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DAMAGE ASSESS

Could we deflect an asteroid to stop it from hitting Earth? The success of NASA's DART mission suggests so, but only after ESA's soon-to-launch Hera mission has checked the results will we know if this approach to planetary defence is a viable possibility

M E N T

by **DR STUART CLARK**

Another day, another rocket launch. So many, in fact, it's easy to get blasé. In 2023, almost 200 rockets lifted off from Earth, carrying satellites and other spacecraft into orbit. By early September this year, the number for 2024 had already reached 158, most of them from Elon Musk's SpaceX company, which has launched 89 rockets and is aiming for around 150 by year's end.

In October, one of those additional SpaceX launches will carry the European Space Agency's (ESA) Hera mission into space. Although one more launch may seem almost insignificant, Hera could prove to be one of the most important missions ever launched, because it'll tell us how capable we are of deflecting asteroids.

In November 2021, NASA launched the Double Asteroid Redirection Test (DART) mission. It targeted Dimorphos, a small asteroid with a diameter of 177m (580ft) in orbit around a larger one called Didymos. The DART spacecraft would collide with Dimorphos on purpose to see if it could alter its orbit around Didymos. Any change would be reflected in a shift in the small moonlet's orbital period.

The mission was designed to test a deflection technique known as the kinetic impactor – essentially smashing one thing into another – and it succeeded spectacularly. The spacecraft impacted Dimorphos at a speed of approximately 6.6km/s (over 14,750mph) in September 2022, changing its orbital period around Didymos by 33 minutes – far more than had been expected. It was a historic moment, marking the first →

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→ time we had intentionally altered the trajectory of a celestial body.

"DART has really shown how effective a kinetic impactor can be in moving and diverting small asteroids. It was a complete and utter success of a mission," says Prof Alan Fitzsimmons, an astronomer from Queen's University Belfast, Northern Ireland, who specialises in asteroid research.

To really make use of DART's success, however, astronomers need to know a number of crucial facts about its target – for example, the internal structure of Dimorphos and exactly how it responded to being hit.

This is where Hera comes in. Arriving at the Didymos-Dimorphos system in 2026, Hera will perform a detailed post-impact survey of both asteroids, carrying out high-resolution imaging, measuring the asteroids' masses and studying the full aftermath of DART's impact.

"DART succeeded so well that we have no clue what Dimorphos now looks like," says Dr Patrick Michel of the Université Côte d'Azur, in France, and Hera's principal investigator. "We have different kinds of predictions that all work, but are all very different."

One of the predictions says there will be a well-defined crater on the surface, while another says that the asteroid could have been completely reshaped and that boulders might have been thrown from it onto the surface of the larger Didymos. Astronomers will find out by comparing the images from DART's Draco camera to those from Hera. "It'll be like the discovery of a new world," says Michel.

THE HERA SPACECRAFT

Hera is a 1.2-tonne (2,645lb) spacecraft carrying five science instruments that will gather complementary data to help characterise Dimorphos. There are two cameras, one working at visible wavelengths and another in the infrared; a hyperspectral imager that allows light to be split into small bands to aid geological and compositional investigations; a laser altimeter to gauge how far Hera is from the asteroid's surface; and a radio experiment that helps determine the asteroids' masses and gravitational fields.

In addition, Hera will also deploy two CubeSats, nanosatellites named Milani and Juventas. These small, secondary spacecraft will carry out additional investigations, including radar and spectroscopic analyses. Milani will allow the mineralogy of the asteroids' surfaces to be detected, whereas Juventas carries a radar that will allow the scientists to look inside the asteroids to help determine their internal structure and composition.

Taken together, the data will prove essential in our understanding of asteroid deflection techniques and their potential applications in future planetary defence efforts.

ABOVE Solar wings will power the Hera asteroid mission as it ventures out to meet the Dimorphos and Didymos asteroids

RIGHT The Hera spacecraft's antenna will transmit back the close-up images of the asteroids

This is because asteroids can come in two broad types: monolithic and rubble piles.

