National Aeronautics and Space Administration

Double Asteroid Redirection Test

NASA'S First Planetary Defense Test Mission

PRESS KIT

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THE FIRST PLANETARY
DEFENSE TEST MISSION

"This incredible mission will use innovative technologies as it autonomously navigates toward the Didymos system, and it is an integral part of NASA's planetary defense program."

—Andrea Riley, DART program executive, NASA Headquarters

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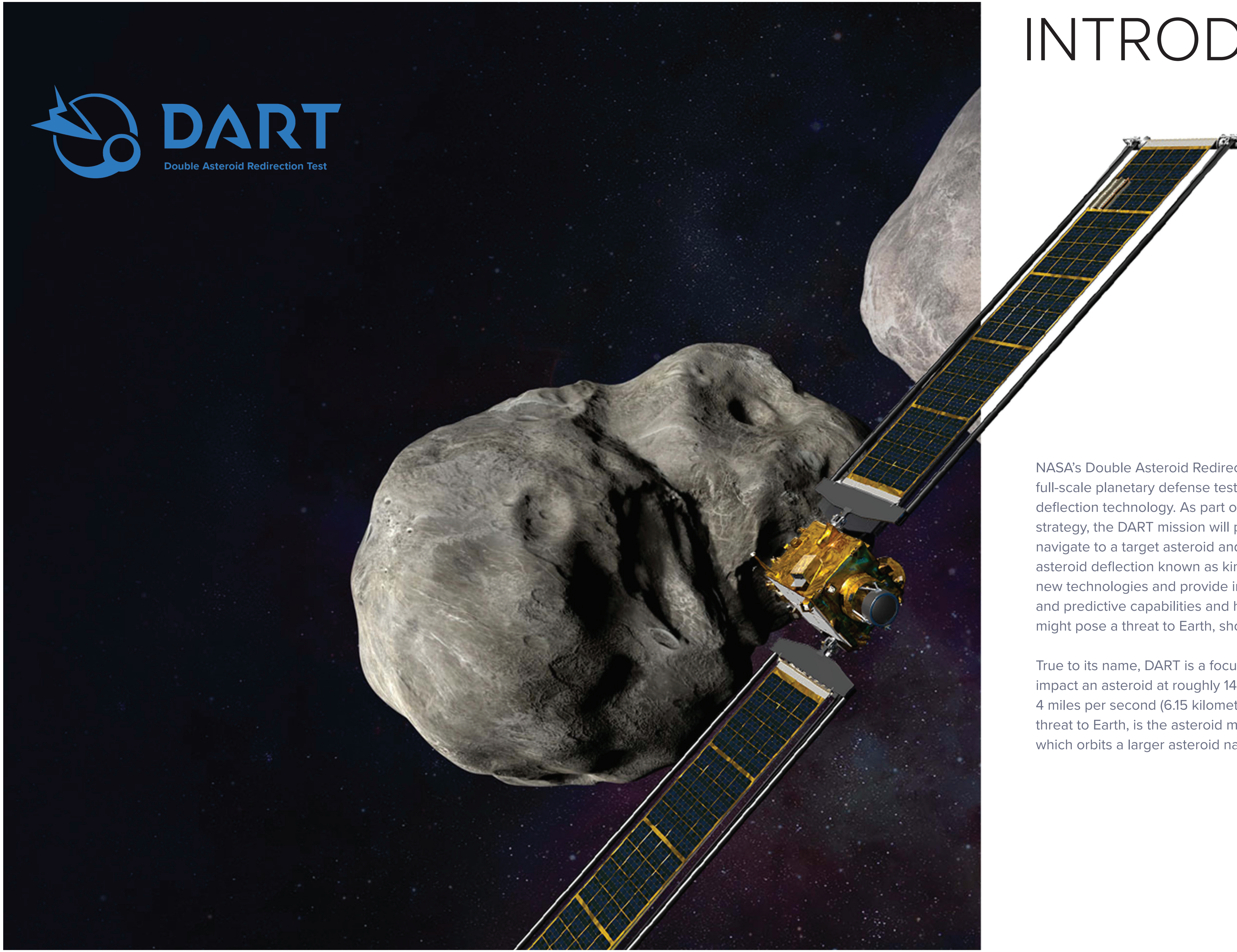


INTRODUCTION

NASA's Double Asteroid Redirection Test, or DART, is the world's first full-scale planetary defense test, demonstrating one method of asteroid deflection technology. As part of NASA's larger planetary defense strategy, the DART mission will prove that a spacecraft can autonomously navigate to a target asteroid and intentionally collide with it, a method of asteroid deflection known as kinetic impact. DART will simultaneously test new technologies and provide important data to enhance our modeling and predictive capabilities and help us better prepare for an asteroid that might pose a threat to Earth, should one be discovered.

True to its name, DART is a focused spacecraft, designed to direct itself to impact an asteroid at roughly 14,000 miles per hour, or approximately 4 miles per second (6.15 kilometers per second). Its target, which poses no threat to Earth, is the asteroid moonlet Dimorphos (Greek for "two forms"), which orbits a larger asteroid named Didymos (Greek for "twin").

THREE BIG TAKEAWAYS FROM THE DART MISSION

INTRODUCTION

1

DART is testing and demonstrating one method of deflecting an asteroid.

Very few of the billions of asteroids and comets orbiting our Sun are potentially hazardous to Earth, and no known asteroid poses a threat to our planet for at least the next century. The DART mission is a key test that NASA will perform before any actual need, better preparing our defenses should we ever discover an asteroid on a collision course with Earth.

The DART spacecraft, which was built and is operated by the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, at the direction of NASA's Planetary Defense Coordination Office (PDCO), is designed to demonstrate that an asteroid that could cause regional devastation — one just a few hundred feet across — can be deflected by intentionally crashing a spacecraft into it. This method, called kinetic impact deflection, is just one of several proposed ways to redirect potentially hazardous asteroids, but it's the one currently assessed as the most technologically mature.

DART is a test of our ability to achieve a kinetic impact on an asteroid and observe the asteroid's response to that impact. DART's engineers have developed and are implementing the technology to make an impact happen; after impact, the investigation team will measure how much the asteroid is deflected using telescopes on Earth. This mission also engages the international planetary science community in many ways, embracing worldwide cooperation to address the global issue of planetary defense.

2

DART's kinetic impact can improve models and better prepare us to mitigate hazardous asteroids.

Although planetary scientists can create miniature impacts in a lab and build sophisticated computational models based on those results, asteroids are complicated bodies with a range of physical properties, internal structures, shapes and geologic features. Carrying out a real-world test on an asteroid of relevant size is a necessary next step to evaluate the models developed to date and advance them further to address potentially hazardous asteroids in the future.

As the first planetary defense test mission to demonstrate one method of asteroid deflection, DART's impact into an asteroid with mostly unknown physical properties will both enhance and validate scientific computational models that are crucial to predicting the effectiveness of a kinetic impactor. Scientists will use the telescopic observations of the Didymos system, images of Dimorphos taken by the onboard **Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO)** and images of the DART impact event collected by the Italian Space Agency's **Light Italian CubeSat for Imaging of Asteroids (LICIACube)** — along with data collected later by the European Space Agency's Hera mission — to build more accurate models and better prepare us to successfully defend the planet should a future asteroid impact threat ever be discovered.

