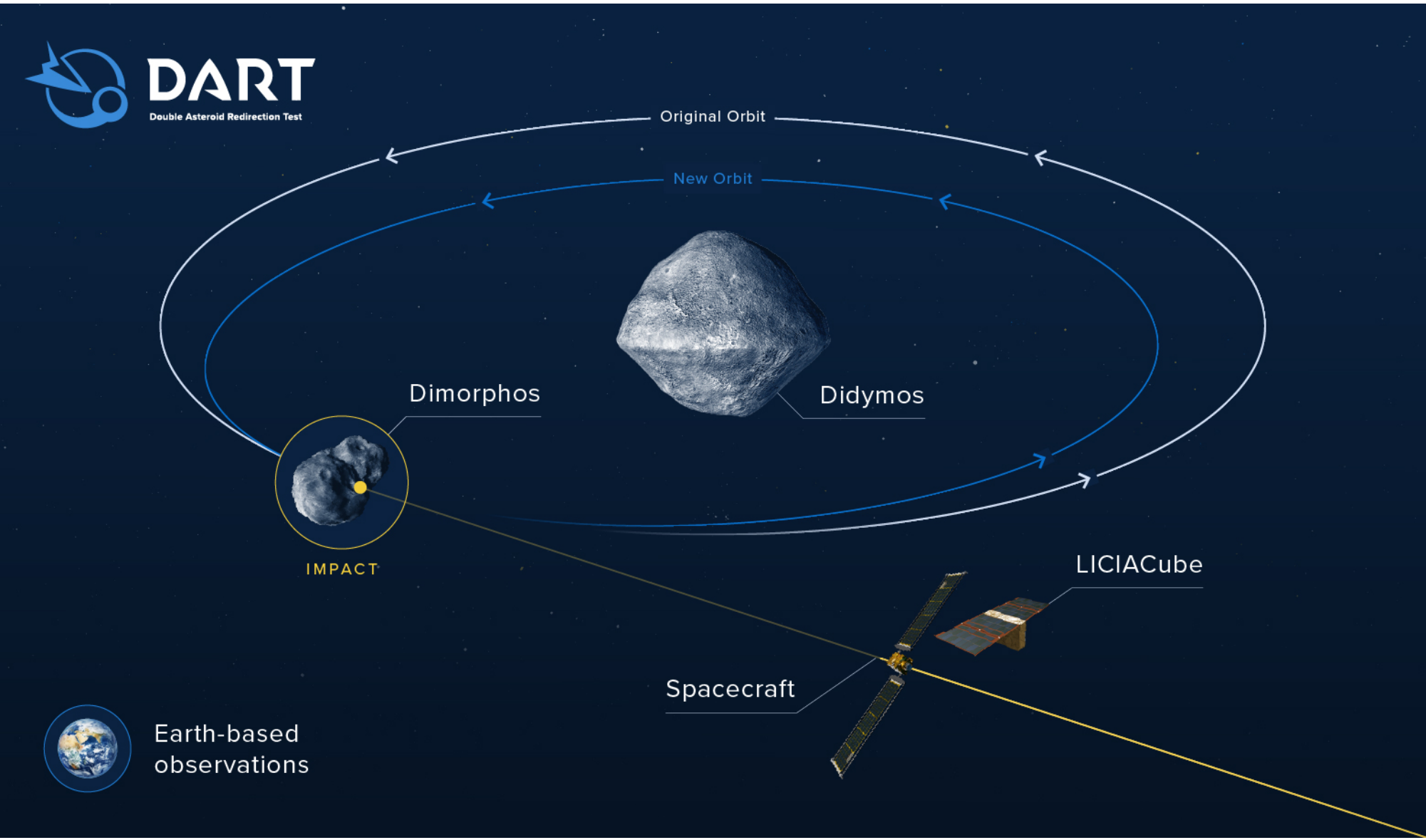
SPH simulations for space defense

Maximilian Rutz

July 16, 2020

Roadmap

1. Dart and Hera Missions
2. SPH setup
3. SPH results


DART
Double Asteroid Redirection Test
Original Orbit
New Orbit
Dimorphos
Didymos
IMPACT
LICIACube
Spacecraft
Earth-based
observations