Monolithic asteroids are single slabs of rock that were once molten. Rubble piles are conglomerations of pieces of debris with no real solid structure to them. Each would react to a kinetic impactor in a different way. Dimorphos is thought to be a rubble pile asteroid.

"When we get those first images back from Hera at the end of 2026, we'll know very quickly what the internal structure of Dimorphos is, how it reacts and its physical characteristics," says Fitzsimmons.

GLOBAL EFFORTS

During the past 20 years, planetary defence has become a major focus for space agencies around the world, reflecting the growing recognition of the threat asteroids pose. It's not just NASA and ESA that are involved in protecting the planet from dangerous asteroids.

"PLANETARY DEFENCE HAS BECOME A MAJOR FOCUS FOR SPACE AGENCIES AROUND THE WORLD"

China is also working on a deflection test similar to DART and Hera. Although unnamed at present, the mission is due for launch sometime around 2027 and the current target is asteroid 2015 XF261. This is a small asteroid that's estimated to be between 17–78m (55–255ft) wide.

"China plans to combine the DART and Hera missions into one launch. So they would have a single launch sending two probes. One would go on a course to intercept this asteroid and, at the same time, the other probe would take a different trajectory and be able to do follow-up observations," says Andrew Jones, a space journalist who specialises in covering China's space industry.

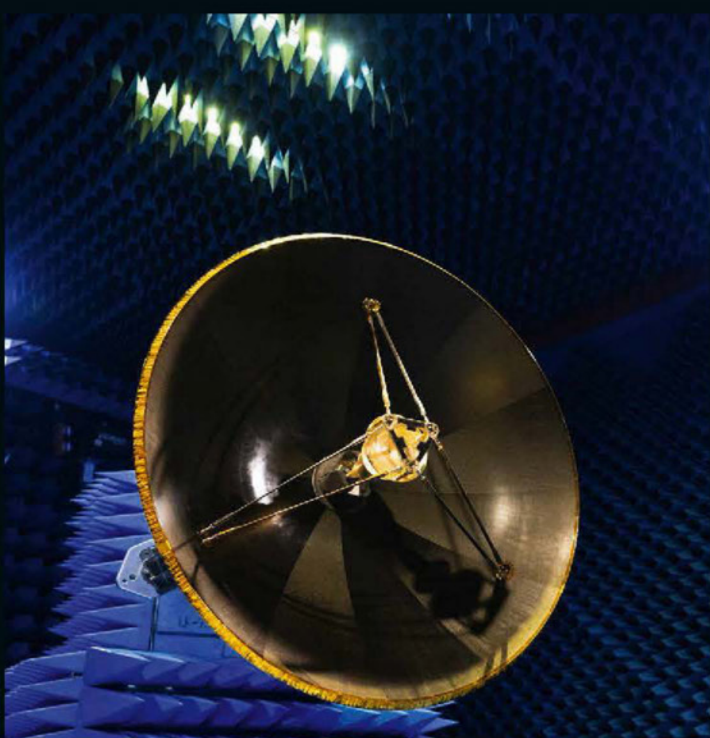
Reversing the DART and Hera process, the Chinese observer spacecraft would arrive first so that it could spend months studying the unblemished target asteroid. It would also watch the impact in real-time and begin scrutinising the aftermath instantly.

As well as advancing our understanding of planetary defence, there's a lot of pure science to come from these missions. Asteroids are the leftover remnants from the beginning of the Solar System. They hold crucial clues about the formation of Earth and other planets. Any mission that studies an asteroid's structure and composition is adding to our knowledge of our origins, as well as to our future survival as a species.

There's also a geopolitical angle to China's interest. "China aims to demonstrate leadership in space and generate prestige, similar to NASA," says Jones. "So national security and strategic implications are also motivating factors."

