NASA/Double Asteroid Redirection Test: Orbital perturbation by the ejecta-collision driven reshaping of Didymos after the impact event

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IAA Planetary Defense Conference

26 – 30 April 2021

Didymos is spinning at close to its spin limit.

- Didymos is a ∼780 m dia. top-shaped asteroid, spinning at 2.26 hr.
- May be structurally sensitive to reshaping

  → Even small perturbations may trigger reshaping.
  - Ejecta cloud hitting on Didymos (delivers kinetic energy)
  - Seismic shaking attenuation due to the DART impact

Understanding the orbital perturbation due to reshaping is important to determine the momentum transfer coefficient and to assess the DART deflection capability.

Statistically determine the effect of asymmetric reshaping.

<u>How Didymos' reshaping affects the orbital period after the DART impact?</u>

- While the reshaping magnitude is unknown, we have knowledge of possible reshaping processes of top-shaped asteroids.
- Ejecta will distribute heterogeneously on Didymos, which will lead to asymmetric reshaping.

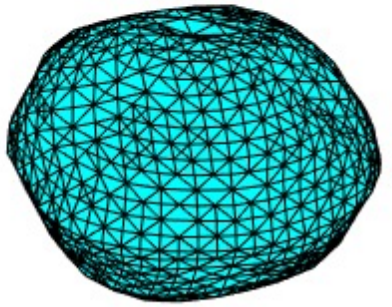
→ We developed a shape model generator to create "reshaped" shape models.

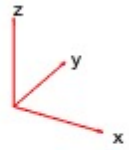
6,000 asymmetric reshaped cases are prepared.

- We characterize the reshaping with 4 parameters: α_{+x}, α_{-x}, α_{+y}, and α_{-y}.
- Each represents the ratio of the $\pm x$ or $\pm\, y$ axis for the reshaped body to that of the original body.
- We randomly define a value for each, in a range from 1 to α_{max}. (= maximum reshaping magnitude).
- α for z axis is uniquely determined by keeping the volume constant regardless of the shape.

Ex: $\alpha_{max} = 1.1 \quad \approx 40\, m$

$\alpha_{+x} = 1.099 \quad \approx 38\, m$
$\alpha_{-x} = 1.085 \quad \approx 33\, m$
$\alpha_{+y} = 1.021 \quad \approx 8\, m$
$\alpha_{-y} = 1.049 \quad \approx 19\, m$





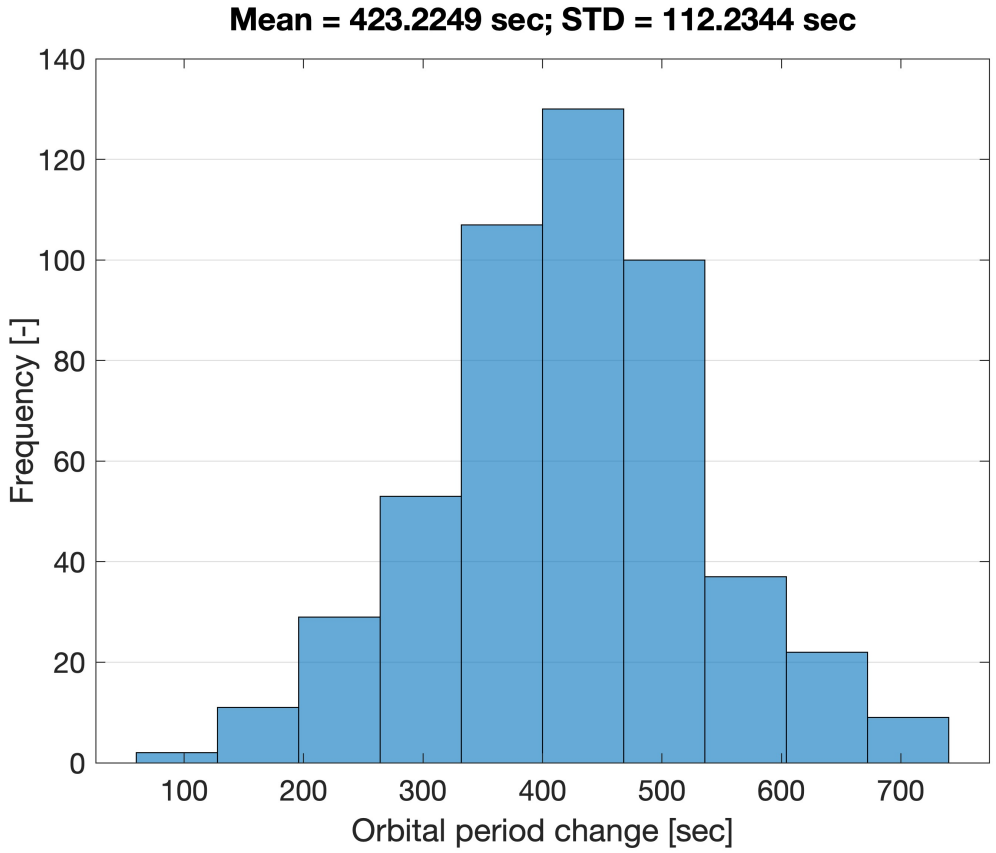
12 different α_{max},
500 cases for each α_{max}