THREE BIG TAKEAWAYS FROM THE DART MISSION

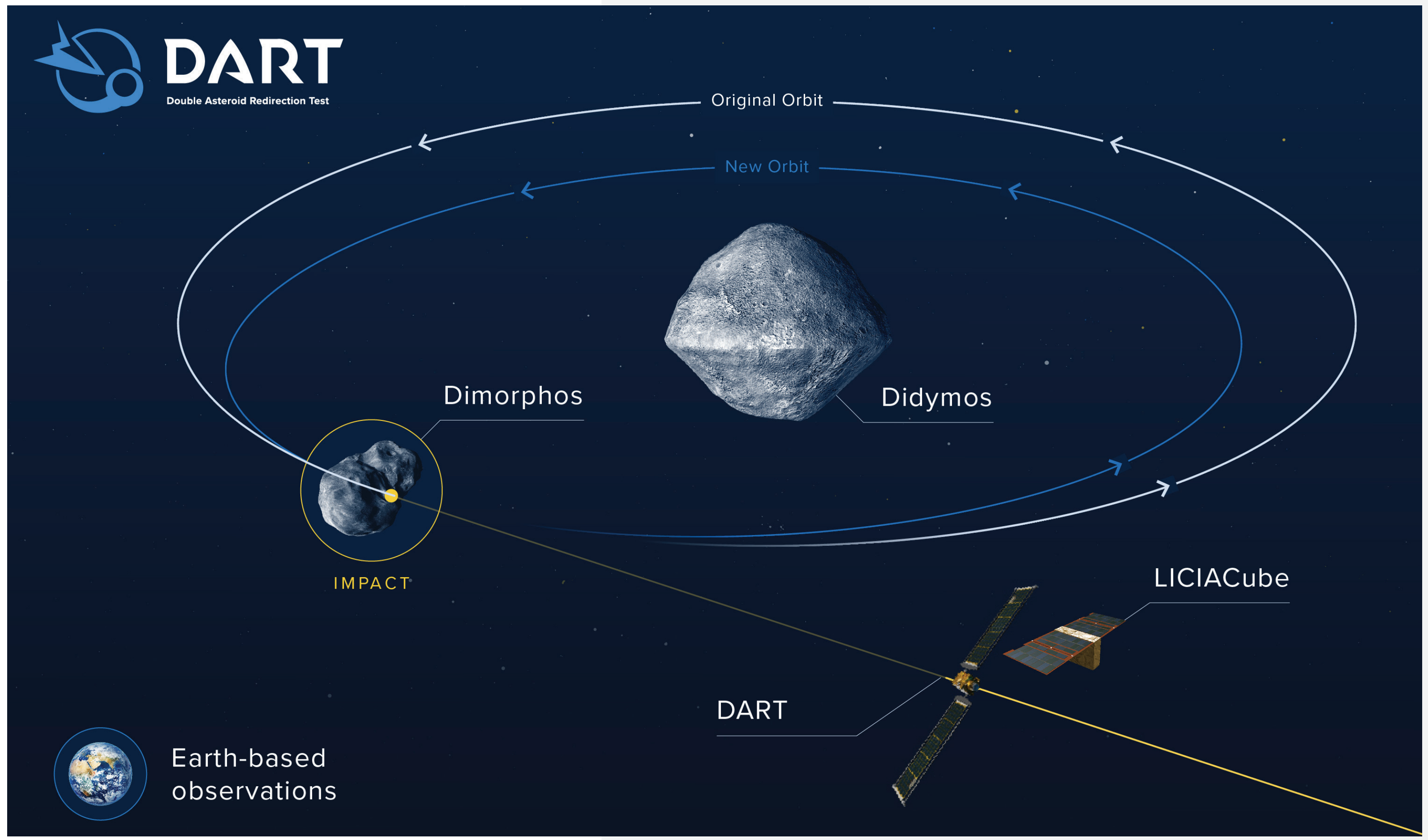
INTRODUCTION

3

DART is testing several innovative technologies, including a new autonomous guidance system.

The APL-developed **Small-body Maneuvering Autonomous Real Time Navigation (SMART Nav)** system allows the DART spacecraft to guide itself without operator assistance. SMART Nav works with **DRACO** and the guidance, navigation and control (GNC) system to create an autonomous optical navigation capability that will identify and distinguish between Didymos and Dimorphos, then independently direct and maneuver the spacecraft during its last four hours before impact.

The DART mission is also testing **Transformational Solar Array** technology. Laced within small portions of the spacecraft's two **Roll-Out Solar Arrays (ROSA)**, these high-efficiency, APL-developed solar cells and reflective concentrators provide three times more power than standard solar arrays.



SPACECRAFT ORBIT DIAGRAM

Additionally, DART is testing **NASA's Evolutionary Xenon Thruster–Commercial (NEXT-C)**, a solar-powered ion propulsion system developed by NASA's Glenn Research Center and Aerojet Rocketdyne. Although NEXT-C is not DART's primary propulsion system, its inclusion allows for in-flight testing and demonstrates its potential application to future deep-space missions.

FAST FACTS

MISSION

Launch:
November 23, 2021, 10:21 p.m. PST
(November 24, 2021, 1:21 a.m. EST)

Launch Site:
Vandenberg Space Force Base, California

Launch Vehicle:
SpaceX Falcon 9

DART Impact:
September 26, 2022, 7:14 p.m. EDT

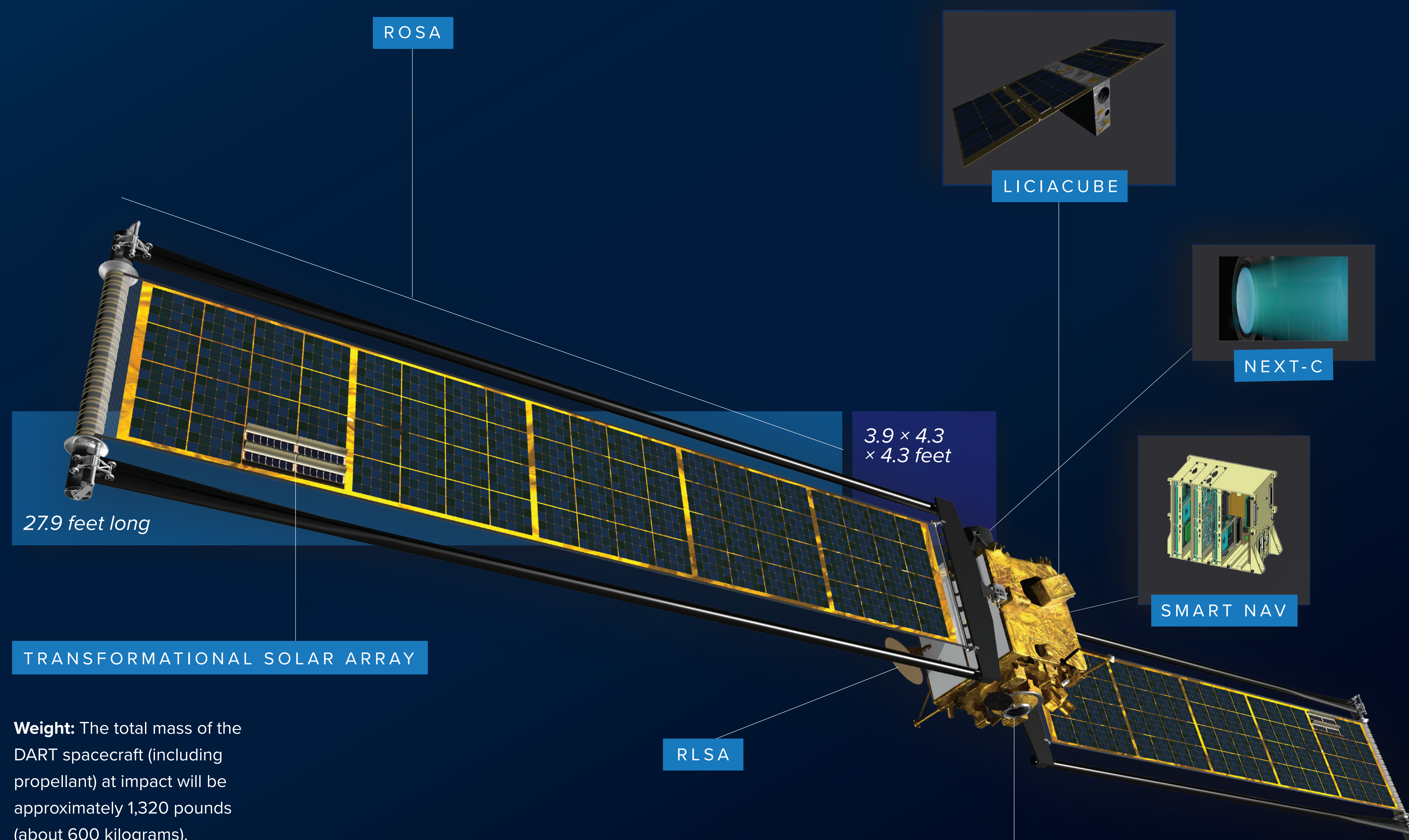
FAST FACTS

Mission Objectives:

1. Demonstrate a kinetic impact with Dimorphos.
2. Change the binary orbital period of Dimorphos.
3. Use ground-based telescope observations to measure Dimorphos' orbit before and after impact.
4. Measure the effects of the impact and the efficiency of the deflection.

Payload Instruments and Technologies:

- Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO)
- Light Italian CubeSat for Imaging of Asteroids (LICIACube)
- Small-body Maneuvering Autonomous Real Time Navigation (SMART Nav)
- NASA's Evolutionary Xenon Thruster–Commercial (NEXT-C) ion propulsion system
- Roll-Out Solar Array (ROSA)
- Transformational Solar Array
- CORE Small Avionics suiTe (CORESAT)
- Radial Line Slot Array (RLSA)



Weight: The total mass of the DART spacecraft (including propellant) at impact will be approximately 1,320 pounds (about 600 kilograms).

Dimensions: The DART probe is a box roughly 3.9 × 4.3 × 4.3 feet (1.2 × 1.3 × 1.3 meters), from which other structures extend, resulting in measurements of roughly 5.9 feet (1.8 meters) in width, 6.2 feet (1.9 meters) in length and 8.5 feet (2.6 meters) in height. The spacecraft also has two very large solar arrays that, when fully deployed, are each 27.9 feet (8.5 meters) long.

FAST FACTS

Size: The asteroid Didymos is approximately 2,500 feet (780 meters) in diameter, or roughly the height of the Burj Khalifa in Dubai, the tallest building in the world. Its moonlet, Dimorphos, is about 525 feet (160 meters) in size, or about the size of the High Roller in Las Vegas, the world's tallest operating Ferris wheel.

