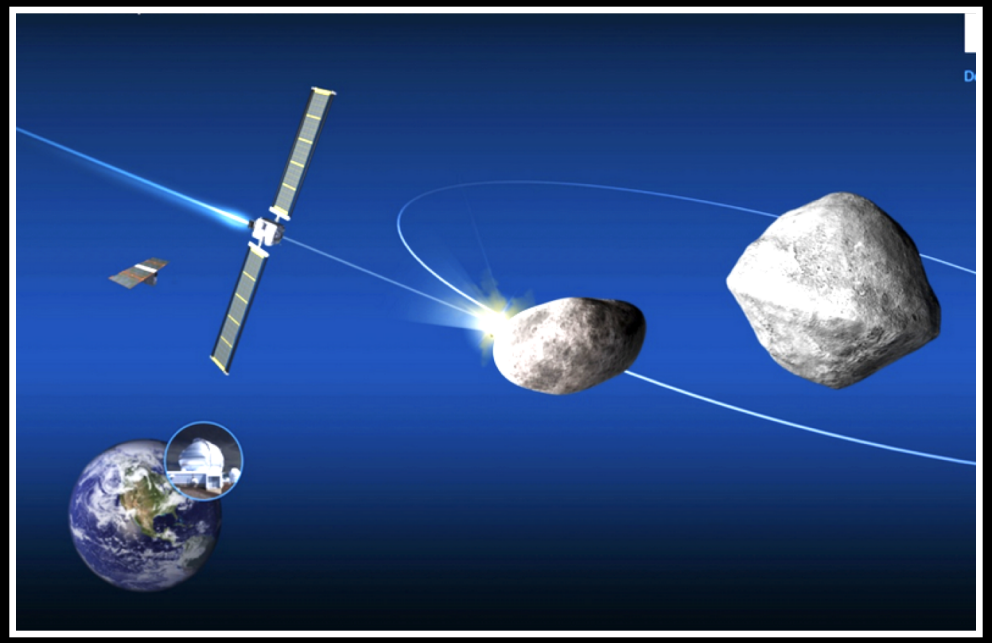
Planetary Defense: The DART Spacecraft Mission



Drs. Eileen and Bill Ryan

DART Investigation Team members

(NM Tech/Magdalena Ridge Observatory)

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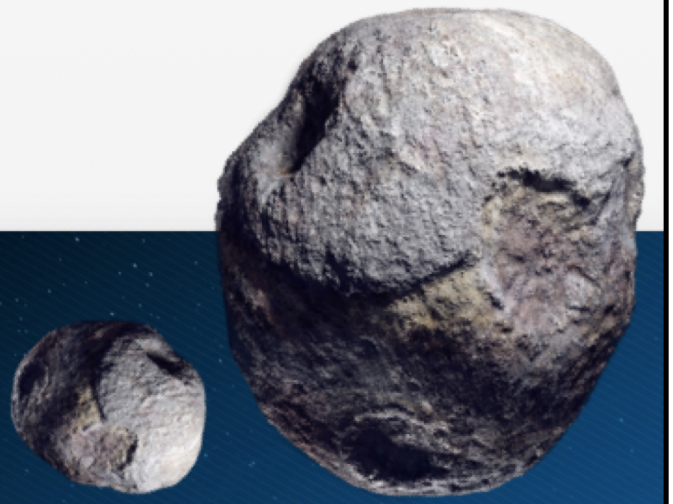
NM Tech's NASA Spaceguard-funded MRO 2.4m Telescope Facility has for the last *15 years* performed accurate, rapid, real-time follow-up of Near-Earth Asteroids & Comets.

How often?

Hazard by the Numbers



How big?	4 meters	25 meters	160 meters	1,000 meters	10,000 meters
How often?	~1 per year	~1 per 100 years	~1 per 25,000 years	~1 per 500,000 years	~1 per 100-200 million years
How bad?	Bright flash, no ground effects, but could leave meteorites	Air burst explosion, could cause widespread injuries if over populated area	Crater of 1-2 kilometer diameter, deadly over metro areas/states, mass casualties	10-kilometer crater, global devastation, possible collapse of civilization	100-kilometer crater, global devastation, mass extinctions of terrestrial life
How many?	~500 million	~5 million	~20,000	~900	~3
How many found?	< 0.1%	0.4%	42%	> 90%	100%

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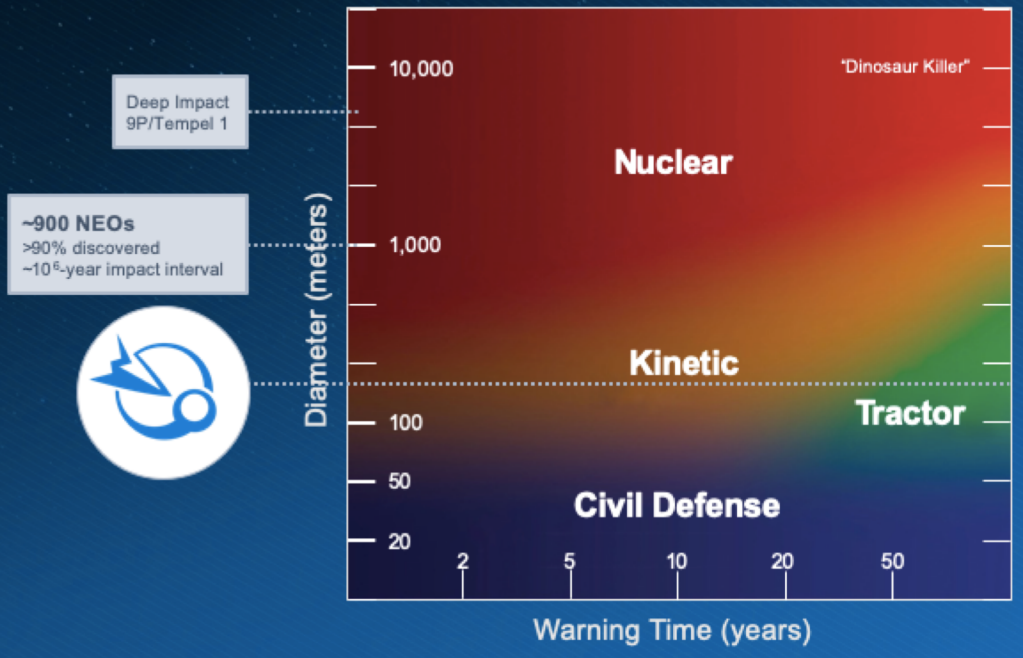
Mitigation Techniques for Potentially Hazardous Asteroids

*"The **first priority** for a space mission in the mitigation area is an **experimental test of a kinetic impactor.**"*

— from ***Defending Planet Earth: Near-Earth-Object Surveys and Hazard Mitigation Strategies***
published in 2010 by the
National Academy of Sciences



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Planetary Defense: NASA DART Mission

In 2022, NASA's Double Asteroid Redirection Test (DART), the first full-scale demonstration of an asteroid deflection technology for planetary defense, crashed into the Didymos/Dimorphos binary system on 9/26/22 at 6.3 km/s and changed its motion in space.

