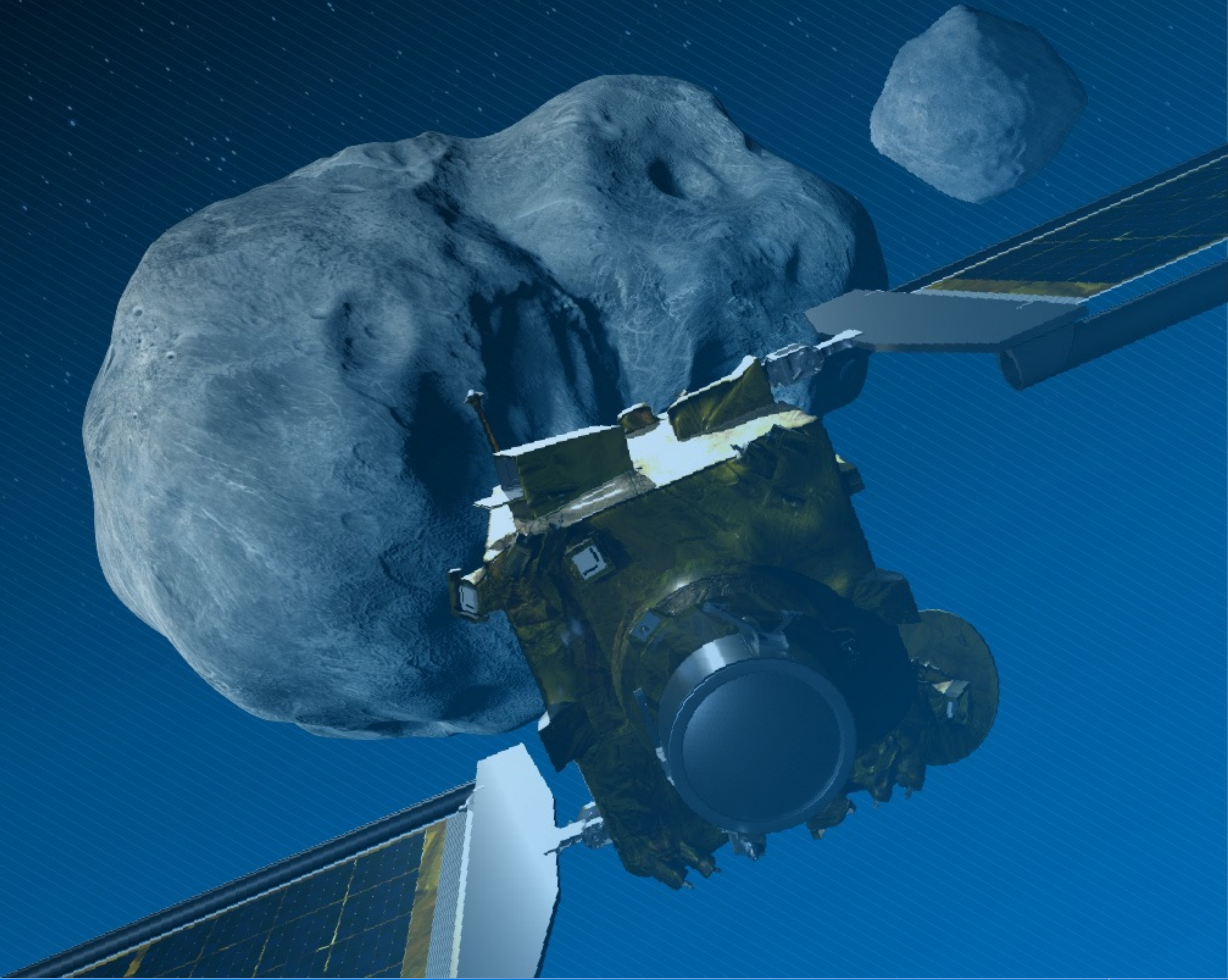
DART Legacy: Determination of beta, data archive

Kinetic Impactor Demonstration

Andrew Cheng
andy.cheng@jhuapl.edu



DART

Kinetic impactor demonstration at Didymos

- Demonstrate orbital deflection of a representative threat asteroid
- The DART target is a realistic-sized asteroid (160 m) of the most common NEO composition (S-type)
- A controlled impact experiment to increase confidence of kinetic impact predictions and improve understanding of asteroid physical properties and high-speed collisions