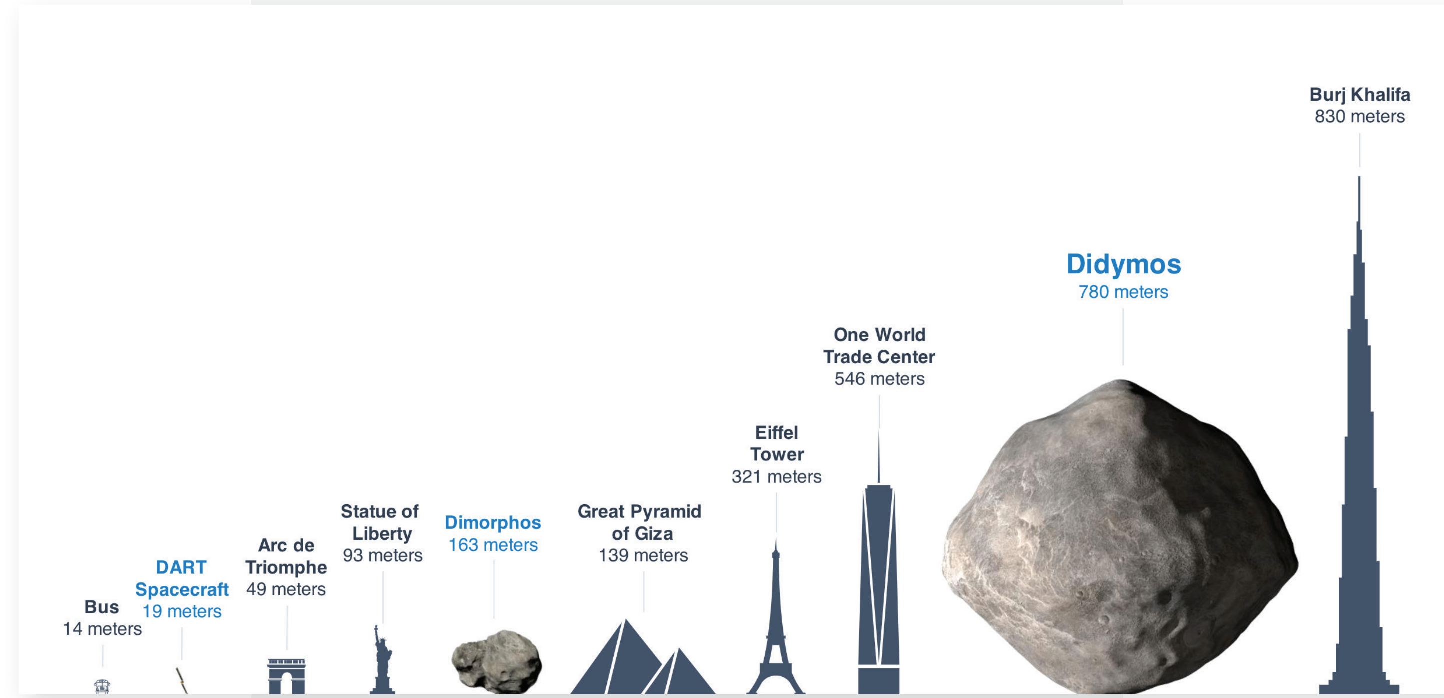
Binary Orbit: Dimorphos orbits Didymos at a distance of about 0.75 miles (1.2 kilometers), measured from center to center. At a speed of about 7 inches per second (17 centimeters per second), it completes an orbit in 11 hours and 55 minutes.

Rotation: Didymos rotates on its axis about once every 2.26 hours. Dimorphos most likely rotates at the same rate as it orbits — once in just under 12 hours — always keeping the same side pointed toward Didymos, although this is not quite proven based on evidence to date.

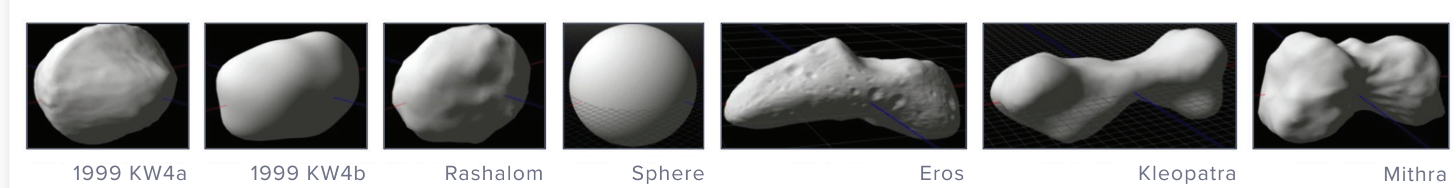
Shape: Past radar imaging observations have shown that Didymos has a shape reminiscent of a toy top, with a narrow ridge running along the asteroid's equator; all that is known about the shape of Dimorphos is that it is slightly elongated, with its long axis pointed at Didymos.

Orbit Around the Sun:
The Didymos system takes 2.11 years (770 days) to make one full orbit around the Sun. Its elliptical orbit stretches from beyond Mars (about 2.27 astronomical units [AU], or Earth-Sun distances) to just outside Earth's orbit (about 1 AU).

Distance from Earth at Impact:
DART's kinetic impact on Sept. 26, 2022 will occur when the distance between Earth and the Didymos system is near its minimum, roughly 6.8 million miles (11 million kilometers). That timing allows scientists to make higher quality telescopic observations of Didymos after the collision. The last time Didymos was this close to Earth was in 2003; the next time will be in 2062.



DART AT SCALE



DIMORPHOS – Examples of possible asteroid shapes considered during DART simulation and testing.

MEDIA SERVICES

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Products and Events

News Releases, Features and Status Reports

News, updates and feature stories about the DART mission are available at https://dart.jhuapl.edu/.

Video and Images

A collection of videos, animation, images and infographics can be found on the mission website's gallery: https://dart.jhuapl.edu/Gallery/.

The NASA image use policy is available at https://www.nasa.gov/multimedia/guidelines/index.html.

Media Events

The most up-to-date information about DART mission media events and where to watch them is available at http://www.nasa.gov/multimedia/nasatv/schedule.html.

More information on NASA TV and streaming channels can be found on the next page.

THE FIRST PLANETARY DEFENSE TEST MISSION

"Though DART ramming into Dimorphos means the end of the spacecraft, it's just the start of the science."

—Andy Rivkin, DART investigation team lead, Johns Hopkins APL

MEDIA SERVICES

Briefings and Availabilities

A virtual news conference previewing the DART impact is scheduled for Sept. 22, 2022; information on start time and how members of the media can dial in to ask questions will be available on the NASA and DART mission websites. Members of the public will be able to submit questions via social media using the hashtag #AskNASA.

Additional news conferences will be scheduled as events warrant. All news briefings will be broadcast on NASA TV and streamed on nasa.gov/live.

Interviews with mission team members may be arranged by calling or emailing any of the media contacts listed on page 14.

How to Watch

News briefings and impact commentary will be streamed on NASA TV, NASA.gov/live, and YouTube.com/NASA. On-demand recordings will also be available on YouTube after the live events have finished.

For more information about NASA TV's programming schedule, visit http://www.nasa.gov/ntv.

Additional Resources on the Web

Digital versions of this press kit are available at https://dart.jhuapl.edu/press-kit.

Additional information about the DART mission can be found on the mission's websites: www.nasa.gov/planetarydefense/ and https://dart.jhuapl.edu.

Social Media

Join the conversation and keep your target locked on Dimorphos by following these accounts and hashtags for the latest mission updates:

Twitter:

@NASA, @NASASolarSystem, @AsteroidWatch, @JHUAPL

Facebook:

/NASA, /NASASolarSystem, /JHUAPL

Instagram:

@nasa, @nasasolarsystem, @johnshopkinsapl

Hashtags:

#DARTMission, #planetarydefense

OVERVIEW

MISSION

Bits of interplanetary dust and rock hit Earth all the time. Most of these are harmless and burn up in our planet's atmosphere. Occasionally, some bigger objects make it through, causing local damage or, in extreme cases, massive devastation. But with the right technology and knowledge of asteroids' orbits, scientists can anticipate and prevent an impact by deflecting an asteroid just enough to avoid a collision.

NASA's Double Asteroid Redirection Test, or DART, is the first mission to demonstrate the technology to deflect an asteroid. DART will use an autonomous guidance system to aim itself at the asteroid moonlet, Dimorphos, which it will strike at approximately 14,000 miles per hour (22,000 kilometers per hour), causing a small change in the asteroid's motion. Telescopes on Earth will then measure the amount the asteroid is deflected by observing the change in the moonlet's orbit around its larger asteroid, Didymos.

DART's impact at Dimorphos will occur on Sept. 26, 2022, at 7:14 p.m. EDT.

Why Planetary Defense?

On Feb. 15, 2013, an undetected asteroid entered Earth's atmosphere and exploded over Chelyabinsk, Russia, causing an airburst and shockwave that struck six cities around the region. The blast injured more than 1,600 people and caused an estimated $30 million in damage. It was a stark reminder that potentially hazardous objects can enter Earth's atmosphere at any time, and that even relatively small ones can be of concern. The Chelyabinsk object was just about 60 feet (18 meters) in size. Astronomers estimate that there are approximately 25,000 near-Earth asteroids close to 500 feet (140 meters) or larger in size — big enough to cause regional devastation if they were to hit Earth. This underscores the need to both discover and track near-Earth objects, as well as perform real-world tests of potential asteroid deflection.