MRO is a team member providing ground-based observational support prior and post-impact.

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The MRO 2.4-meter Telescope

MRO is one of four of the DART NASA-funded telescope that is collecting data to confirm changes to the Didymos/Dimorphos asteroid pair's orbit.

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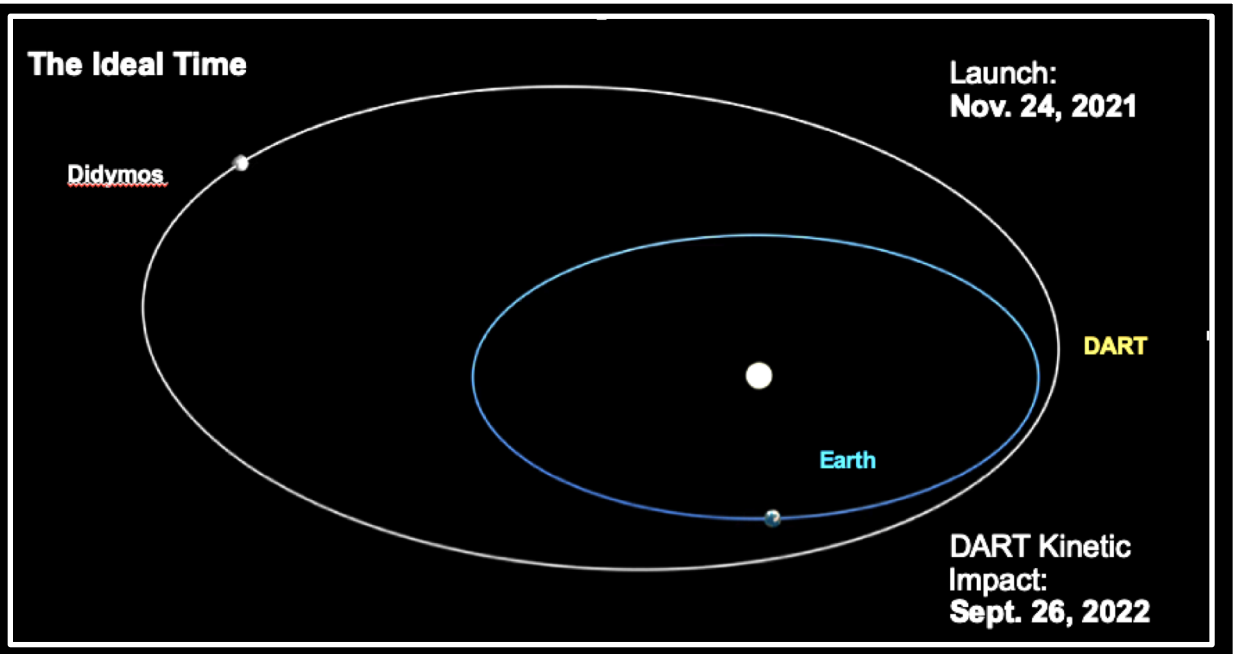
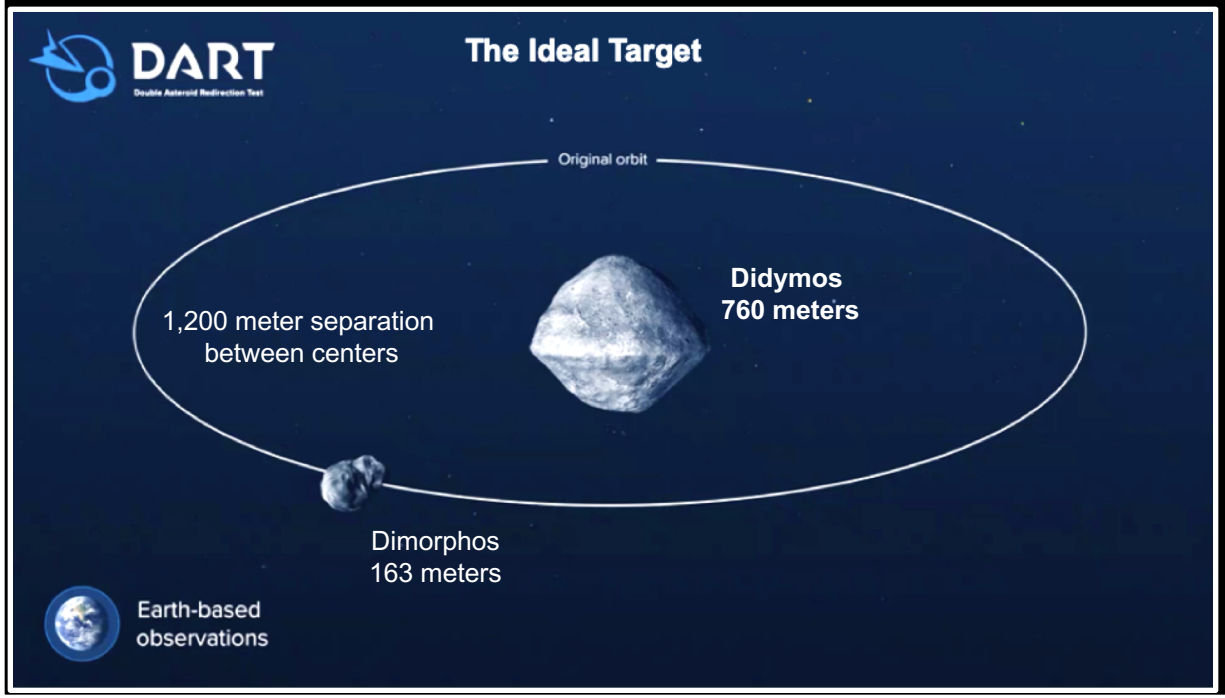
Binary Near-Earth Asteroid Target