→ 6,000 simulation cases in total

Dimorphos' orbital period change after 180 days from the impact

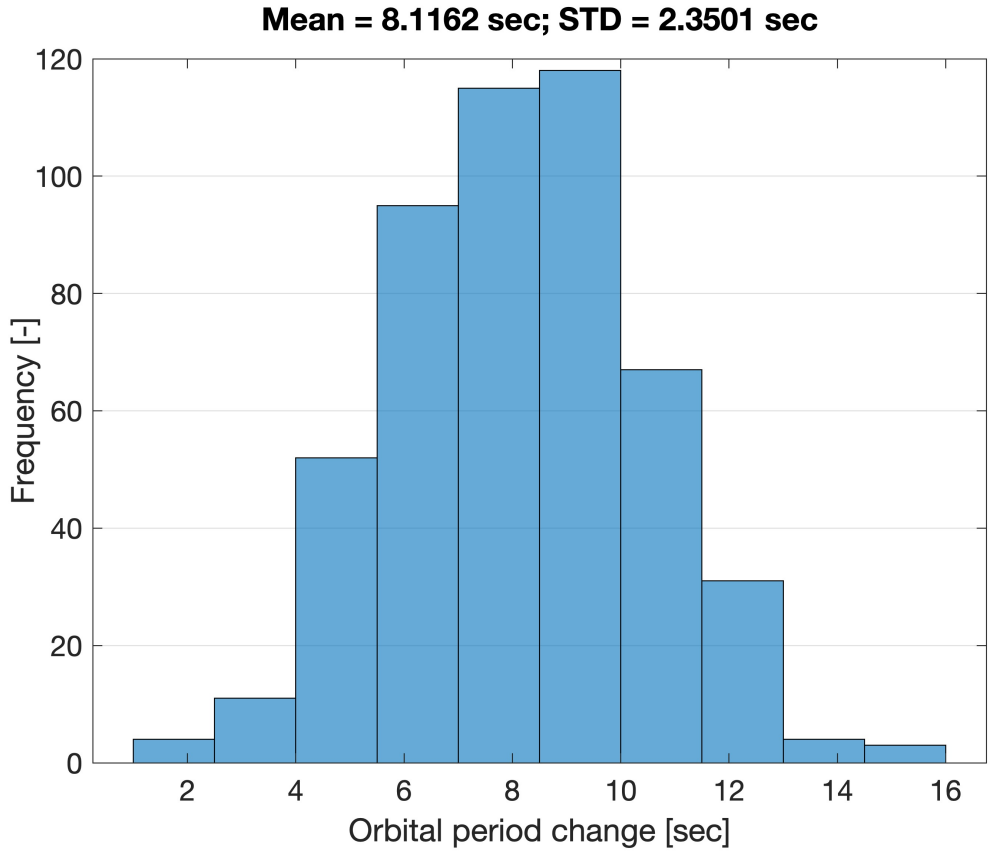
$\alpha_{max} = 1.05$

→ less than 20 m of reshaping



$\alpha_{max} = 1.001$

→ less than 1 m of reshaping

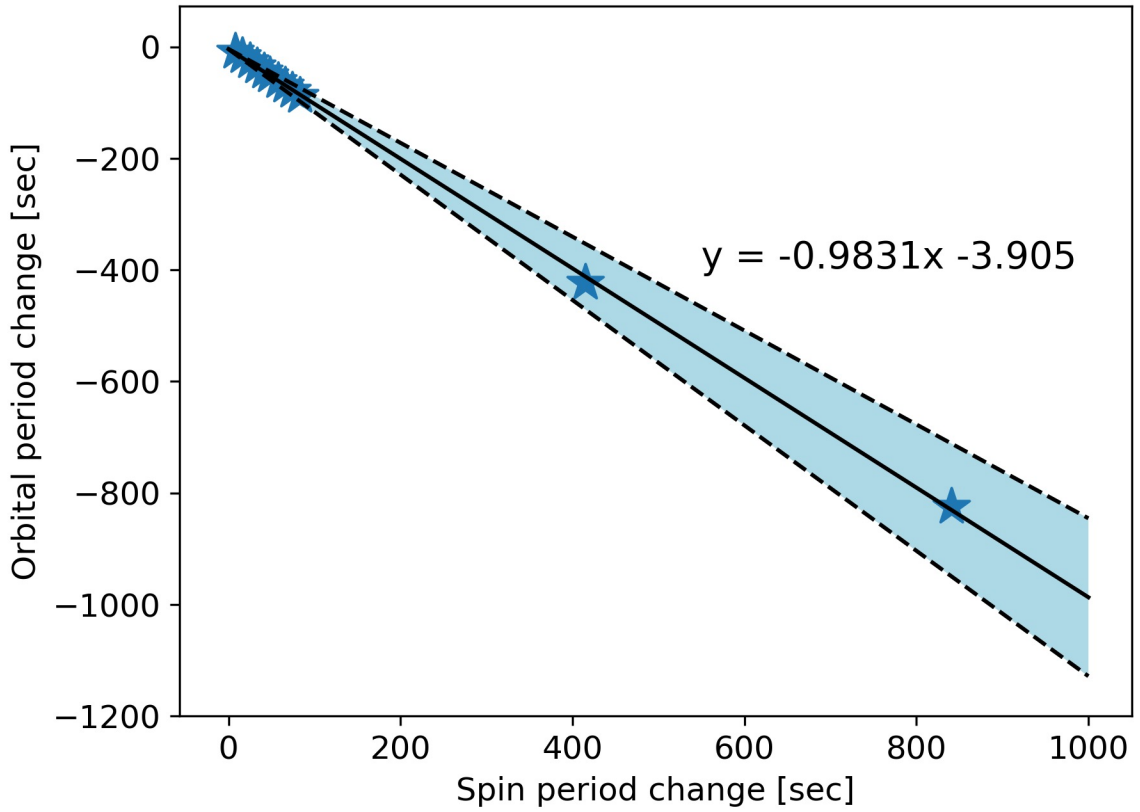


Reshaping magnitude can be constrained with the spin period change.

Didymos' angular momentum should be conserved.

→ The spin period changes during the reshaping event.

α_{max}	(Reshaping scale)	$\Delta\bar{P}_{spin}$ [sec]
1.1	(≈ 40 m)	840.57
1.05	(≈ 20 m)	415.09
1.01	(≈ 4 m)	82.684
1.009	(≈ 3.5 m)	74.192
⋮		⋮
1.002	(≈ 0.8 m)	15.701
1.001	(≈ 0.4 m)	8.0486



The orbital period linearly decreases as reshaping mag. increases.

From the statistical investigation, we found:

- For a shape change of less than 40 m, the reshaping-driven orbital period change is characterized to be linear.
- We predict the relationship: $\Delta P_{orb} = -0.9831\ \Delta \mathrm{P_{spin}} - 3.905$
- The orbital period should always become shorter than the original period, for the head-on DART impact scenario.
- Detailed observation of Didymos' spin period change can constrain the magnitude of reshaping,
- from which we can decouple the reshaping-driven orbital period change and can accurately determine the momentum transfer efficiency.

Thank you!