Dart Mission

- Launch in July 2021 on a SpaceX Falcon 9
- Impact in fall 2022
- Impact at 0.07 au to Earth, 29x Earth-Moon, 1/5x Earth-Mars
- Observations with LICIACube and earth based telescopes

Dart Mission

- Launch in July 2021 on a SpaceX Falcon 9
- Impact in fall 2022
- Impact at 0.07 au to Earth, 29x Earth-Moon, 1/5x Earth-Mars
- Observations with LICIACube and earth based telescopes

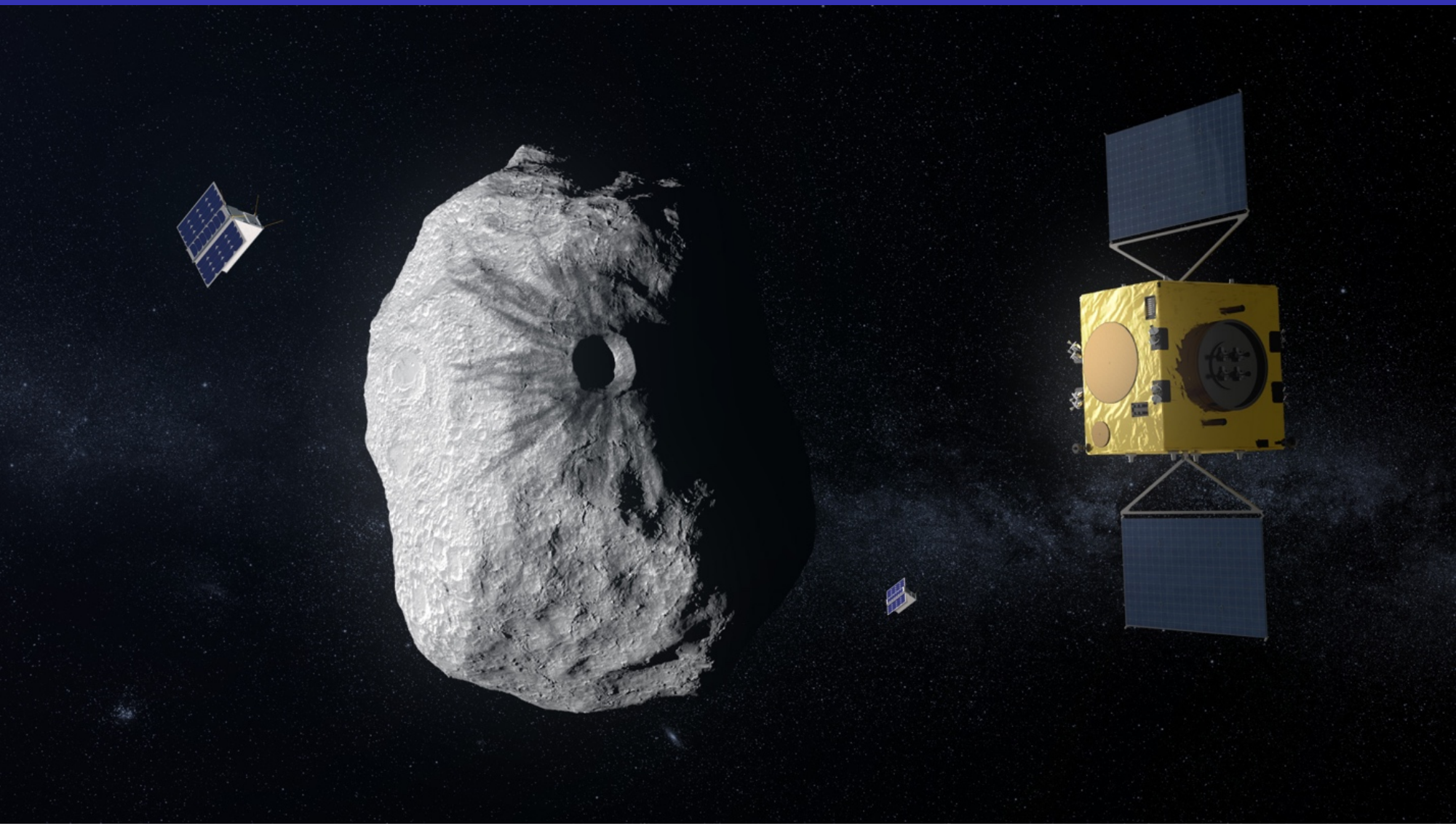
Dart Mission

- Launch in July 2021 on a SpaceX Falcon 9
- Impact in fall 2022
- Impact at 0.07 au to Earth, 29x Earth-Moon, 1/5x Earth-Mars
- Observations with LICIACube and earth based telescopes