Ideal Timing and Target for Ground-based Telescopes

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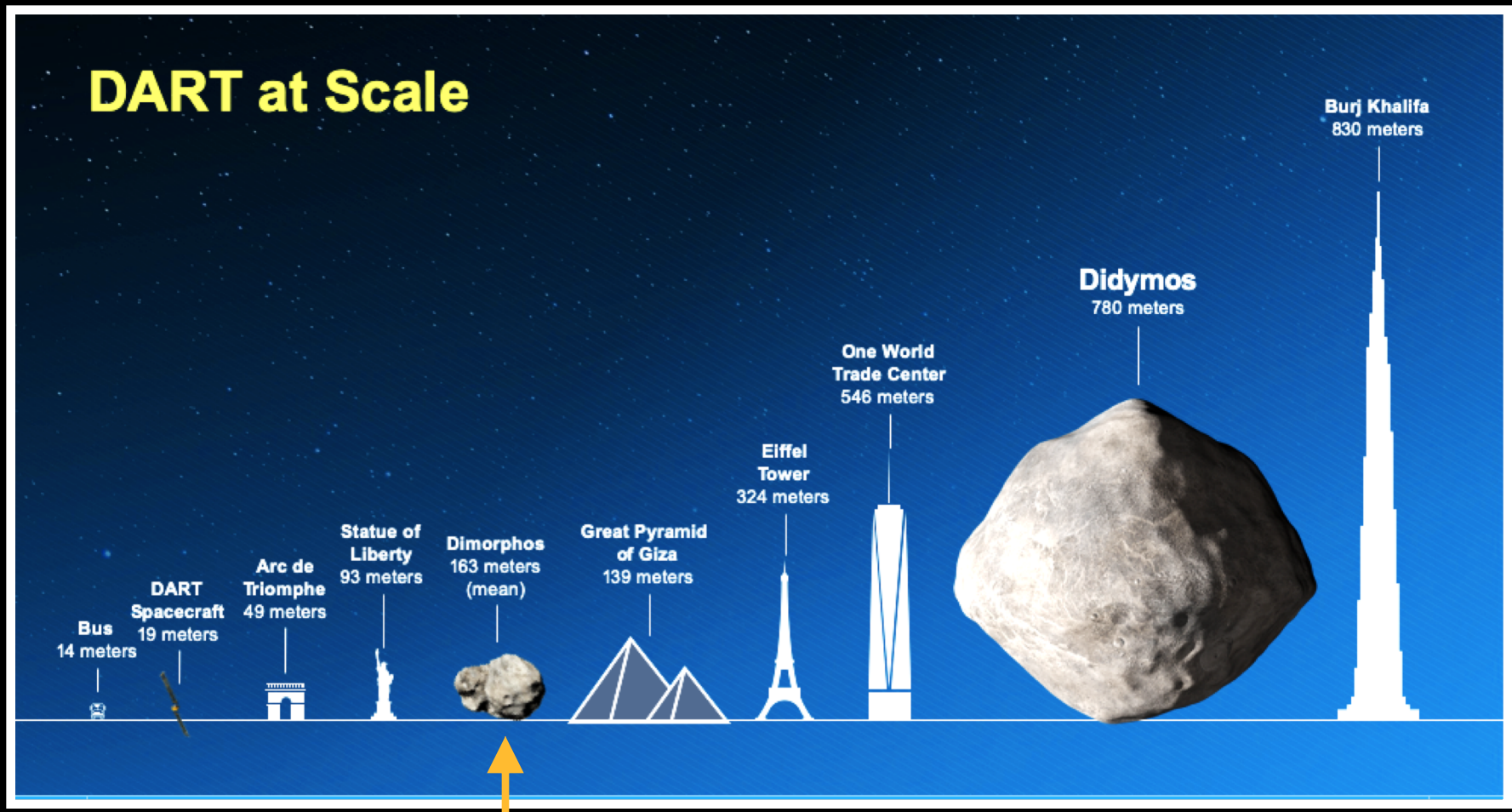

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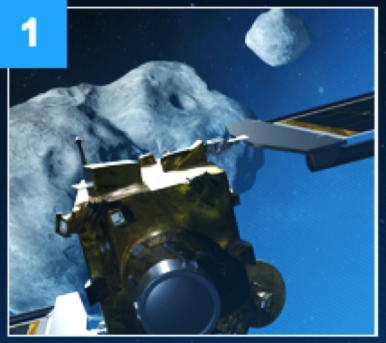
What will DART do?

1



Impact Dimorphos

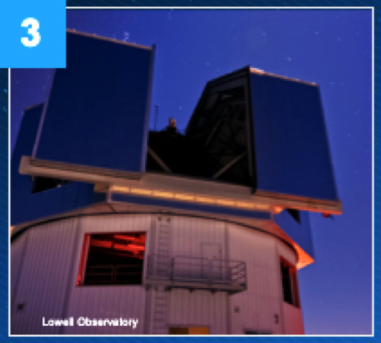
During its Sept /Oct 2022 close approach to Earth

2

Change the binary orbital period

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

3



Measure the period change

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

4

Measure "Beta" and characterize the impact site and dynamics

***Beta** = the momentum enhancement factor*

MRO Task

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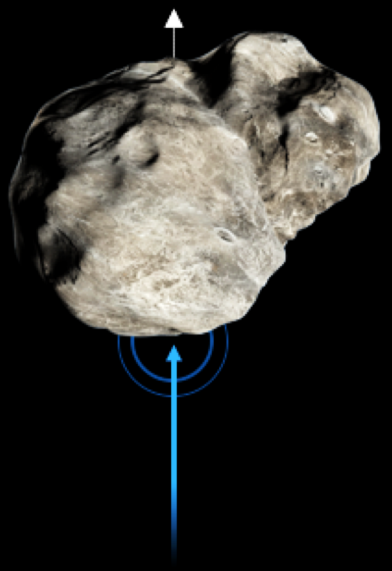
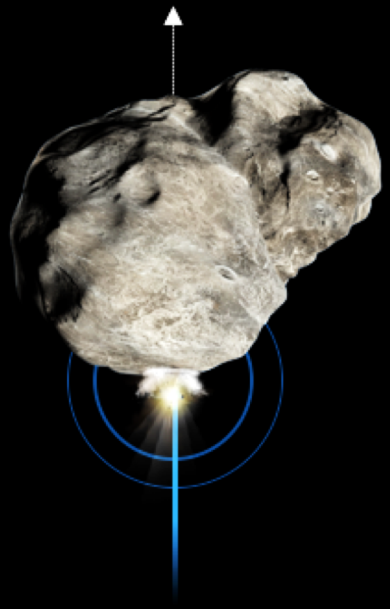
How much do we move the asteroid?