This may not lead to competition, however. Instead, the global nature of asteroid threat could bring similar nations together in collaboration, according to Jones.

Fitzsimmons agrees: "Asteroids don't care about boundaries or geopolitics, so perhaps having a little bit more openness and being able to work with each other would be quite nice."



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EARLY WARNING SYSTEMS

While it's the deflection tests that capture the headlines, the true cornerstone of planetary defence is detection.

Former Army officer Jonathan Tate established Spaceguard UK in 1997. It's an independent observatory and visitor centre in Powys, Wales, that supplies information to schools, universities and tourist parties about the asteroid threat and what's being done to detect and prepare for them.

For Tate, the message is clear. "There's absolutely no reason that a proper, well-organised, reasonably well-funded planetary defence organisation can't protect Earth," he says.

While The Spaceguard Centre is modest in global terms, it continues to perform essential follow-up work of tracking known asteroids to refine the knowledge of their orbits. Tate is also just coming to the end of a long project to install a discovery camera to help in the search.

Of the larger government-funded initiatives, ground-based telescopes and radar systems, such as those operated by NASA's Planetary Defence Coordination Office (PDCO) and the International Asteroid Warning Network (IAWN), now continuously scan the skies for objects that could come →

→ dangerously close to Earth. There are dozens of facilities around the world that contribute to this effort, and two stand out. They are the Pan-STARRS (Panoramic Survey Telescope and Rapid Response System) telescopes at the Haleakalā Observatory on Maui, Hawai'i, and the Catalina Sky Survey (CSS) in the Santa Catalina Mountains, Arizona in the US. Together they've discovered more than 17,000 near-Earth asteroids, or near-Earth objects (NEOs) as they tend to be called.

A particular success for the CSS was the discovery of asteroid 2024 RW1, a one-metre-wide (3ft) space rock that was detected by the system on 4 September 2024. ESA instantly analysed the data and realised that it was heading for Earth, posting the prediction on X (formerly Twitter), stating: "A roughly 1 metre asteroid will strike Earth's atmosphere over the Philippines near Luzon Island at 17:08 UTC today, 4 September. The object is harmless, but people in the area may see a spectacular fireball! Discovered this morning by the Catalina Sky Survey, this is just the ninth asteroid that humankind has ever spotted before impact."

And, indeed, the disintegrating space rock produced a super-bright meteor that was caught on numerous cameras and videos. Although the time between detection and impact was around eight hours, it proves to Fitzsimmons the progress that's being made in impact prediction.

"The important thing is that it was actually found," he says. "The orbit was calculated, it was tracked, and we knew it was going to hit; the impact time was calculated and the impact position was calculated very accurately before it entered Earth's atmosphere. Go back 20 or 30 years and that wouldn't have happened."

In other words, the telescope survey systems and the associated follow-up calculations are now sensitive and quick enough that they can predict impacts. And if we can do it for a small, one-metre-wide object found only a few hours before it enters Earth's atmosphere, we should be able to discover incoming 50m objects a week before impact, or objects the size of Dimorphos around a month or longer before they hit.

This is crucial because early detection is the key to success when deflecting asteroids. The sooner a dangerous asteroid can be detected, the smaller the nudge it'll need to move it out of harm's way.

INTENSE OBSERVATION

To bolster our ability to detect NEOs, there are a number of new facilities being planned and built. ESA is working on a ground-based telescope called Flyeye, which uses specially constructed optics inspired by the compound eyes of insects to view a large area of the night sky all at once. It's currently scheduled to be built on the Italian island of Sicily.

In 2025, the Vera C Rubin Observatory, located on Cerro Pachón in Chile, will begin operation. Housing a giant survey telescope with a diameter of 8.4m (27.5ft), it's expected to prove an amazing discovery machine for finding NEOs.

