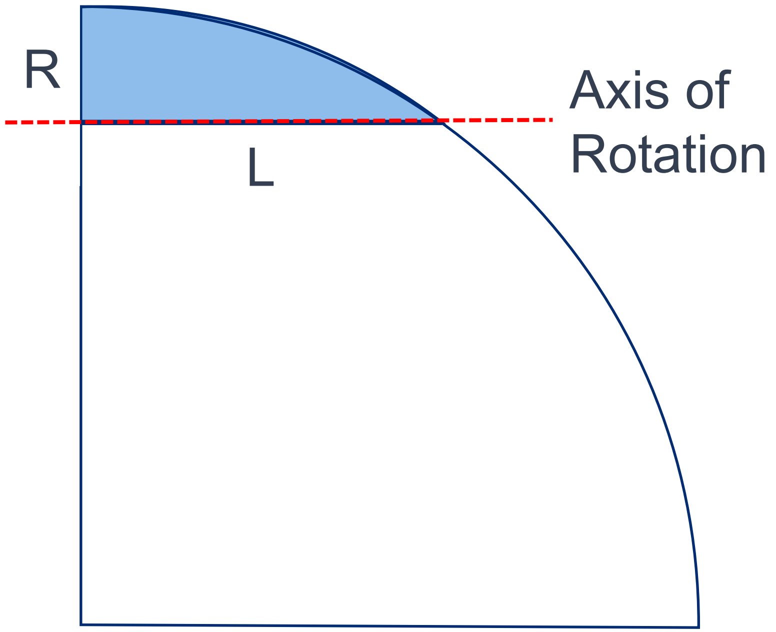
- A commonly studied shape in the ballistics literature is the ogive, which is formed by taking a section of a circle and rotating it.

- We chose to use the tangent ogive (full half cap) as a way to vary the contact angle. This is controlled by varying the radius (R) to length (L) ratio, R/L.

- We used 4 R/L ratios, ranging from nearly hemispherical (R/L = 0.8) to more rod-like (R/L = 0.2) with intermediate values (0.6 and 0.2)

- Each impactor had the same total mass (500 kg)





Tangent Ogive is parameterized by it’s Radius to Length ratio

Run Matrix and Target Strength Models

Impact Speed	Strong Target	Weak Target
2 km/s	RL02, RL04, RL06, RL08	RL02, RL04, RL06, RL08
6.65 km/s	RL02, RL04, RL06, RL08	RL02, RL04, RL06, RL08
15 km/s	RL02, RL04, RL06, RL08	RL02, RL04, RL06, RL08

- 3 Impact Speeds (2 km/s, 6.65 km/s, 15 km/s)
- 4 Ogive Shapes (R/L = 0.2, 0.4, 0.6, 0.8)
- 2 Target Strength Models (Weak/Strong)
- Both strength models are the CTH Geological Yield Surface (GEO) model with user-defined Johnson-Cook fracture and appropriate spall (FRACTS) parameters.
    - The weak model has a negative DYDP and should behave as a granular material

Strength Model (GEO + FRACTS) Parameters

Parameter	Strong Model	Weak Model
YIELD	1.0E10	1.0E10
YZERO	4.0E8	1.0E1
DYDP	0.5	-0.8
POISSON	0.25	0.25
JFD1	0.05	0.05
JFTM	0.16	0.16
JFPF0	-8.0E8	-1.0E1
JFWM	10.0	10.0
PFRAC2	-8.0E8	-1.0E1