12 different α_{max}, 500 cases for each α_{max}, 6,000 simulation sets

α_{max}	$\Delta\overline{P}_{spin}$	$\Delta\overline{P}_{orb}$
1.1	840.57	824.47
1.05	415.09	423.22
1.01	82.684	87.354
1.009	74.192	78.527
1.008	65.933	69.719
1.007	57.823	61.155
1.006	47.863	51.004
1.005	40.937	43.781

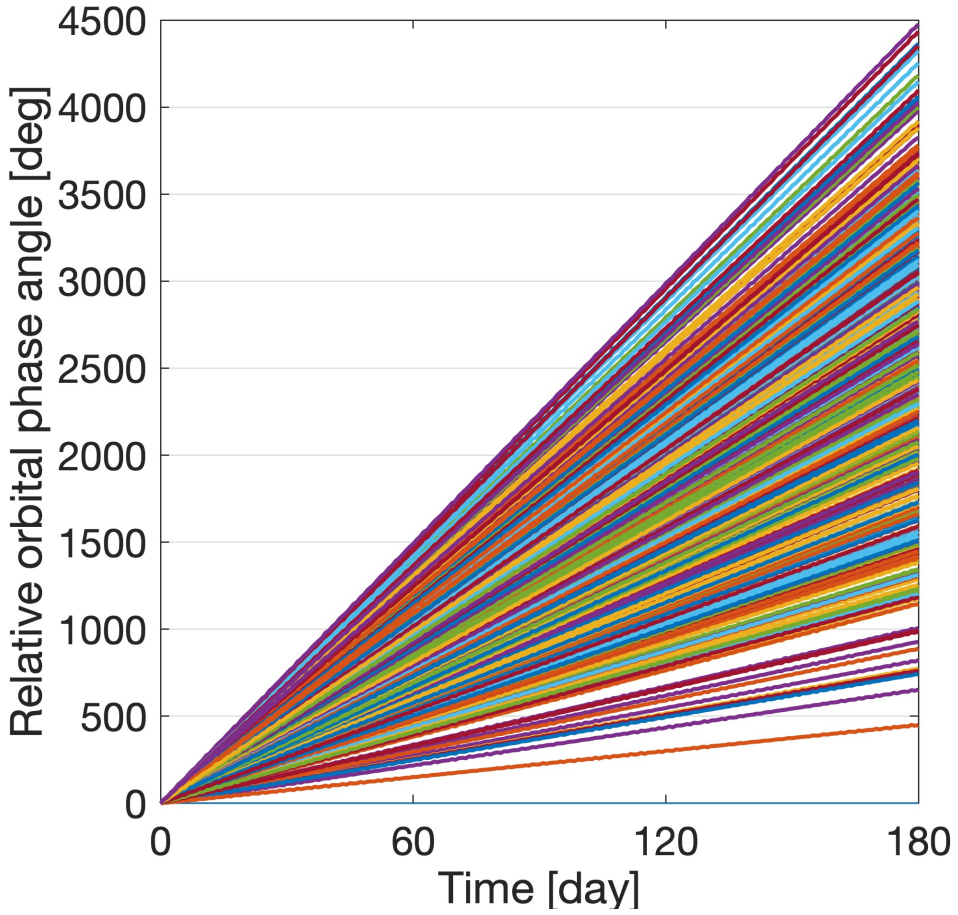
α_{max}	$\Delta\overline{P}_{spin}$	$\Delta\overline{P}_{orb}$
1.004	32.844	34.983
1.003	24.762	26.054
1.002	15.701	16.078
1.001	8.0486	8.1162