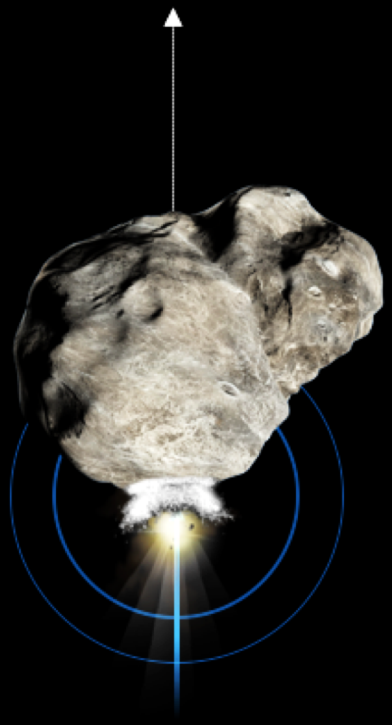
No ejecta and small momentum increase

Beta=1



Moderate ejecta and momentum increase

Beta=2



Heavy ejecta and large momentum increase

Beta=4

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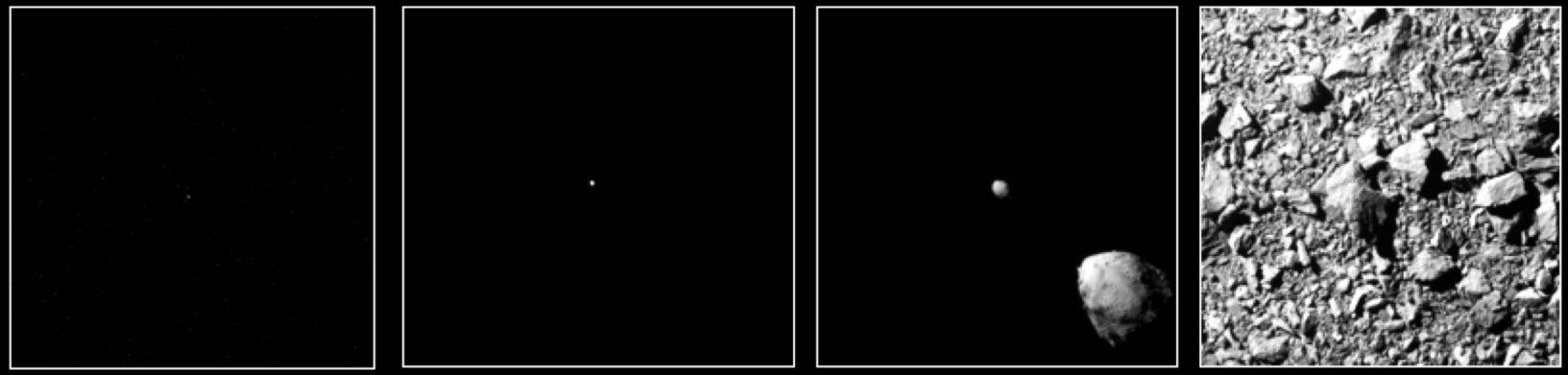
DART Impact September 26, 2022

Autonomously Navigating to Asteroid Impact



90,000 kilometers
Didymos – 1 pixel
Started SMARTNav
autonomous navigation

25,000 kilometers
Didymos – 8 pixel
Dimorphos – 2 pixel
Started tracking
Dimorphos

920 kilometers
Didymos – 180 pixel
Dimorphos – 38 pixel
Final downlinked images
to contain all of Didymos

12 kilometers
Dimorphos image
31 meters across
Penultimate Image

4 hours	68 minutes	2.5 minutes	2 second

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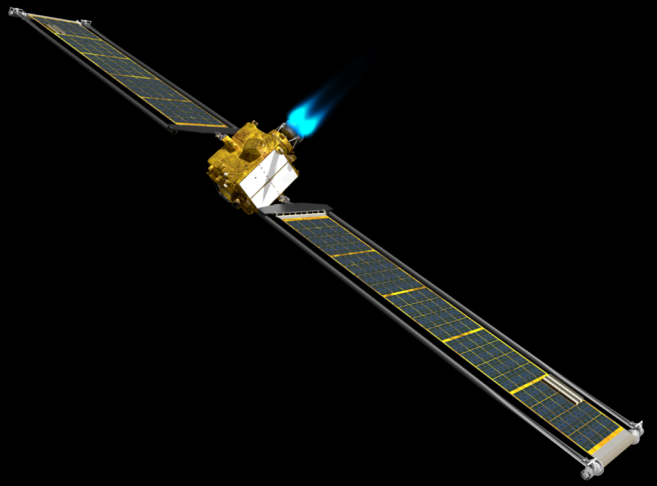
Atlas Telescope, South Africa 9/26/22



DART DRACO
Dimorphos
11 seconds before DART's impact
42 miles (68 km) distance

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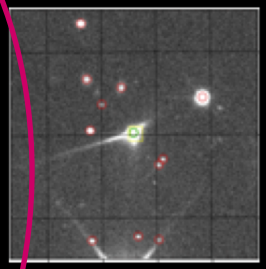
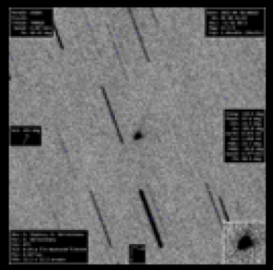
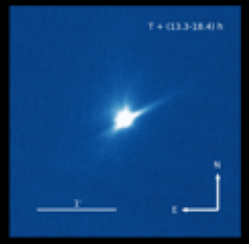
Telescopic observations of the Didymos system from DART team members around the world

Africa (South Africa)	North America (United States)	South America (Chile)	Europe (Romania)	Asia (Israel)	Oceania (New Zealand)	Antarctica (Concordia)
						