Asteroids, like Earth and the other planets, orbit the Sun, but they become hazardous only if their orbits and Earth's orbit intersect at the same point and time. The key to preventing an impact is the ability to predict such mutual arrivals well in advance, then alter the asteroid's path, even slightly, to make the asteroid arrive early or late, missing a collision with Earth.

DART will demonstrate an asteroid deflection technique called kinetic impact, in which a spacecraft deliberately collides with an asteroid at high speed to slightly change the object's motion. The DART spacecraft will collide with the asteroid moonlet, Dimorphos, attempting to change the orbit around its larger companion, Didymos. Although simple in principle, the execution of such a technique demands a lot of engineering expertise and advanced planning, including extensive modeling and simulation of the kinetic impact ahead of launch, as well as precise Earth-based telescope observations of the asteroid system before and after impact.

The Hazard by the Numbers

Asteroid Size	4 meters	25 meters	140 meters	1,000 meters	10,000 meters
Frequency	~1 per year	~1 per 100 years	~1 per 20,000 years	~1 per 500,000 years	~1 per 100-200 million years
Impact	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
# of NEOs	~500 million	~5 million	~25,000	~900	4
% Discovered	< 0.1%	0.4%	39%	> 95%	100%

OVERVIEW

MISSION

Why the Didymos System?

DART's target is the binary asteroid system Didymos, which is made up of a larger asteroid named Didymos (2,500 feet, or 780 meters, in diameter) and a smaller, orbiting asteroid moonlet named Dimorphos (525 feet, or 160 meters, in size).

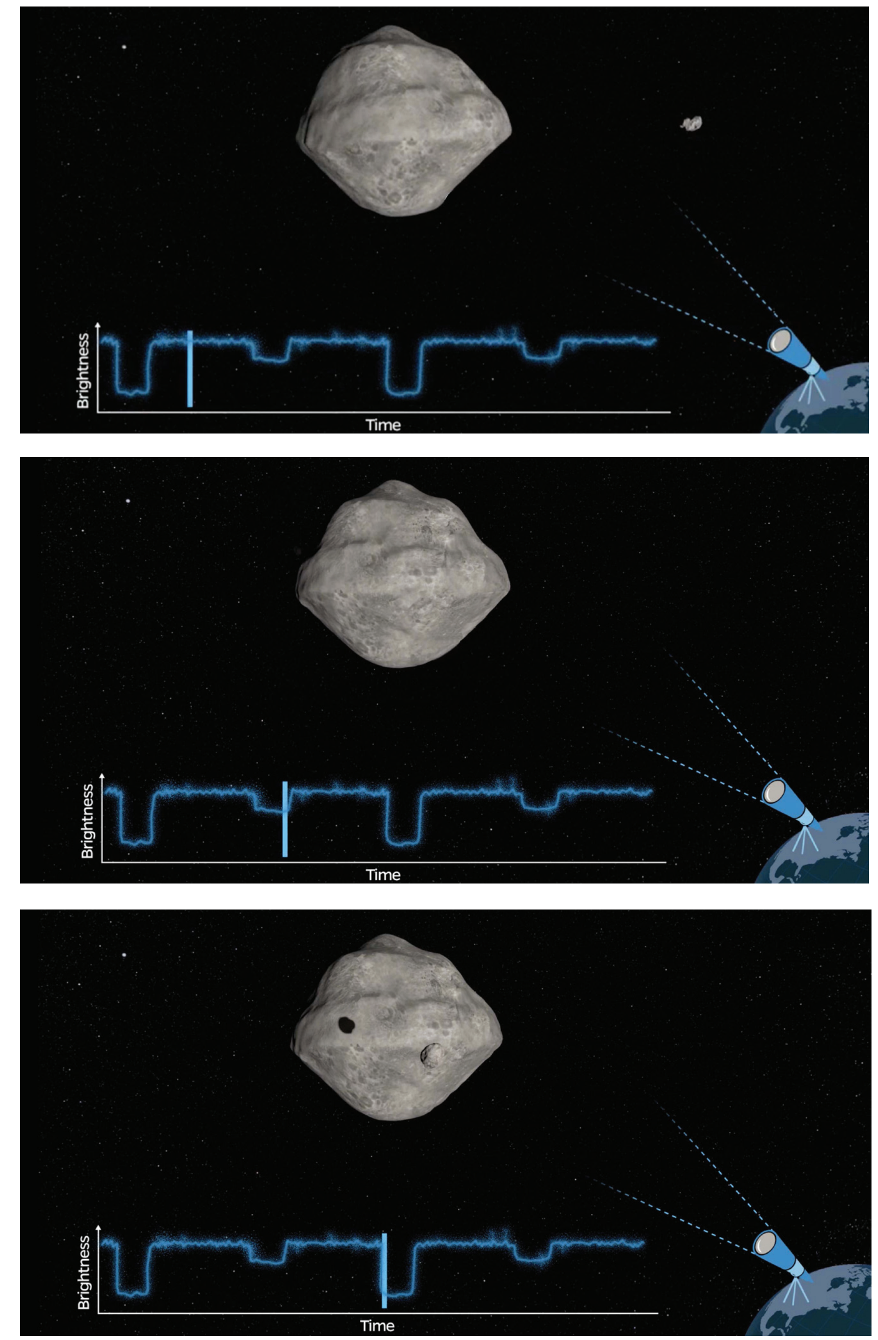
This asteroid system is the ideal natural laboratory for DART's tests. For one, the Didymos system is an eclipsing binary, meaning that from our vantage on Earth, Dimorphos regularly passes in front of and behind Didymos as it orbits. Consequently, Earth-based telescopes can measure the regular variation in brightness of the combined Didymos-Dimorphos system to determine how long it takes Dimorphos to orbit Didymos.

Because it's not on a path to collide with Earth, the Didymos system poses no actual impact threat to our planet, yet its relatively close proximity provides an easy way for planetary defense experts to observe and measure the effect of DART's kinetic impact. Mission planners selected fall 2022 for DART's impact to minimize the distance between Earth and the Didymos system. Although Didymos will still be roughly 6.8 million miles (11 million kilometers) from Earth, telescopes around the world will be able to contribute to an international observation campaign to determine the spacecraft's effect. The close proximity will allow for higher quality telescopic observations and streaming video of DART's final hours back to Earth just prior to impact.

The DART demonstration has been carefully designed. DART will hit Dimorphos nearly head-on, delivering enough energy to leave an impact crater but not enough to destroy the asteroid, eject it from its orbit around Didymos or noticeably change the pair's orbit about the Sun. Scientists estimate the collision will shorten Dimorphos' orbital period by several minutes. Telescopic observations in the weeks after impact will confirm that DART changed Dimorphos' orbital period and reveal by exactly how much. Choosing a binary asteroid target for this demonstration takes advantage of the fact that changes in the smaller asteroid's orbit around its larger partner can be more easily measured than changes in a single asteroid's orbit around the Sun.