Yield Strength at Zero Pressure → YZERO

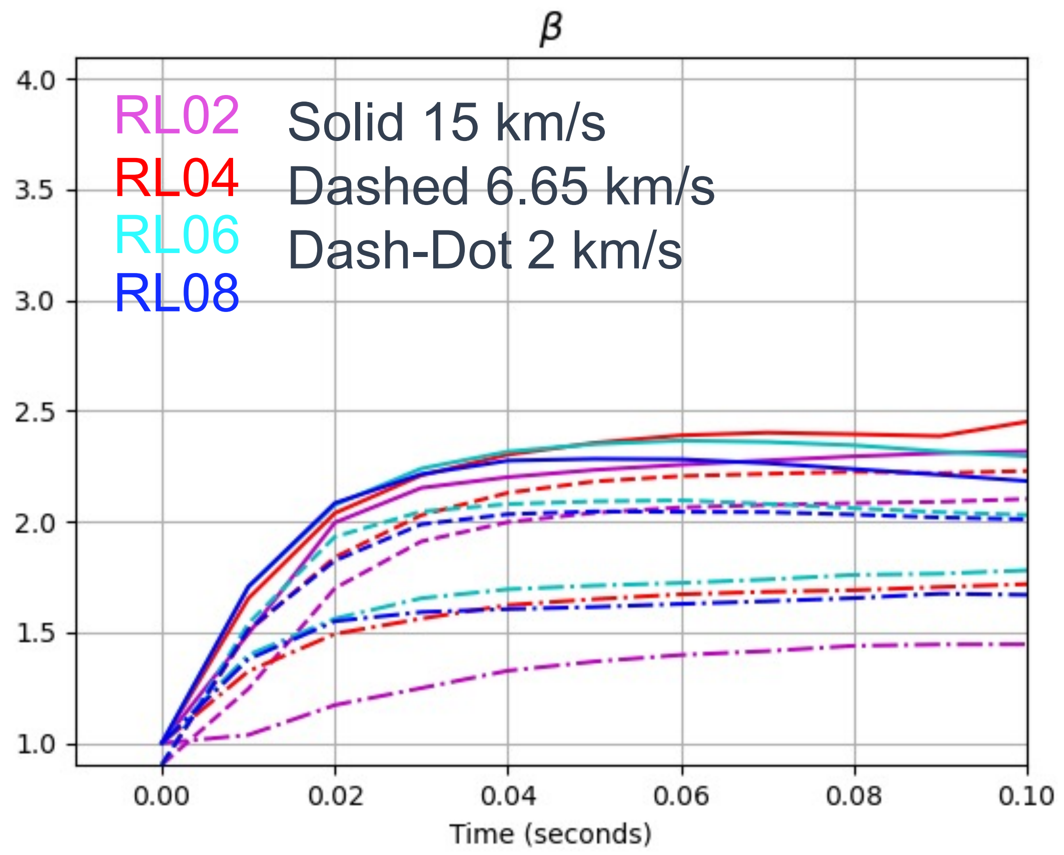
Slope of Yield Surface → DYDP

Tensile Strength → JFPF0

Fracture Pressure → PFRAC2

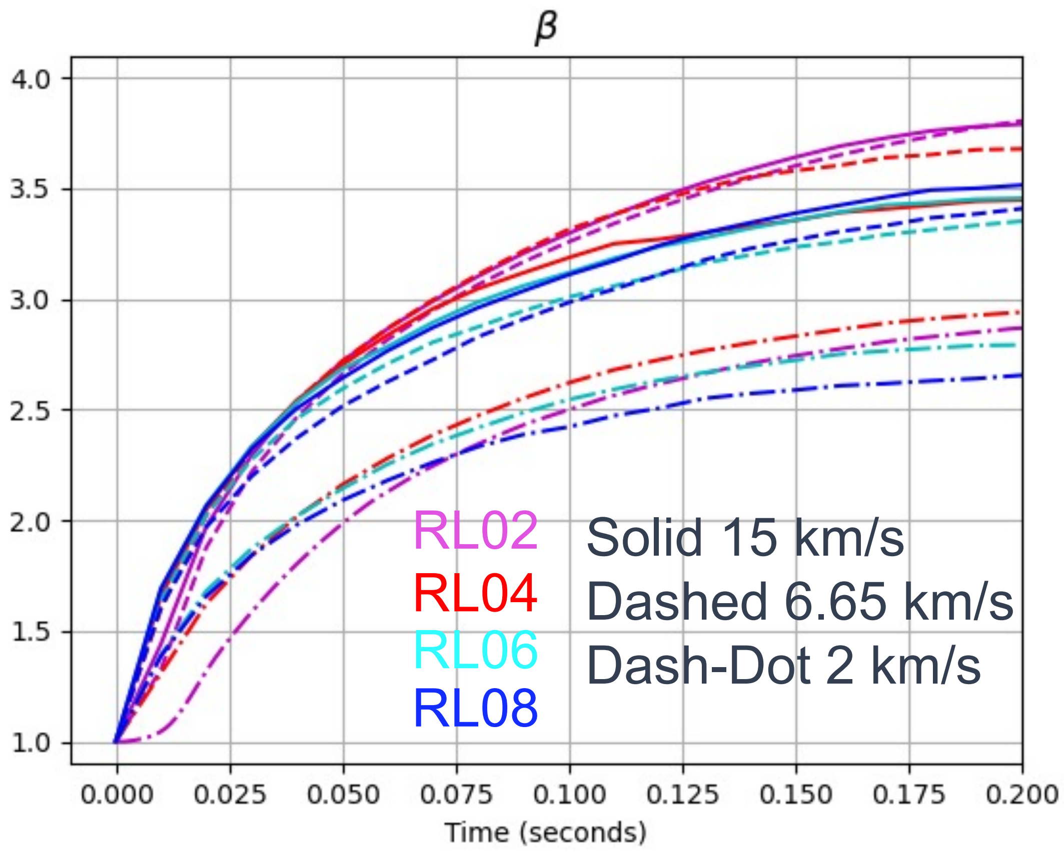
Results for Strong Target

- β curves in time for the strong target level off relatively rapidly, by 0.1 seconds
- Few trends in the ogive shape (colors) are discernible
- Strongest effect seems to be speed in this case, but the 6.65 and 15 km/s have relatively small differences
- 2 km/s is less efficient