ATLAS project: U. Hawai'i.	Bill and Eileen Ryan: Magdalena Ridge Obs NM Tech	T. Lister, J. Chatelain, E. Gomez: Las Cumbres Observatory	Popescu: Astronomical Institute of the Romanian Academy	Ofek/Polishook: Weizmann Institute of Science.	R. Ridden-Harper/M. T. Bannister/N. Tan/T. Brown/P. Tristram: U. Canterbury	Abe: ASTEP+

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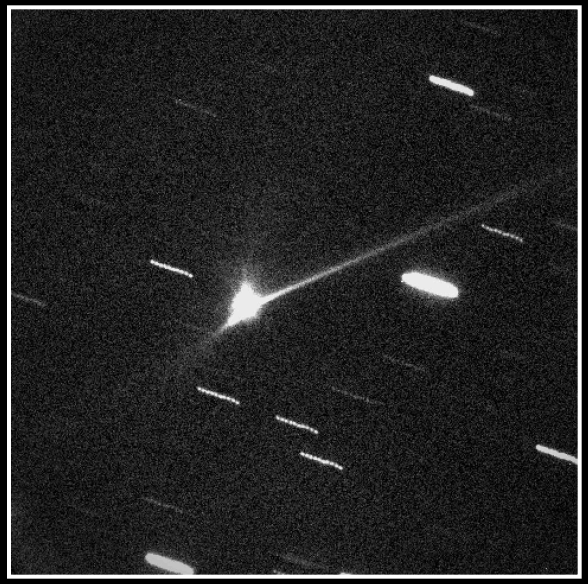
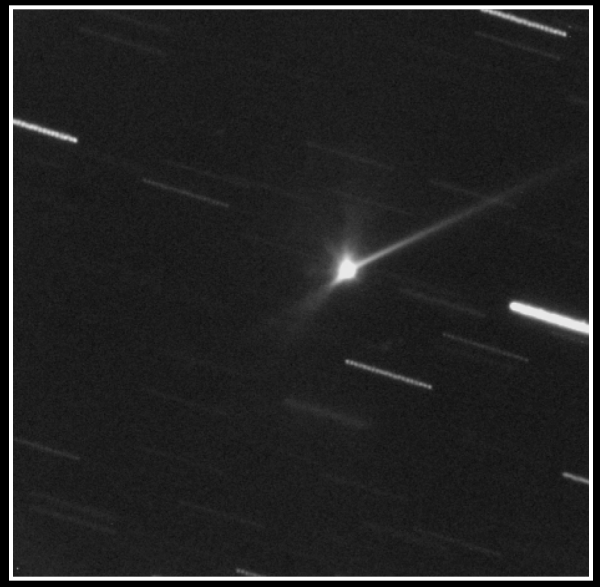
MRO Initial Post-Impact Ejecta Images

09/27/22
(10 hours after impact)



09/28/22
(34 hours after impact)



09/29/22
(58 hours after impact)

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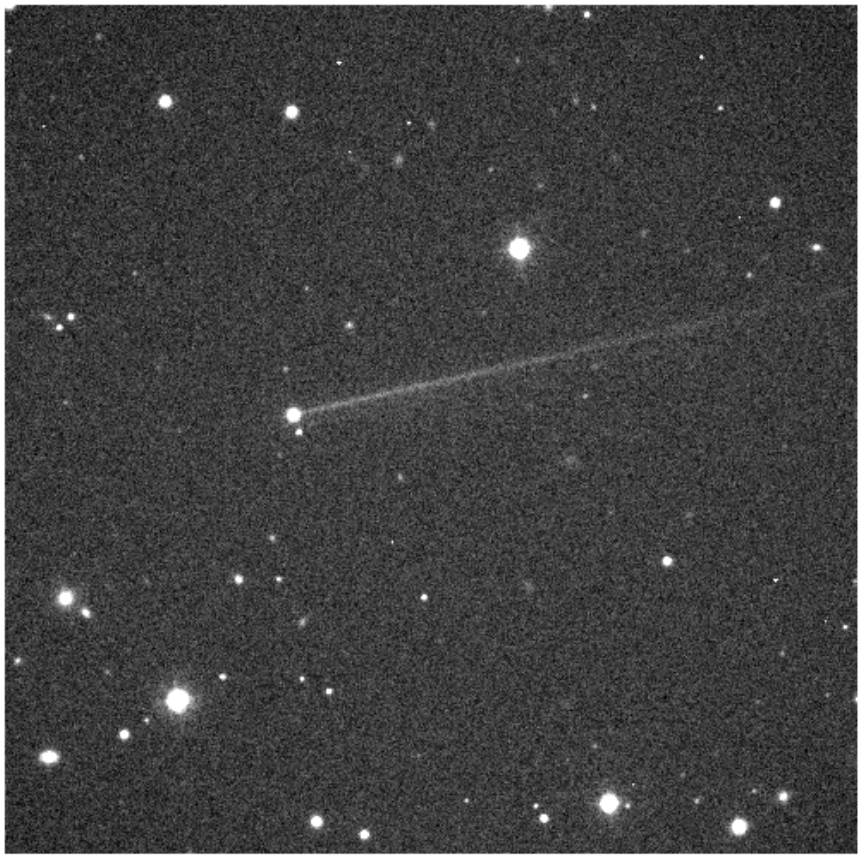
MRO 2.4-meter Observations: 11/30/22