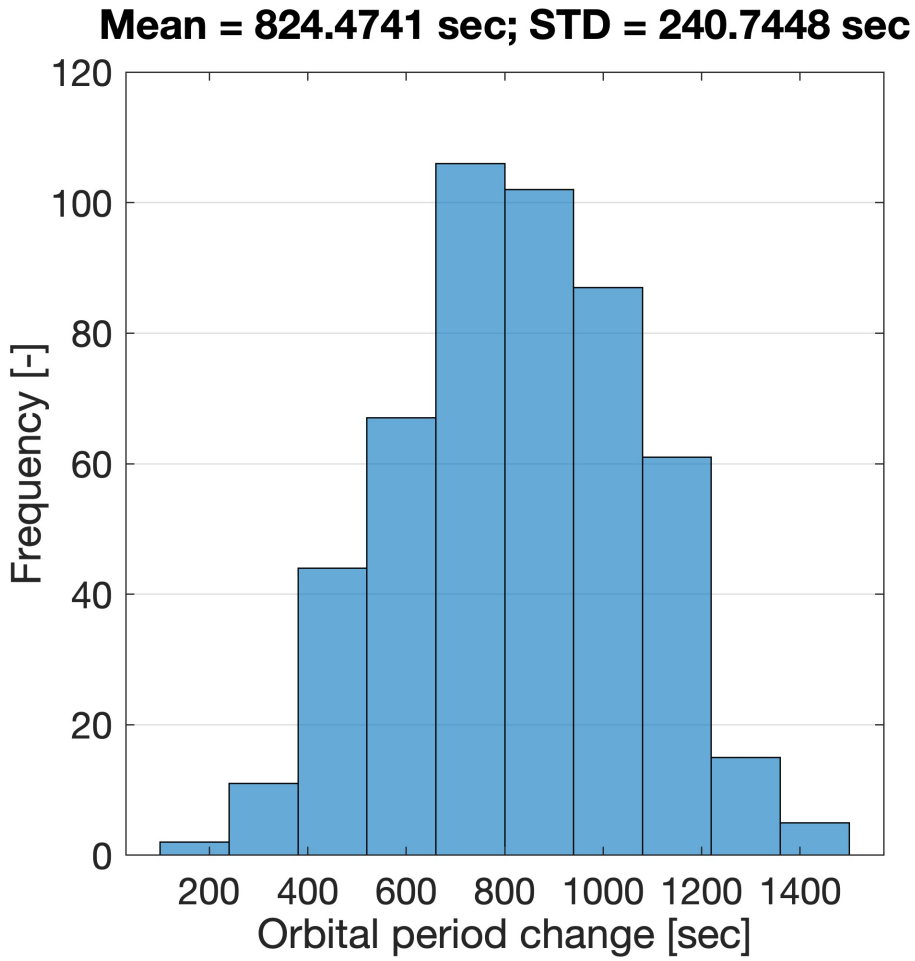
$\Delta\bar{P}_{spin}$: Mean spin period change

$\Delta\bar{P}_{orb}$: Mean orbital period change

Relative phase angle evolution 180 days after the DART impact

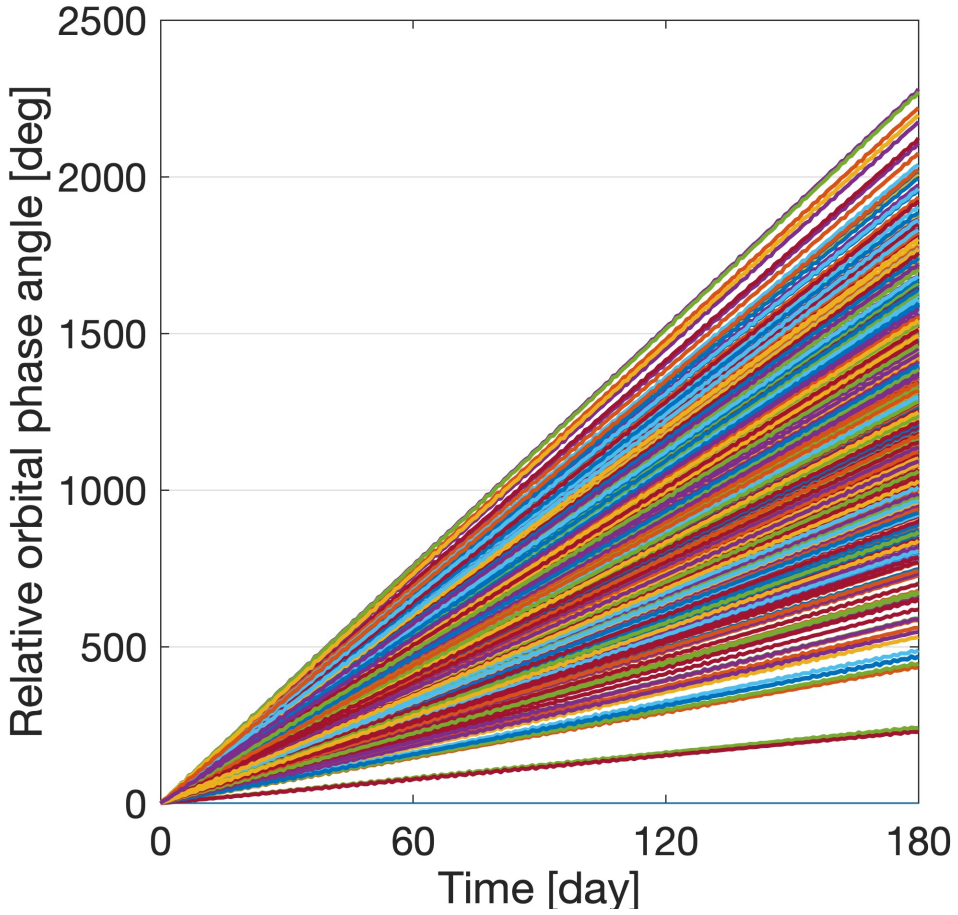
$\alpha_{max} = 1.1 \rightarrow$ less than 40 m of reshaping in each axis