Measuring the Binary Asteroid System from Earth

Dimorphos Orbiting About Didymos



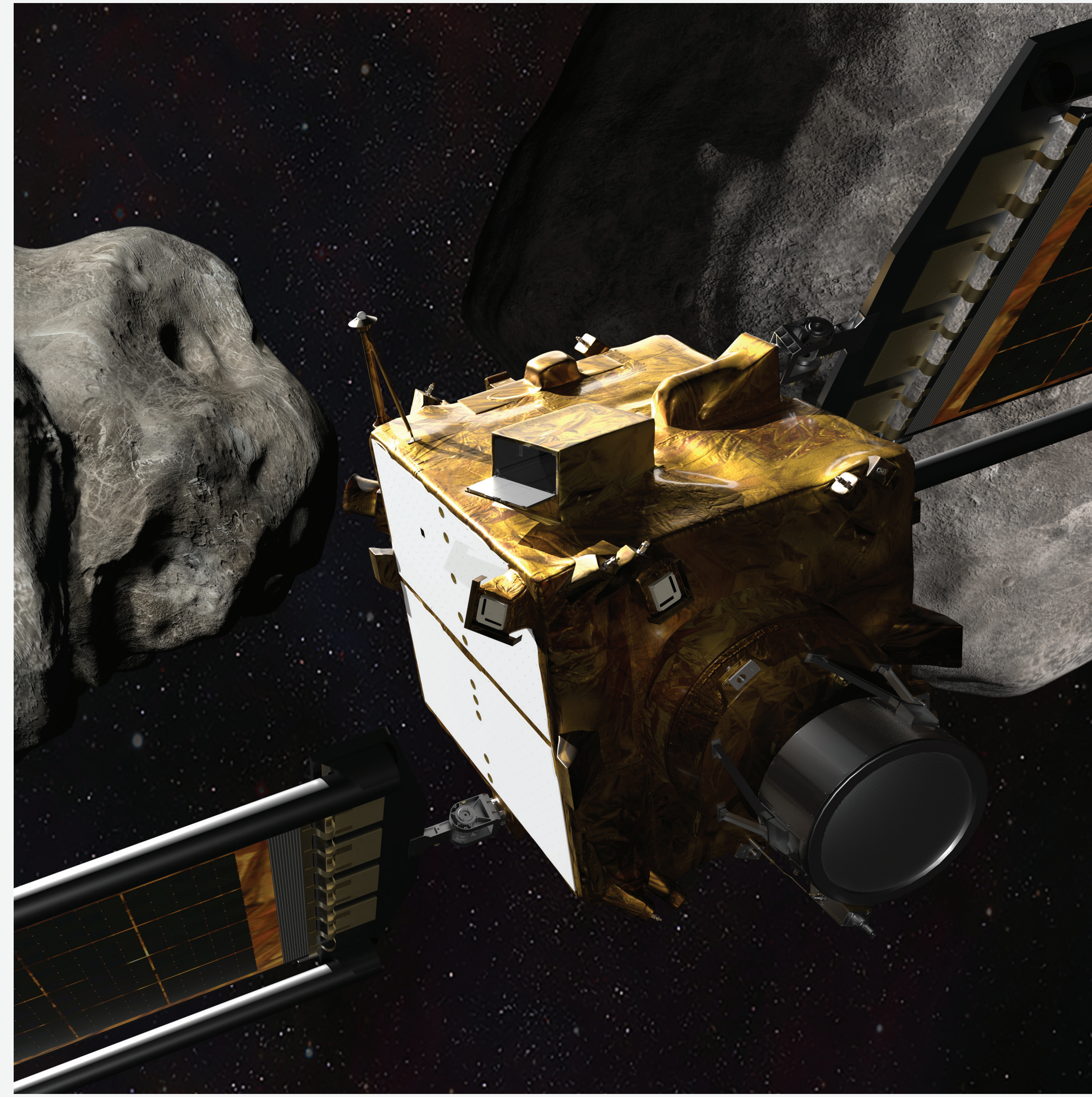
Scientists are using ground-based telescopes to observe the Didymos system before and after impact. Though the asteroids will appear as little more than a point of light through even the most powerful telescopes, the investigation team is measuring the brightness over time and graphing its changes, producing a diagram called a light curve. The brightness changes indicate when the smaller moon, Dimorphos, passes in front of or is hidden behind Didymos from Earth's point of view.

Precise knowledge of how long it takes Dimorphos to make one trip around Didymos is essential for the DART mission. Repeated observations of the system enable more accurate predictions of where Dimorphos is at any given moment — including the moment of impact. Post-impact observations will enable scientists to determine how effectively DART changed Dimorphos' orbital period.

MISSION

The DART spacecraft was built by the Johns Hopkins Applied Physics Laboratory (APL), where it underwent integration and testing before traveling nearly 3,000 miles to Vandenberg Space Force Base, California, for its launch on November 23, 2021, 10:21 p.m. PST (November 24, 2021, 1:21 a.m. EST). The main structure of the spacecraft is a box roughly the size of a vending machine, from which two large solar arrays extend. APL designed and built DART along with its single instrument, the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO).

DART has two propulsion systems: the main hydrazine propulsion system, which features 12 small thruster engines and is used to perform spacecraft maneuvers and attitude control, and the xenon ion propulsion system, which was used to demonstrate NASA's Evolutionary Xenon Thruster–Commercial (NEXT-C) system in space. The spacecraft also manipulates the solar arrays and high-gain antenna to ensure that DART can stay pointed at the asteroid during its approach and still send data back to Earth in real time.



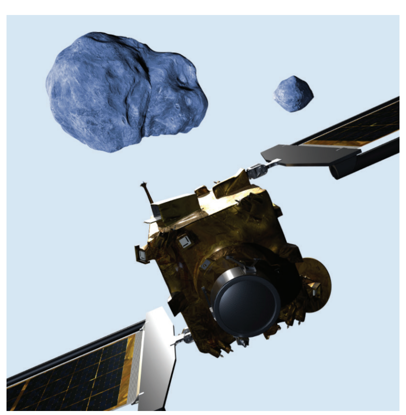
MISSION

DRACO

DRACO

The DART payload consists of a single instrument called DRACO, a high-resolution imager. Inspired by the Long-Range Reconnaissance Imager on the New Horizons spacecraft, which delivered the first close-up images of the Pluto system and a Kuiper Belt object, the upgraded DRACO will not only snap images of Didymos and Dimorphos on approach to measure the size and shape of the asteroid target, providing essential data for the analysis and interpretation of the kinetic impact test results, but it will also support the autonomous guidance system for the DART spacecraft.

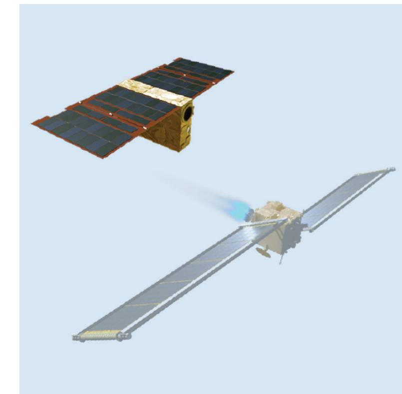
DRACO is a narrow-angle telescope with a 208-millimeter aperture and field of view of 0.29 degrees. It has a complementary metal-oxide semiconductor (CMOS) detector and sophisticated onboard image processor to determine the relative location of Dimorphos and support SMART Nav. The images acquired by DRACO before the kinetic impact will be streamed back to Earth in real time. In its final moments, DRACO will help characterize the impact site by providing high-resolution, scientific images of the surface of Dimorphos.



GNC AND SMART NAV

Guidance, Navigation and Control, and SMART Nav

DART's primary challenge is to reliably navigate to and squarely impact Dimorphos. As part of guidance, navigation and control (GNC), the DART team developed algorithms called Small-body Maneuvering Autonomous Real Time Navigation (SMART Nav). This autonomous optical guidance system will use images taken by DRACO to identify and distinguish between the two bodies, then, working in concert with the other GNC elements, direct the spacecraft toward the smaller body, all within roughly an hour of impact.

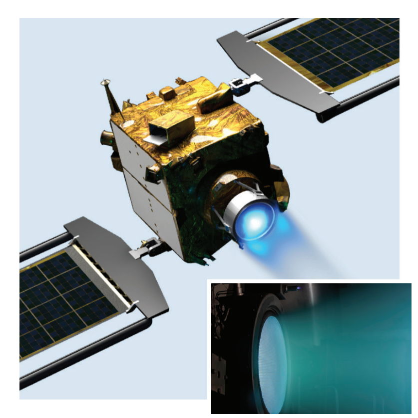


LICIACUBE

LICIACube

While DART's four mission objectives can be achieved using DRACO imaging and ground-based observations, the knowledge return of the mission will be significantly enhanced with images collected by the Light Italian CubeSat for Imaging of Asteroids (LICIACube). This 6U+ CubeSat — contributed by the Italian Space Agency and designed, built and operated by Argotec — largely mirrors the ArgoMoon CubeSat, part of NASA's Artemis 1 mission. LICIACube carries two optical cameras, dubbed LUKE (LICIACube Unit Key Explorer) and LEIA (LICIACube Explorer Imaging for Asteroid); an autonomous system to acquire and track the asteroid throughout the encounter; and an X-band communication system to transmit encounter imagery back to Earth.

The CubeSat will be deployed from the DART spacecraft 15 days prior to impact with Dimorphos. LICIACube will use its onboard propulsion system to alter its trajectory, offsetting so that it flies past Dimorphos approximately three minutes after the DART impact. This gives it the opportunity to image the kinetic impact itself, the resultant ejecta plume, possibly the impact crater and the departure (back-side) hemispheres of both Didymos and Dimorphos. These images, in addition to ground-based telescope observations, can help confirm impact. More importantly, LICIACube's images of the ejecta plume can complement the DRACO images, helping to better characterize the momentum exchange and the effectiveness of the kinetic impact deflection.



ADVANCED ION PROPULSION

Advanced Ion Propulsion

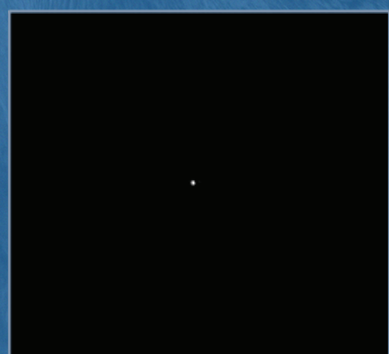
DART is also demonstrating the NEXT-C system, an ion propulsion system developed by NASA's Glenn Research Center and Aerojet Rocketdyne. NEXT-C is a solar-powered electric propulsion system that uses a gridded ion engine, producing thrust by electrostatic acceleration of ions (electrically charged atoms) formed from the xenon propellant. NEXT-C offers improved performance (higher specific impulse and throughput), fuel efficiency and operational flexibility compared to the ion propulsion systems flown on NASA's Dawn and Deep Space 1 spacecraft.

HOW DART TARGETS DIMORPHOS

SMARTER NAVIGATION

Before DART can impact Dimorphos, the spacecraft first must find the asteroid moonlet and get to it. That's no small task considering that a few hours before collision, the Didymos system will still hardly be visible. Yet DART will be able to find the asteroids and autonomously guide itself to them.