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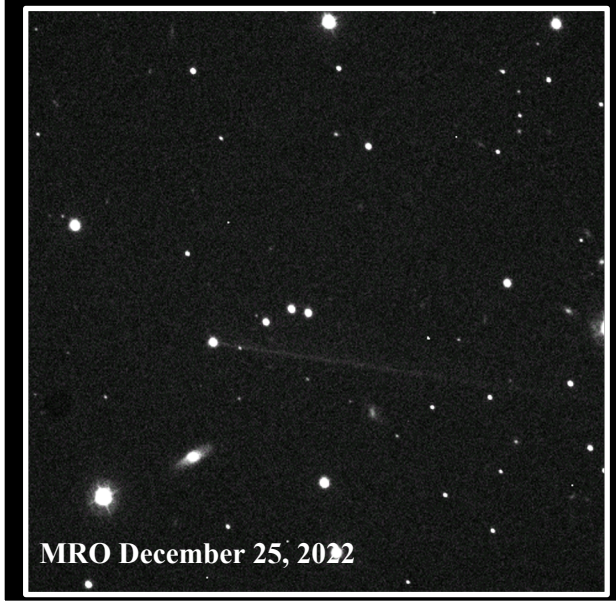
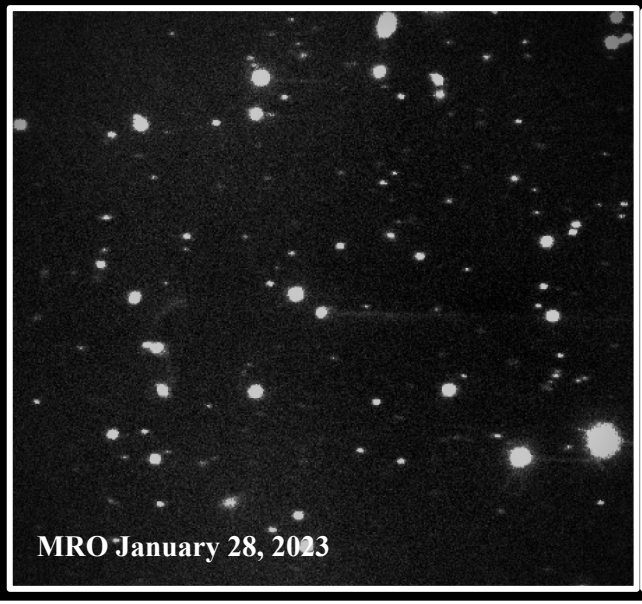
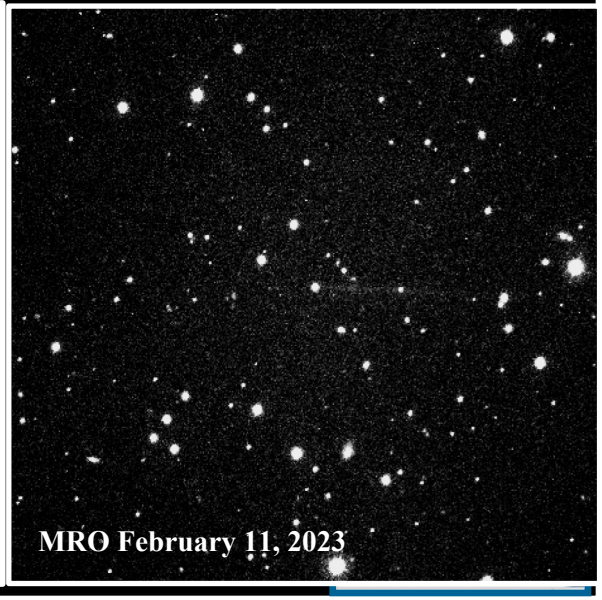
Ejecta Tail Evolution







Ejecta Tail

MRO October 11, 2022

HST October 11, 2022

Observations from MRO on October 11th, ~14.5 days after impact, clearly show the two tails first seen approximately a week earlier by Hubble.

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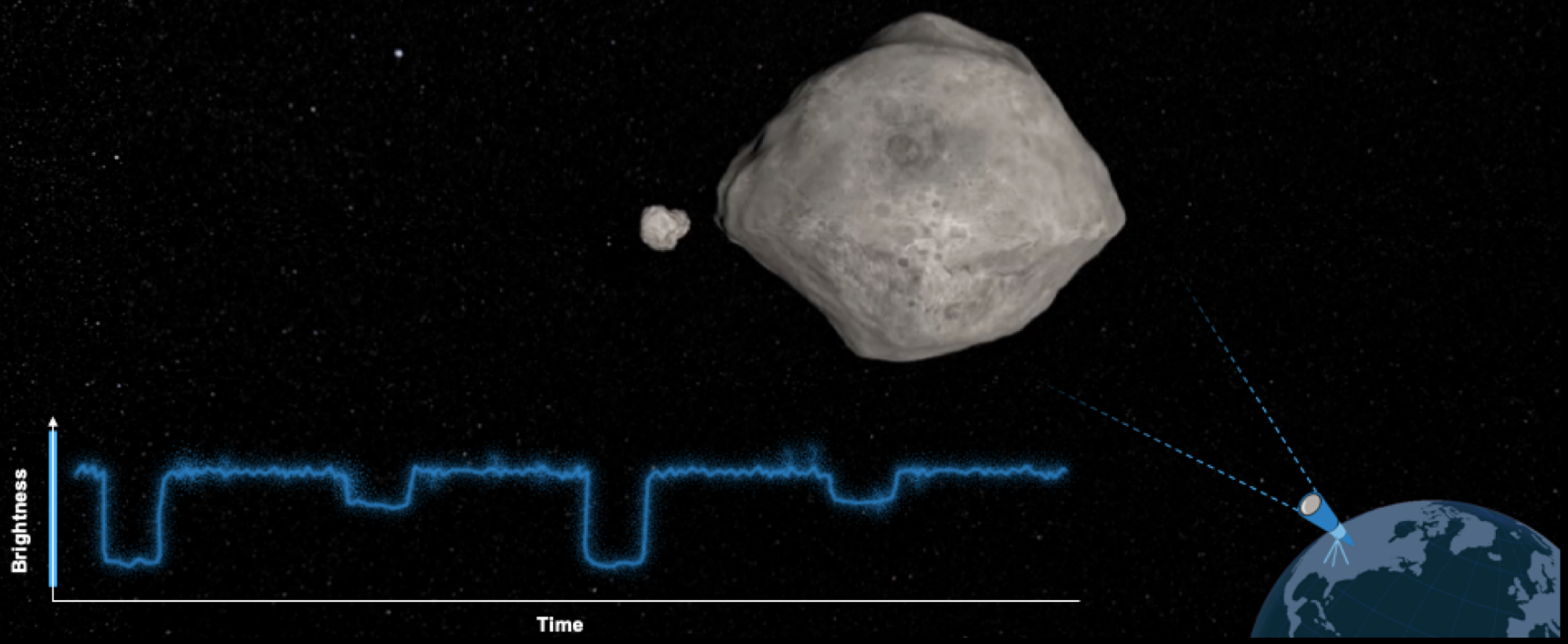
Measuring result of the impact: new orbit for Dimorphos