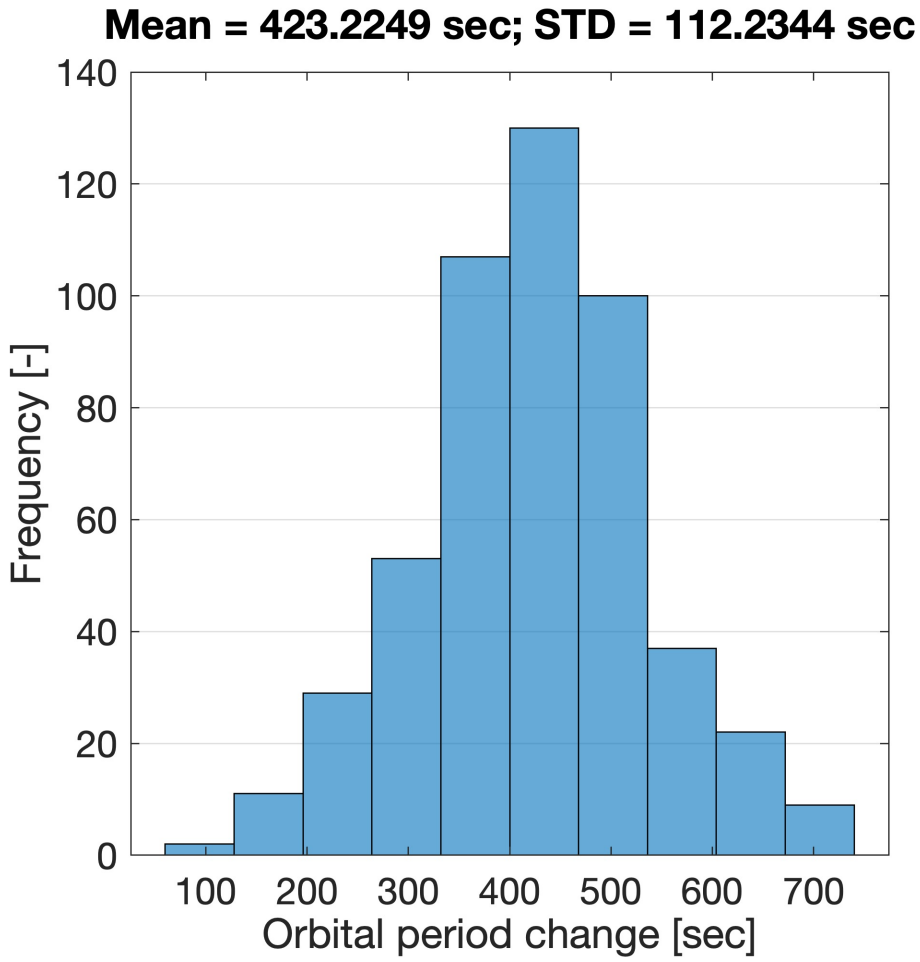




Relative phase angle evolution 180 days after the DART impact

$\alpha_{max} = 1.05 \rightarrow$ less than 20 m of reshaping in each axis





Relative phase angle evolution 180 days after the DART impact

$\alpha_{max} = 1.001 \rightarrow$ less than 1 m of reshaping in each axis