The visuals below show how large each asteroid will likely appear in DART's camera, DRACO, over time. DRACO's images are fed to a series of guidance algorithms, called SMART Nav, which can identify the asteroids and tell the spacecraft how to maneuver toward them. This autonomous process begins four hours before impact — still 56,000 miles (90,000 kilometers) from the asteroid system — and can isolate Dimorphos from Didymos once the asteroids come into view. SMART Nav will continue to guide DART until approximately two minutes before impact, when the spacecraft will coast at roughly 14,000 miles per hour (22,000 kilometers per hour) to its end.



14,000 miles
(22,000 kilometers)
Didymos – 7 pixel
Dimorphos – 1.5 pixel

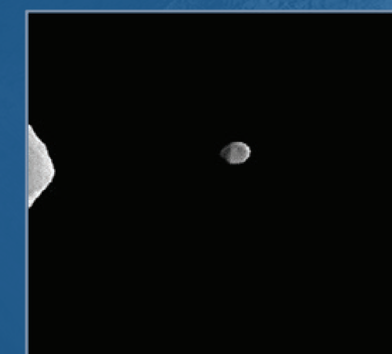
Dimorphos becomes observable

60 MINUTES

920 miles
(1,500 kilometers)
Didymos – 107 pixel
Dimorphos – 22 pixel

Final divert maneuver corrections

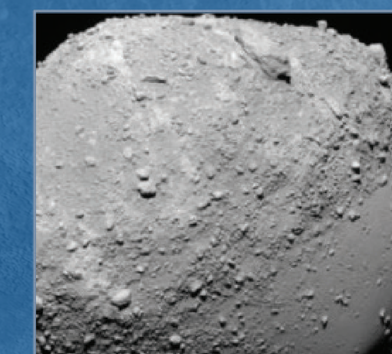
4 MINUTES



460 miles
(740 kilometers)
Dimorphos – 45 pixel

Divert maneuvers complete, drift to impact

2 MINUTES



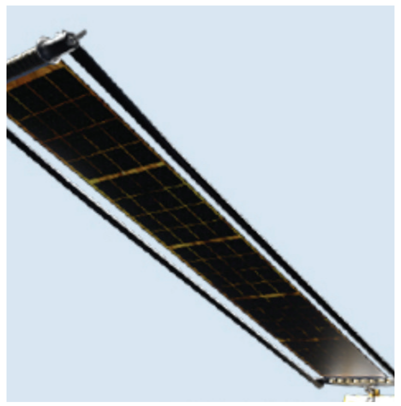
11 miles
(18 kilometers)
Dimorphos – 9 cm/pixel

High-resolution image of the impact site obtained

3 SECONDS

30 Days · **10 Days** · **8 Hours** · **4 Hours** · **60 Minutes** · **4 Minutes** · **2 Minutes** · **3 Seconds**

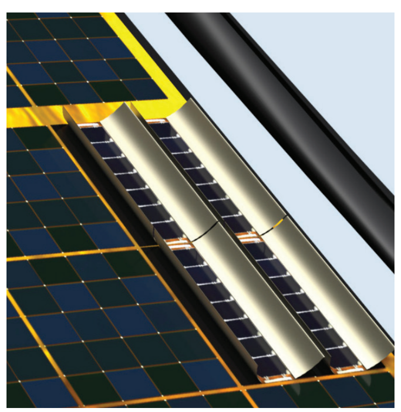
MISSION



ROLL-OUT SOLAR ARRAY

Roll-Out Solar Array

The DART spacecraft is equipped with two Roll-Out Solar Arrays (ROSA), which provided a compact form and light mass for launch, then deployed into two large arrays once DART arrived in space. The flexible and rollable “wings” are lighter and more compact than traditional solar arrays, despite their size. In space, each array slowly unfurls to about 28 feet (8.5 meters) in length. This technology was first tested successfully in 2017 on the International Space Station, with newer versions installed in June 2021 for full-time use. DART is the first planetary spacecraft to fly the new arrays, paving the way for their use on future missions of discovery. ROSA is developed by Redwire’s Deployable Space Systems, a commercial manufacturing company in Goleta, California.



TRANSFORMATIONAL SOLAR ARRAY

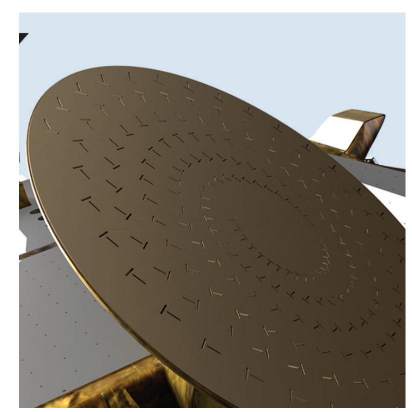
Transformational Solar Array

Using ROSA as the structure, a small portion of the DART solar array is configured to demonstrate the APL-developed Transformational Solar Array technology, which has very high-efficiency solar cells and reflective concentrators, designed to provide three times more power output than current solar array technology. This technology would allow solar arrays to be made smaller and still provide sufficient power output. With this capability, future missions to Jupiter and beyond might not require expensive nuclear power sources for electricity, which could ultimately decrease the overall cost of future missions.

CORESAT

CORESAT

DART’s CORE Small Avionics suiTe (CORESAT) uses a single-board computer and an interface module, both with field-programmable gate array-based electronics, to provide flexible control and data handling for the spacecraft’s navigation, image processing, communication and propulsion systems.



RADIAL LINE SLOT ARRAY (RLSA)

Radial Line Slot Array (RLSA)

DART also has a Radial Line Slot Array (RLSA), a low-cost, high-gain antenna that enables high-efficiency communications in a compact, planar form. A novel approach to slot-array technology that has existed for decades but has not been used in this manner, the DART antenna offers the unique capability to both send and receive data.

MISSION

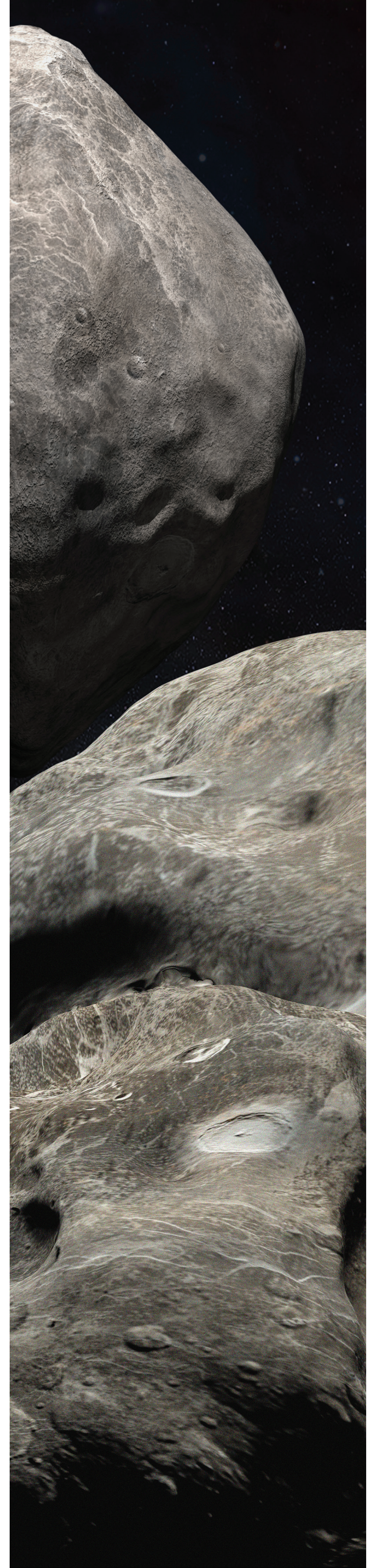
Asteroids

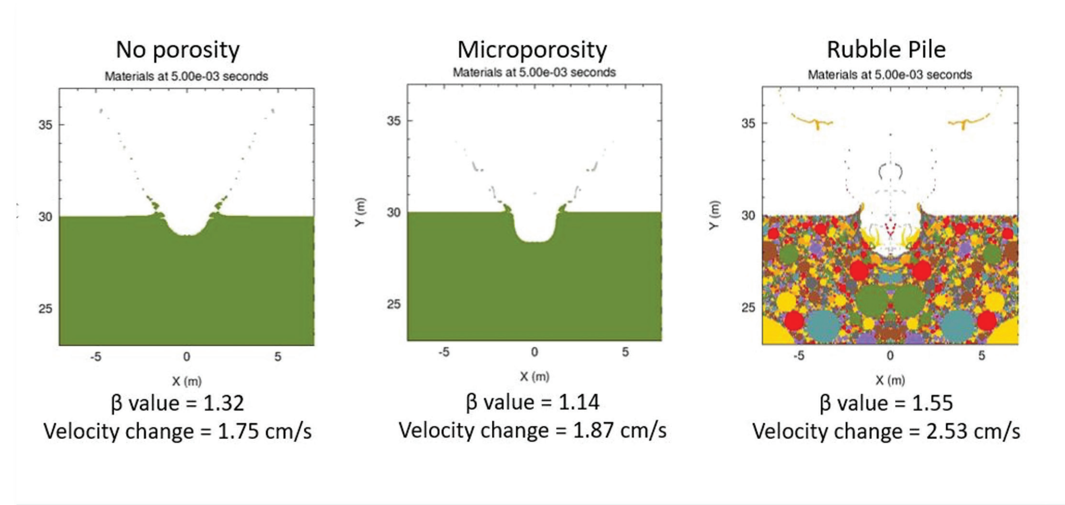
Asteroids are time capsules — rocky relics that date back to the formation of our solar system roughly 4.6 billion years ago and carry chemical signatures that can help us understand how the solar system formed. They come in a variety of shapes, sizes and compositions, from one-meter boulders to planetoids stretching hundreds of miles across. Some are dense, solid objects while others are rubble piles, like floating boulder fields held together by their own weak gravity. Many, such as near-Earth asteroids Bennu, Ryugu, Itokawa and Eros, are chondritic, meaning they're made of clay and silicate rocks. Others, such as the asteroid Psyche, have metallic components, with high amounts of iron and nickel. Asteroids can come alone or as a set — sometimes two orbiting each other, occasionally even three.