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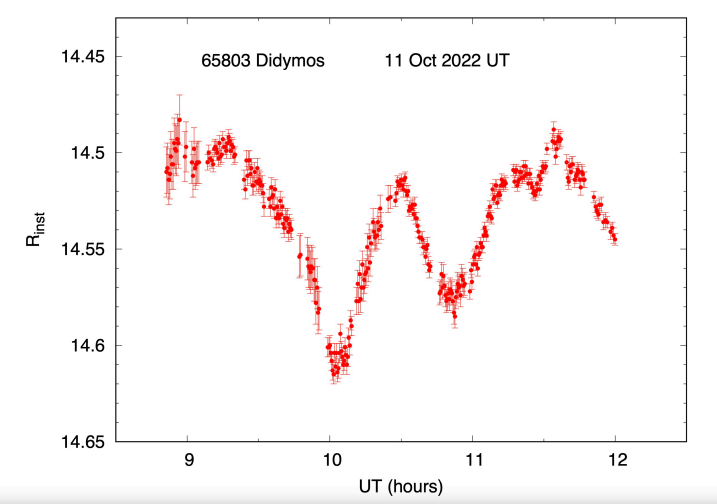
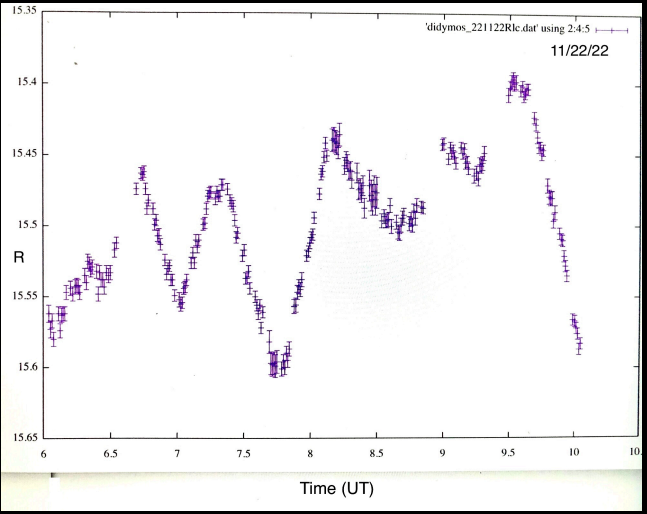
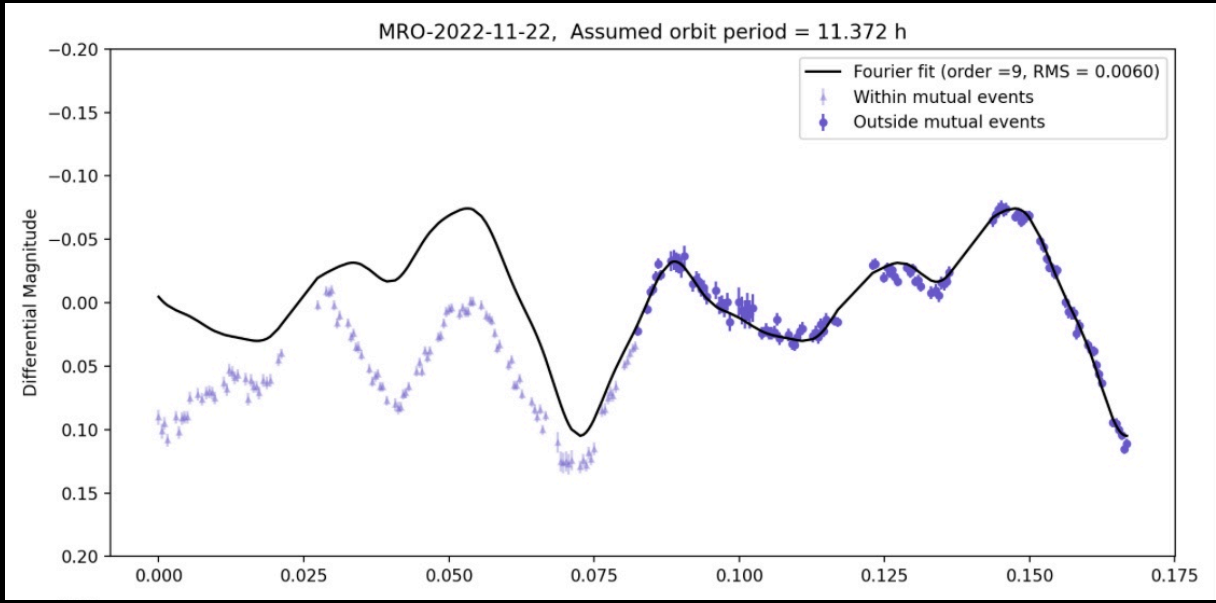
Didymos/Dimorphos Lightcurves