Dart Mission

- Launch in July 2021 on a SpaceX Falcon 9
- Impact in fall 2022
- Impact at 0.07 au to Earth, 29x Earth-Moon, 1/5x Earth-Mars
- Observations with LICIACube and earth based telescopes

Hera Mission



Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

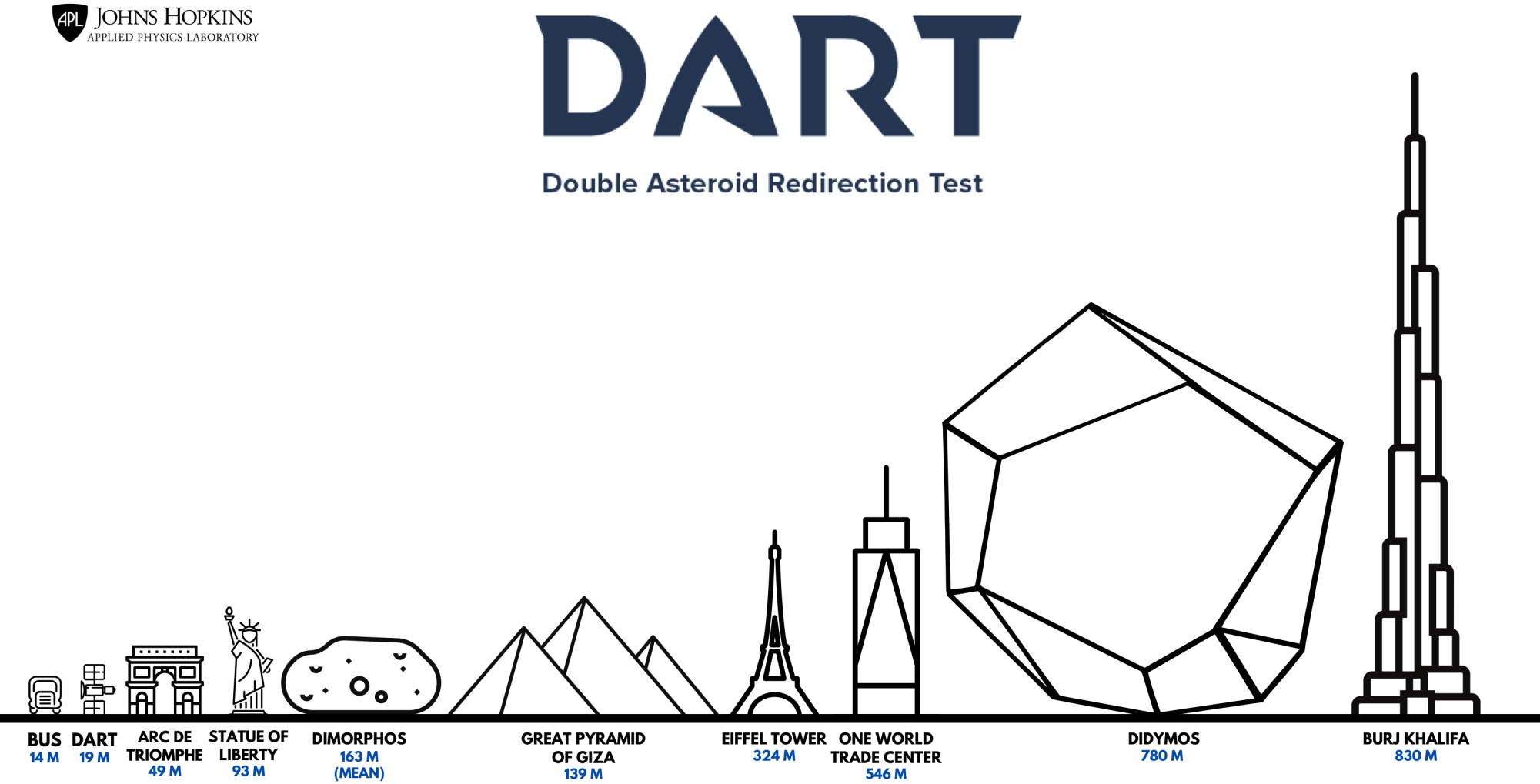
- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...