There are a number of space-based telescopes in the offing, too. NASA is funding the NEO Surveyor space telescope for launch in around 2027–28. This 50cm-diameter (20in) space telescope is designed to discover and characterise most of the potentially hazardous asteroids and comets that come within 30 million miles of Earth's orbit. Working at two infrared wavelengths, the telescope will provide good size estimates for the asteroids that it finds and provide information on their compositions, shapes and rotation rates. The mission is expected to work for at least five years.

Meanwhile, ESA is planning NEOMIR (Near-Earth Object Mission in the Infrared) that, if approved, would provide early warning of asteroids approaching Earth from the direction of the Sun. These can't be detected by ground-based observatories, as they are hidden in its glare. A prime example of an asteroid 'coming out of the Sun' was the Chelyabinsk meteor of 13 February 2013 that hit Earth's atmosphere close to the city in the Ural Mountains in Russia without warning that morning.

Chinese researchers have also proposed an early warning system for Chelyabinsk-like objects. Known as CROWN, instead of NEOMIR's single space telescope, the ambitious Chinese concept proposes six space telescopes in Venus-like orbits to keep a close watch on this difficult-to-survey region of space.

THE GREAT SERPENT

Even before Hera has launched, ESA is already setting its sights on its next asteroid target. In 2029, asteroid Apophis will make a historic close flyby to Earth. With a diameter of 370m (1,213ft), Apophis caused concern upon its discovery in December 2004, when initial orbital calculations gave it a 2.7-per-cent chance of hitting Earth on 13 April 2029 (ironically a Friday). Somewhat melodramatically, it was

BELOW Dr Patrick Michel of the Université Côte d'Azur, France, is Hera's principal investigator

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"THE ASTEROID WILL COME SO CLOSE TO EARTH THAT OUR PLANET'S GRAVITATIONAL FIELD HAS THE POTENTIAL TO ALTER ITS ROTATION AXIS AND ORBIT"

named after the ancient Egyptian mythological serpent who was said to attack the Sun god Ra each night to stop sunrise.

Subsequent observations refined the orbit of Apophis to the point that the collision was ruled out, but it'll pass Earth just 32,000km (19,880 miles) above its surface – lower than the ring of geostationary communications satellites at 36,000km (22,370 miles), and bright enough to be seen by the naked eye. More than two billion people in Africa, Europe and Asia could have the opportunity to see it pass across the sky. Calculations suggest that such a sight is a once-in-every-7,000-years event.

The asteroid will come so close to Earth that our planet's gravitational field has the potential to alter its rotation axis and orbit, and may even create 'quakes' on its surface. So, Michel and others from the Hera team are proposing a new mission to ESA, to be built and launched fast enough to rendezvous with Apophis and follow it through its closest approach, gaining valuable scientific data. The mission, dubbed Ramses, is currently in the design phase, and will need to be approved by ESA at its Ministerial Council meeting next year if it's to proceed. It'll then need to be built and launched within three years. "This is challenging," says Michel. He insists, however, that not only is it possible, but also that launching asteroid missions as quickly as possible will be a necessary component of planetary defence. After all, as soon as we detect an asteroid on a collision course, we'll want to take a good look at it – and fast.

"We'll want to send a reconnaissance probe to tell us the properties so that we can design the best deflection mission possible," Michel adds.

It's an extraordinary turnaround. Rewind the clock a few decades and the threat from asteroids was largely swept under the carpet. Now we're on the cusp of having a fully tested and understood deflection mechanism.

"I couldn't have imagined we'd be where we are now 20 years ago, so imagine where we'll be 20 years from now. It's going to be an interesting journey," says Fitzsimmons. SF

ABOVE The Milani CubeSat, built at Tyvak International in Turin, Italy, will investigate the minerals of the Didymos and Dimorphos asteroids

by **DR STUART CLARK**
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Stuart is an astronomer, science journalist and author. His latest book is, Beneath the Night: How the Stars have shaped the History of Humankind *(Guardian Faber, 2020).*