Millions of these rocky remnants orbit the Sun, with the majority of them in one region: the main asteroid belt between Mars and Jupiter. Occasionally, the long reach of Jupiter's incredible gravity, or a chance close encounter with Mars or other asteroids, nudges the orbit of one these asteroids, knocking it out of the asteroid belt and sending it into a new orbit that can cross the orbits of the other planets, including Earth. The asteroids that have been nudged into the inner solar system typically stay there for several million years before colliding with the Sun or one of the inner planets, or being kicked back out to the main belt or beyond.

Such stray asteroids have played a major role in altering Earth's geologic history and the evolutionary course of life on the planet. At least three mass extinctions of life on Earth have been attributed in part or in whole to asteroid impacts. Perhaps the most famous of these is the Cretaceous-Tertiary, or K-T, extinction roughly 65 million years ago that wiped out 70% of life, including the non-avian dinosaurs.

Today, scientists are on the continual lookout for asteroids with paths that intersect Earth's orbit, as well as other near-Earth asteroids that approach within about 30 million miles (50 million kilometers) of Earth. Currently, more than 26,000 near-Earth asteroids are known and tracked. Nearly 10,000 of these are 500 feet (140 meters) or larger in size, and roughly 2,200 move in orbits that pass within 4.6 million miles (7.5 million kilometers) of Earth — designating them as potentially hazardous asteroids. But scientists estimate there are still roughly 15,000 near-Earth asteroids 500 feet (140 meters) or larger in size waiting to be discovered.





A comparison of three simulated collisions of a projectile into asteroids of different kinds of porosity. Researchers found that porosity, or the amount of empty space in a material, plays a significant role in determining the effectiveness of a kinetic impactor such as DART. These simulations show the expected momentum transfer enhancement (beta) and change in the asteroid's velocity. (Credit: Johns Hopkins APL/Angela Stickle and Emma Rainey)

Impact Modeling and Simulations

A key goal of the DART mission is to measure how much the spacecraft's kinetic impact changes the motion of Dimorphos. If DART were planned to gently bump the asteroid, the outcome would be easy to predict, but a collision at approximately 14,000 miles per hour (22,000 kilometers per hour) is an event of literally astronomical proportions.

Not only will DART give Dimorphos a healthy shove at the moment of contact, but the impact's energy will excavate a crater and blast between 22,000 and 220,000 pounds of asteroid surface material, called ejecta, into space. The recoil "kick" from these ejecta on the asteroid could rival, or even exceed, the direct push from the DART spacecraft. It's this enhancement in the asteroid's momentum that makes kinetic impact a particularly attractive deflection technique, and measuring it accurately is a major component of DART's mission.

Even though high-velocity impacts are one of the most widespread processes in the solar system, scientists don't yet have a complete understanding of how they work. Small-scale experiments can be done in laboratories and help in developing computer modeling techniques, but small experiments have their limits, especially when trying to model an event of the magnitude of DART's impact with Dimorphos. The sheer size difference between the spacecraft and the asteroid — essentially a planetary-scale difference — makes modeling the impact computationally challenging, even for supercomputers.

Researchers want to use computational models to predict the momentum enhancement effect and the ultimate result of a spacecraft's collision with an asteroid. In principle, this would require knowing an asteroid's physical properties and how those properties affect the amount of material ejected from the impact crater. But for most asteroids, including Dimorphos, those details are largely unknown.

DART scientists predict that Dimorphos' strength — or ability to withstand breaking or bending from the collision — and porosity could nearly double the enhancement experienced from DART's impact. Measurements following the impact could validate that scientists' current models of planetary-scale impacts are on the right track. Data later collected by the European Space Agency's Hera spacecraft will further refine models for future hypervelocity impact missions, should the need for one ever arise.

SCIENCE

MISSION

Telescopic Observations

Using powerful telescopes located around the world, astronomers have acquired a long-term baseline of data on the Didymos asteroid system. While little is known about the asteroid that DART will impact — the exact shape and structure of Dimorphos, for example, remain a mystery — telescope observations have helped to further characterize the behavior of the Didymos asteroid system. These observations are absolutely critical. Because the core of the second part of DART's test is to measure the effect of the kinetic impact on the asteroid, learning all we can about the Didymos-Dimorphos system before impact, to compare with what we see after, is essential.

Even with the most powerful telescopes, Didymos and Dimorphos still appear as little more than a single point of light from Earth. During observations, scientists measure the brightness of that point of light over and over again, building up a plot of the light curve and looking for changes in brightness. Brightness changes indicate when the asteroid moonlet, Dimorphos, passes in front of or is hidden behind Didymos from Earth's viewpoint. Precise knowledge of Dimorphos' orbital period is essential for the DART mission. Repeated observations of the system enable more accurate predictions of where Dimorphos is at any given moment — including the moment of DART's impact. These observations, some made years before launch, helped scientists determine the location of both asteroids and informed the exact timing of DART's impact to maximize the deflection. Similar observations after impact will reveal the change made to the system and enable the team to calculate the precise effects of the kinetic impact.

The DART mission relies on telescopes at observatories around the globe, including the Lowell Discovery Telescope in Arizona, Las Campanas Observatory in Chile, the Las Cumbres Observatory global network and the Magdalena Ridge Observatory in New Mexico, as well as dozens of other partners and observatories.

LOWELL DISCOVERY TELESCOPE
Credit: Lowell Observatory

SCIENCE

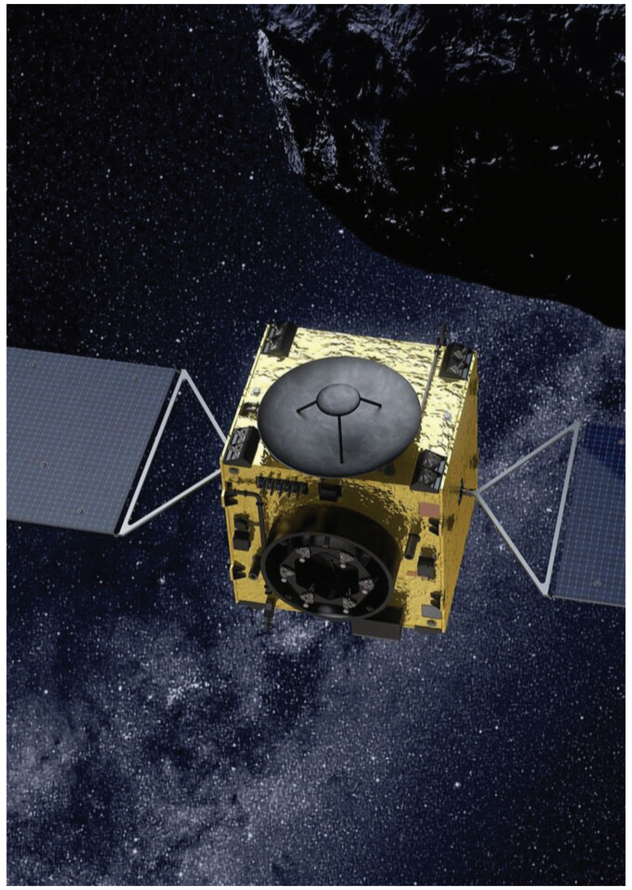
MISSION MANAGEMENT

HERA AND THE AIDA INTERNATIONAL COLLABORATION

The Hera mission, a European Space Agency (ESA) project, is planned to launch in 2024 and rendezvous with the Didymos system in 2026, roughly four years after DART's impact. Hera's main spacecraft and two companion CubeSats will conduct detailed surveys of both asteroids, with particular focus on the crater left by DART's collision and a precise determination of Dimorphos' mass. Hera's detailed post-impact investigations will substantially enhance the planetary defense knowledge gained from DART's asteroid deflection test.

DART and Hera are designed and operated independently, but together they will significantly boost the overall knowledge return of the collaboration. NASA's DART mission is fully committed to international cooperation, and ESA's Hera team members are welcome collaborators on the DART team.