Impact Dimorphos

During its Sept/Oct 2022 close approach to Earth

Change the binary orbital period

Cause a ≥73-second change in the orbital period of Dimorphos

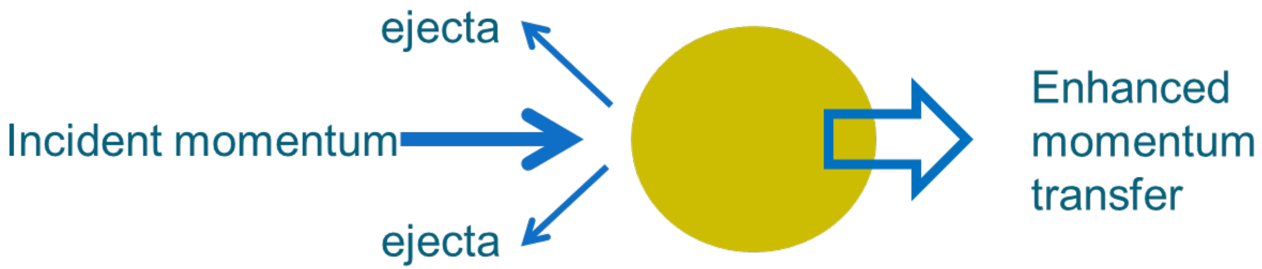
Measure the period change

To within 7.3 seconds, from ground-based observations before and after impact

Measure "Beta" and characterize impact site and dynamics

Beta = *the momentum enhancement factor*

Beta: Momentum Transfer Efficiency



in 1D:

$$\beta = 1 + \frac{p_{\mathrm{ejecta}}}{p_{DART}}$$

- β is defined as momentum transfer divided by momentum input
  - **If no ejecta, then $\beta = 1$**
  - **Ejecta release *enhances* momentum transfer, $\beta > 1$**
- Momentum transfer from kinetic impact is enhanced by impact ejecta
- Estimation of β important for asteroid deflection. How large a kinetic impact is needed, or how many kinetic impacts are needed, depend on β

For DART impact in 3D:

$$\Delta\vec{v} = \frac{m}{M}\left(\vec{u} + (\beta - 1)(\hat{n} \cdot \vec{u})\hat{n}\right)$$

$$\beta = \frac{M(\hat{n} \cdot \Delta\vec{v})}{m(\hat{n} \cdot \vec{u})}$$

β is the transferred momentum component along $\hat{n}$ divided by the incident momentum component along $\hat{n}$.

With some assumptions, the vector $\hat{n}$ is the target surface normal

DART Beta determination

- Measure transverse component of velocity change (from period change)
- Use full 2-body numerical modeling of Dimorphos binary dynamics to relate period change to vector velocity change and beta (using mass)
- Determine size, shape and volume of Dimorphos to infer mass (with assumed density given by bulk density of Didymos)
  - DART approach imaging of approach hemisphere
  - LICIACube imaging of approach and departure hemispheres
- Determine DART impact site location, and geology and topography of impact site, from DART approach imaging
- LICIACube plume observations to constrain plume direction $\hat{n}$
- Use impact simulations for
  - Effects of spacecraft geometry
  - Effects of impact site topography, slopes, rubble structures
  - Estimation of uncertainty

DART Data Archive

DART, LICIACube and Ground-based telescopic data

Data Source	Dataset	Derived data	Archive
DART DRACO	Monochrome imaging	Mosaics, light curves, image backplanes, shape models, facet data	PDS SBN
LICIACube LEIA	Monochrome imaging	Image backplanes	PDS SBN
LICIACube LUKE	3-color imaging	Image backplanes	PDS SBN
Las Cumbres	Ground-based 2m/spectral images	Light curves	PDS SBN
Las Campanas	Magellan/IMACS images	Light curves	PDS SBN
Lowell	DCT/LMI images	Light curves	PDS SBN
Magdalena Ridge	2.4m images	Light curves	PDS SBN
Radio Science	Doppler and ranging		PDS SBN
SPICE data	Ancillary data		NAIF

Anticipating Hera science at Didymos

AIDA: DART and Hera joint studies of kinetic impact demonstration results

- Hera ESA mission to Didymos, arriving late 2026, will
  - Measure mass of Dimorphos
  - Measure DART impact crater
  - Study spins, search for shape changes, and measure librations excited by DART impact
- Didymos telescopic observations
  - Light curve observations of mutual events, spins and orbital period
  - Ejecta imaging from Earth to study activation of comet-like dust tails by DART impact
- Impact simulations
  - DART crater predictions
  - Modeling of spacecraft structure and target structures (rubble, boulders, topography)
  - Inference of Dimorphos target properties (like strength, porosity, friction, crush properties), with Hera data
  - Beta determination and uncertainties, with Hera data
- Didymos binary system dynamics
  - Inference of interior structures
  - Tidal interactions and BYORP

DART Legacy

- DART demonstrates planetary defense capability
  - Showing that a kinetic impactor accomplishes asteroid deflection
  - Demonstrating kinetic impactor technology and concept of operations
- DART determines momentum transfer efficiency for a target asteroid of representative size and most common spectral type
- DART improves and validates models of kinetic impact deflection
  - More reliable predictions of kinetic impactor effects on other asteroids
- DART informs planetary defense decision and policy definition processes and reduces risks

DART

Double Asteroid Redirection Test