Hera Mission

- Launch in 2024
- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
  - Politics ...


JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
DART
Double Asteroid Redirection Test
BUS 14 M
DART 19 M
ARC DE TRIOMPHE 49 M
STATUE OF LIBERTY 93 M
DIMORPHOS 163 M (MEAN)
GREAT PYRAMID OF GIZA 139 M
EIFFEL TOWER 324 M
ONE WORLD TRADE CENTER 546 M
DIDYMOS 780 M
BURJ KHALIFA 830 M

Target

typical representative of possible hazardious asteroid
https://www.nasa.gov/planetarydefense/dart
Dimorphos orbiting Didymos
https://dart.jhuapl.edu/Gallery/media/graphics/lg/DART

Impactor

https://dart.jhuapl.edu/Mission/Impactor-Spacecraft.php

- $1.2 \times 1.3 \times 1.3$ meters
- artifical viscosity

Impactor

https://dart.jhuapl.edu/Mission/Impactor-Spacecraft.php

- $1.2 \times 1.3 \times 1.3$ meters
- artifical viscosity

Impactor

https://dart.jhuapl.edu/Mission/Impactor-Spacecraft.php

- $1.2 \times 1.3 \times 1.3$ meters
- artifical viscosity

SPH method

Smoothed particle hydrodynamics

Miluphcuda

Smoothed particle hydrodynamics

Miluphcuda setup

- x^3 Kernel function
- Runge Kutta fourth order
- no self gravity
- p-α porosity - micro vs macroporosity

Miluphcuda setup

- x^3 Kernel function
- Runge Kutta fourth order
- no self gravity
- p-α porosity - micro vs macroporosity

Miluphcuda setup

- x^3 Kernel function
- Runge Kutta fourth order
- no self gravity
- p-α porosity - micro vs macroporosity

Miluphcuda setup

- x^3 Kernel function
- Runge Kutta fourth order
- no self gravity
- p-α porosity - micro vs macroporosity

Miluphcuda setup

- x^3 Kernel function
- Runge Kutta fourth order
- no self gravity
- p-α porosity - micro vs macroporosity

Initial conditions setup

- x^3 Kernel function
- artifical viscosity
- Runge Kutta Fourth order
- no self gravity
- p-α porosity

Initial conditions setup

- x^3 Kernel function
- artifical viscosity
- Runge Kutta Fourth order
- no self gravity
- p-α porosity

Initial conditions setup

- x^3 Kernel function
- artifical viscosity
- Runge Kutta Fourth order
- no self gravity
- p-α porosity

Initial conditions setup

- x^3 Kernel function
- artifical viscosity
- Runge Kutta Fourth order
- no self gravity
- p-α porosity

Initial conditions setup

- x^3 Kernel function
- artifical viscosity
- Runge Kutta Fourth order
- no self gravity
- p-α porosity

Goal of simulations

Compare numerical results with observations to:

1. test numerical codes
2. identify target material and properties through parameter studies

Goal of simulations

Compare numerical results with observations to:

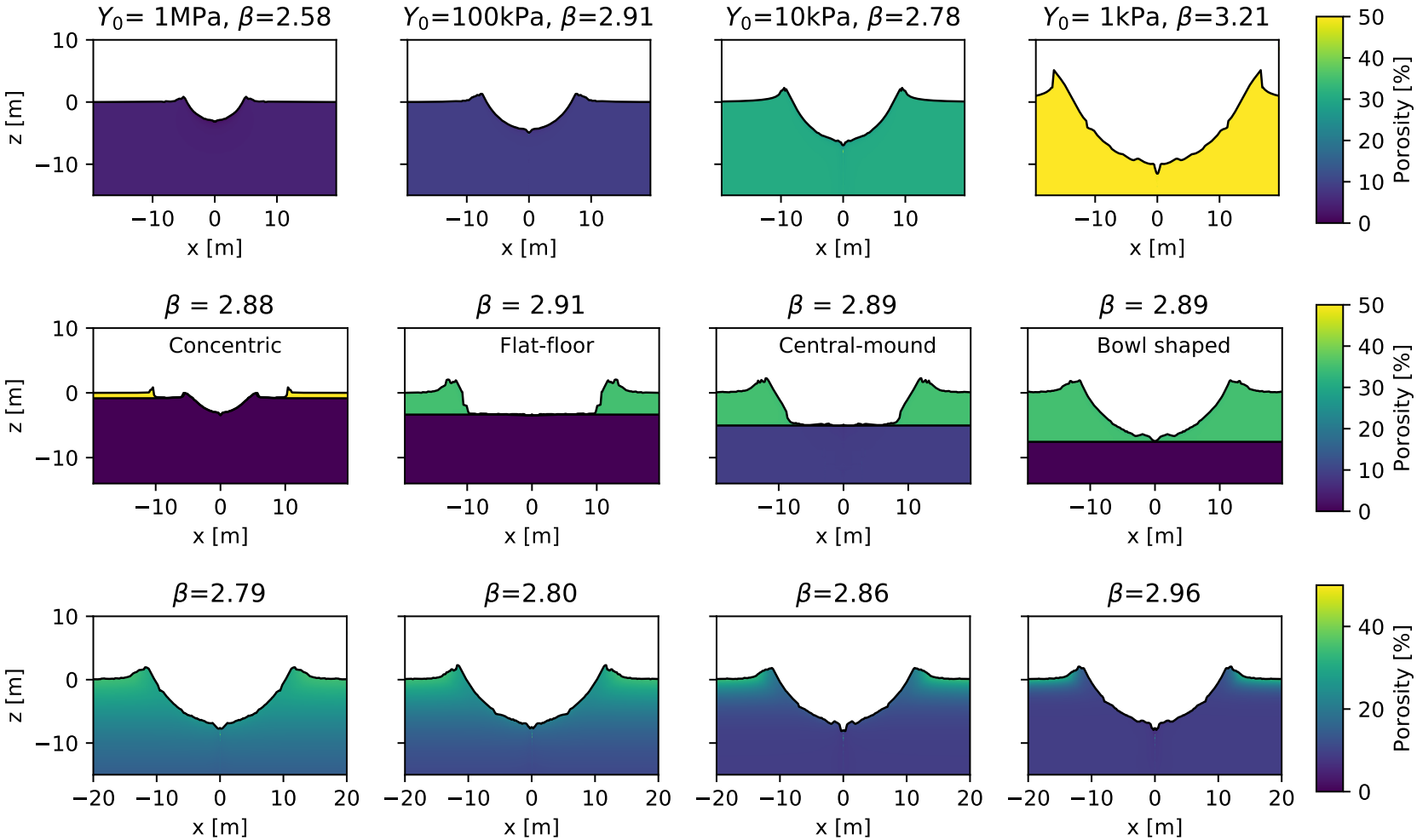
1. test numerical codes
2. identify target material and properties through parameter studies

Beta factor

Momentum change because of ejecta: $\beta = 1 + \frac{p_{ejecta}}{p_{impactor}}$

The DART impact into different targets can produce the same β, but different craters.

Measurements of **both** β and crater size/morphology **together** can be diagnostic of target properties.



Raducan et al. (2020), PSS

Personal observations about SPH

- A lot of individual physics implementable
- Many different codes available
- Difficult to reproduce and compare results between different codes

Sources and additional information

Illustrations taken from Dart and Hera websites:

- https://dart.jhuapl.edu/
- https://www.nasa.gov/planetarydefense/dart
- https://www.esa.int/Safety_Security/Hera

Papers:

- https://dart.jhuapl.edu/
- https://www.nasa.gov/planetarydefense/dart