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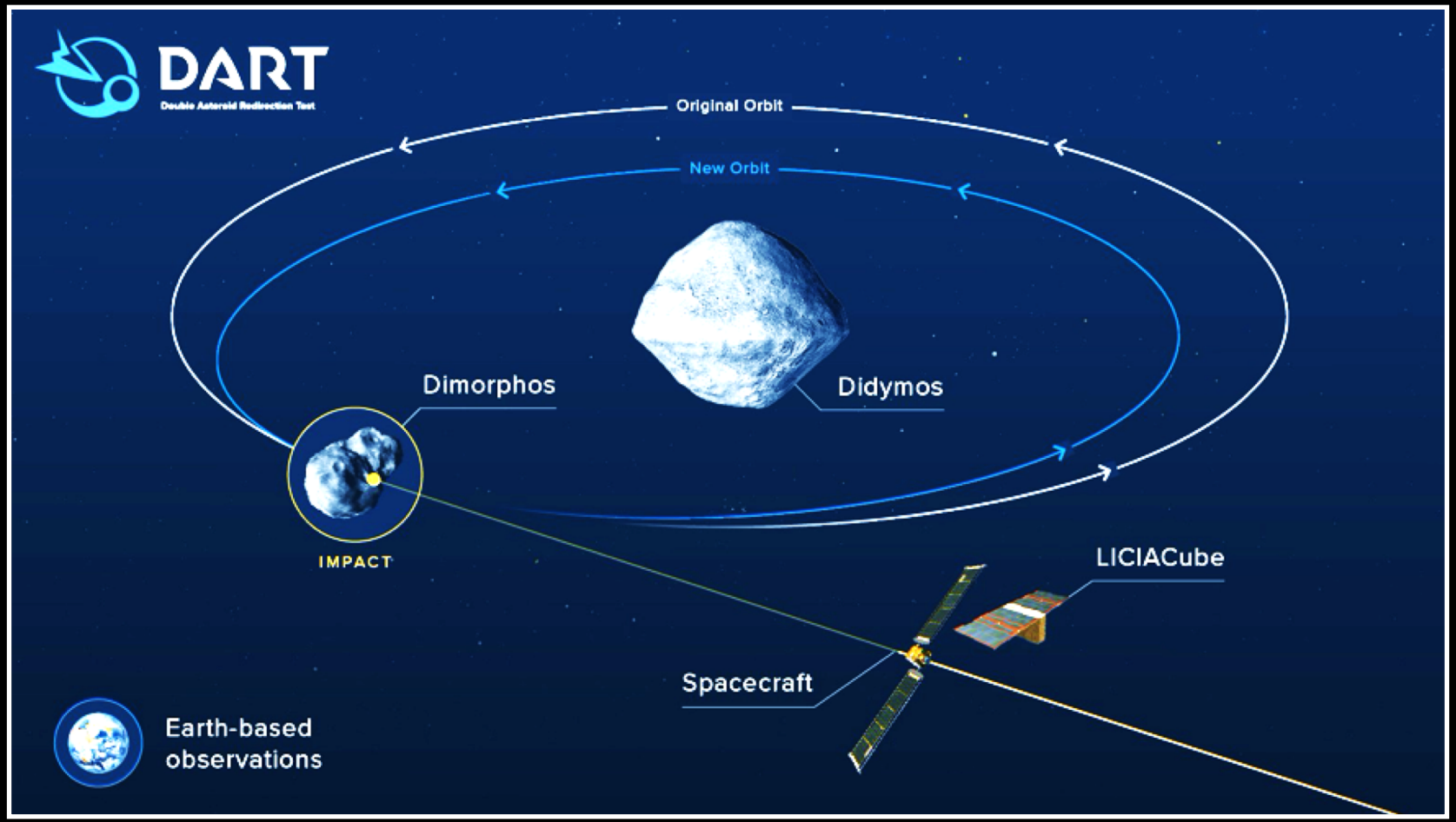
Orbit Change: Period Faster ~32 min



<u>Dimporhos</u>: Pre-Impact= 11 hrs 55 min

Post-Impact= 11 hrs 33 min

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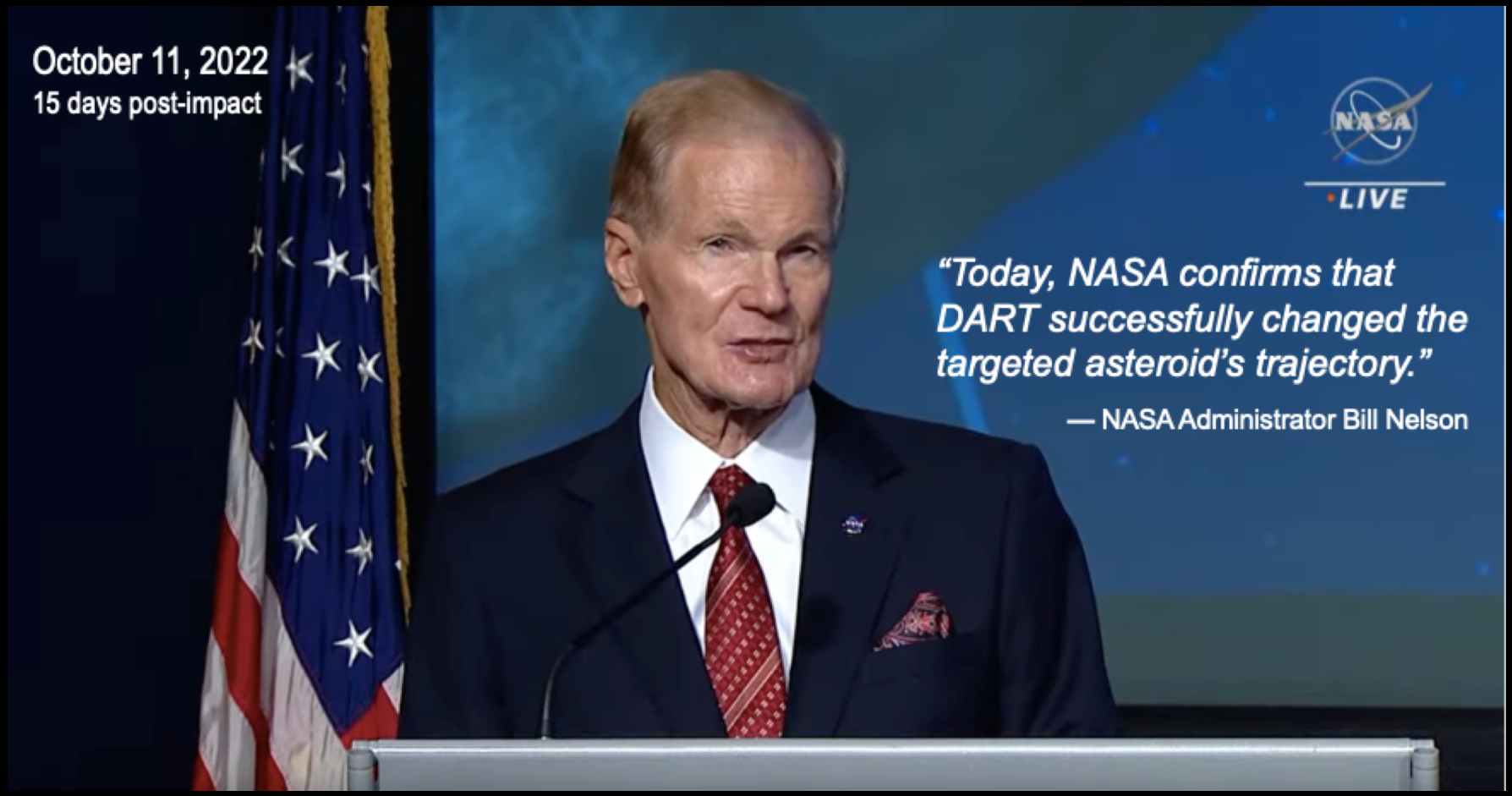

First step in deflecting hazardous asteroids!

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