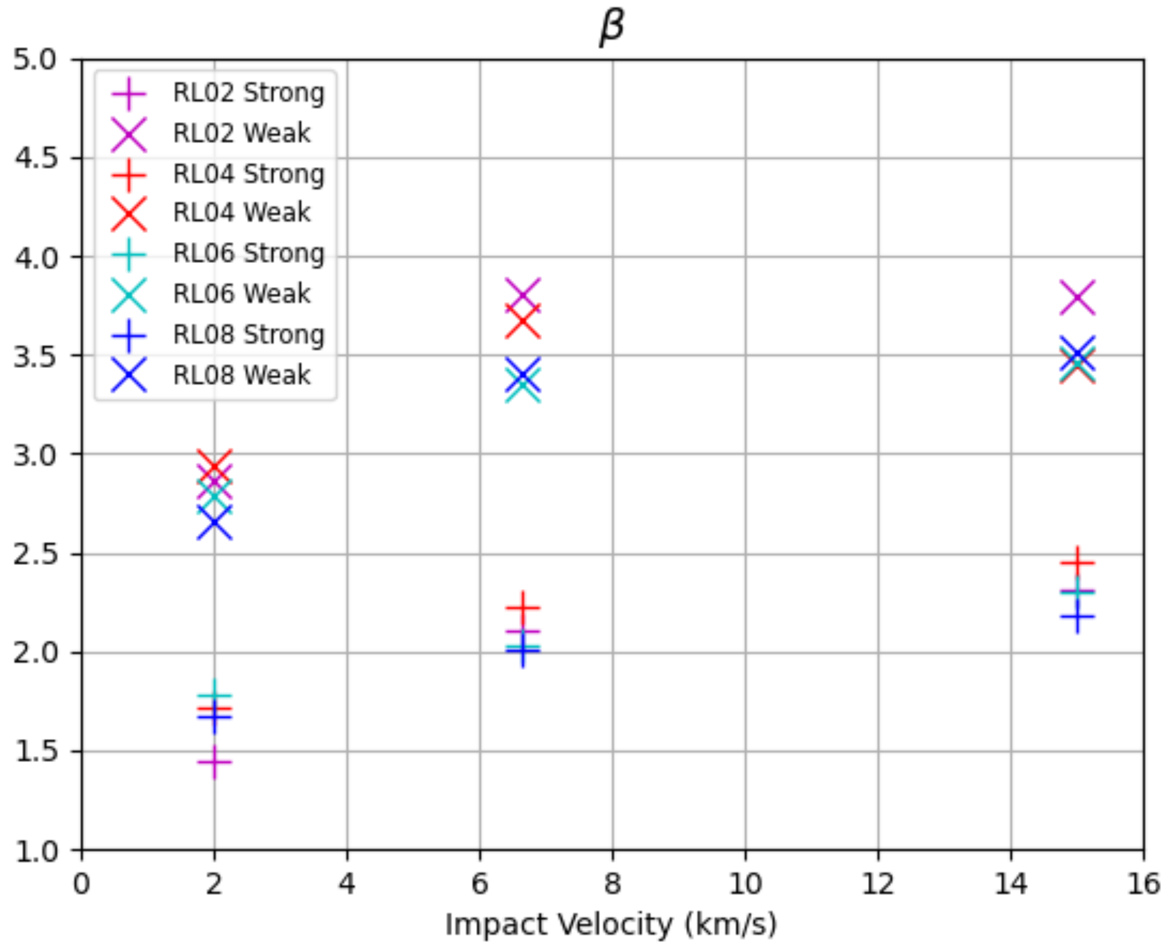
Results for Weak Target

- β curves for the weak target take longer to level off (by 0.2 seconds)
- Similar trends as strong target, with higher overall β achieved
- 2 km/s is again less efficient than the other two cases



Conclusions and Future Directions

- β enhancement of about +1.5 for the weaker target relative to strong target (consistent with expectations and previous work)
- Little different between 6.65 and 15 km/s
- Ogive shape seems to be a ~10% effect
- Will be exploring 3D comparisons and oblique ogive impacts in the immediate future
- Questions?



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