Both DART and Hera team members are part of the international endeavor known as the Asteroid Impact and Deflection Assessment (AIDA) collaboration. AIDA will combine the data obtained from DART, including the Italian Space Agency's LICIACube, and Hera to produce the most accurate knowledge possible from the first demonstration of asteroid deflection technology. AIDA comprises the combined effort of the DART, LICIACube and Hera teams, along with others performing related research worldwide, to extract the best possible information for planetary defense and solar system science from these groundbreaking space missions. The AIDA collaboration exemplifies the understanding that planetary defense is an international effort and that scientists and engineers around the world seek to solve problems related to planetary defense through international collaboration.



HERA

Working Together

NASA's Planetary Defense Coordination Office (PDCO), established in 2016 to manage its ongoing mission of planetary defense, directed APL to build, operate and manage DART with support from several NASA centers, including NASA's Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC), Johnson Space Center (JSC), Glenn Research Center (GRC) and Langley Research Center (LaRC). PDCO supervises NASA-funded projects to find and characterize asteroids and comets that pass near Earth's orbit, coordinates the activities of both U.S. government agencies and international collaborators for planetary defense, and supports the development of techniques and technologies that could be used to respond to an identified impact threat.

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Mission Systems Assurance Manager

MANAGEMENT

DART Partners and Collaborators

Planetary defense is an international endeavor, and the DART team has drawn on expertise from around the world to design and conduct the mission, evaluate its results and enable planning for future planetary defense efforts.

Current U.S. partner institutions include:

- NASA's Goddard Space Flight Center
- NASA's Johnson Space Center
- NASA's Glenn Research Center
- NASA's Marshall Space Flight Center
- NASA's Kennedy Space Center
- NASA's Launch Services Program
- NASA's Jet Propulsion Laboratory
- SpaceX
- Aerojet Rocketdyne
- Las Cumbres Observatory
- Lawrence Livermore National Laboratory
- Auburn University
- University of Colorado
- Carnegie Science Las Campanas Observatory
- Lowell Observatory
- University of Maryland
- New Mexico Tech with Magdalena Ridge Observatory
- Northern Arizona University
- U.S. Naval Academy
- Planetary Science Institute

LICIACube, DART's companion CubeSat, is contributed by the Italian Space Agency and built by Argotec. LICIACube Italian partner institutions include:

- Istituto Nazionale di Astrofisica (INAF) - Osservatorio Astronomico di Roma
- INAF - Istituto di Astrofisica e Planetologia Spaziali, Roma
- INAF - Osservatorio Astronomico di Trieste
- INAF - Osservatorio Astronomico di Padova
- INAF - Osservatorio Astrofisico di Arcetri, Firenze
- INAF - Osservatorio Astronomico di Capodimonte, Napoli
- CNR - Istituto di Fisica Applicata “Nello Carrara” (IFAC)
- Politecnico di Milano
- Università di Bologna
- Università Parthenope, Napoli

MANAGEMENT

About APL

The Johns Hopkins Applied Physics Laboratory is a Department of Defense-sponsored university affiliated research center that develops solutions to critical national challenges through the innovative application of science and technology. From the Sun to Earth and beyond — with the Parker Solar Probe, Dragonfly and New Horizons missions — APL has designed and built more than 70 spacecraft and hundreds of specialized instruments and systems. Combined, these spacecraft and instruments have visited every planet in our solar system and collected information that has expanded humankind's understanding of the universe.

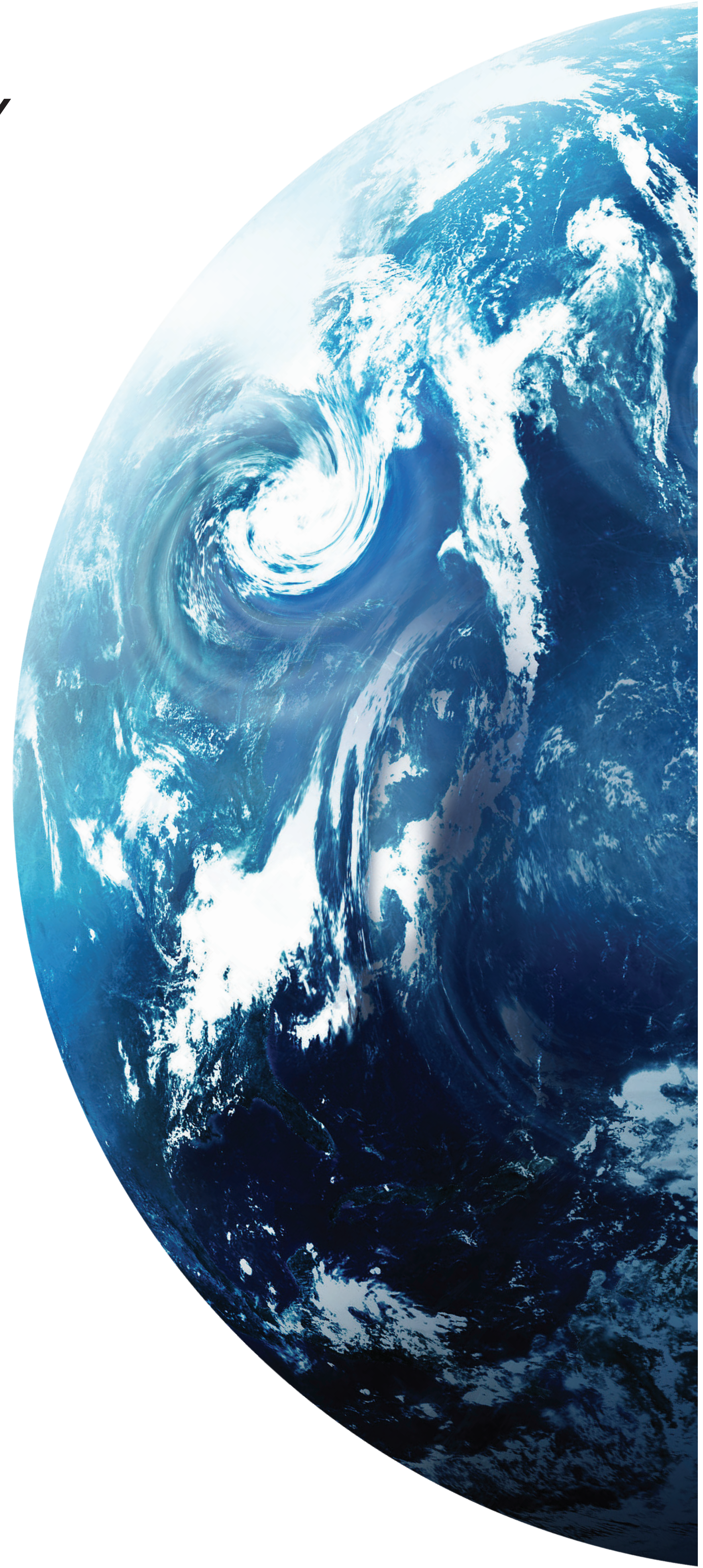
THE APL CAMPUS IN LAUREL, MARYLAND.

THE FIRST PLANETARY DEFENSE TEST MISSION

"DART is the result of years of work by a dedicated team and partners who have overcome unique challenges to accomplish firsts in both technology development and planetary defense."

—Betsy Congdon, DART mechanical engineer, Johns Hopkins APL

PLANETARY DEFENSE



What is Planetary Defense?

Planetary defense encompasses all the capabilities needed to detect and warn of potential asteroid or comet impacts with Earth, and either prevent them or mitigate their possible effects. Near-Earth objects (NEOs) are asteroids and comets that orbit the Sun, just like the planets, but have orbits that bring them within a zone approximately 121 million miles (195 million kilometers) from the Sun. This means they can pass within about 30 million miles (50 million kilometers) of Earth's orbit. Planetary defense is "applied planetary science" to address the NEO impact hazard.

NASA's Planetary Defense Coordination Office (PDCO)

In 2016, NASA established the PDCO to manage its ongoing planetary defense efforts. The PDCO:

- Provides early detection of potentially hazardous objects (PHOs) — the subset of NEOs whose orbits predict they will come within 5 million miles (8 million kilometers) of Earth's orbit, and that are large enough (98 to 164 feet, or 30 to 50 meters) to cause significant damage on Earth;
- Tracks and characterizes PHOs and issues warnings of the possible effects of potential impacts;
- Studies strategies and technologies for mitigating PHO impacts; and
- Plays a lead role in coordinating U.S. government planning for response to an actual impact threat.*

How Does DART Fit In?

DART is one part of NASA's larger planetary defense strategy. The DART mission addresses the "mitigate" component of the overall planetary defense efforts, demonstrating a technology for deflecting an asteroid off a predicted impact course with Earth, if such action were warranted. DART is NASA's first spacecraft mission developed to achieve planetary defense objectives and the first mission being flown by NASA's newly formed PDCO.

For more information visit NASA's Planetary Defense page at https://www.nasa.gov/planetarydefense.

** Source: https://www.nasa.gov/planetarydefense/overview*