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The race to visit near-flying asteroid

An asteroid's extremely close flyby of Earth offers us the chance to learn more about these space rocks – including how to deflect others like it, finds **Robin George Andrews**

IN FOUR years, on 13 April 2029 to be exact, a large asteroid named Apophis will fly by Earth just 32,000 kilometres above the surface. Apophis, like the recently identified asteroid known as 2024 YR4, was once thought to be on a crash course with our planet. After its likelihood of hitting us was lowered to zero, and some presumed sighs of relief, astronomers began planning for the day it would make its exceptionally close flyby.

When it does, a fleet of spacecraft – featuring missions by NASA, the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) – is going to chase it down.

“This kind of approach of a body of Apophis's size occurs only once every few thousand years,” says Patrick Michel at Côte d'Azur University in France, a member of ESA's Apophis-hunting project. “This is extraordinary.”

To prepare for this moment, astronomers and planetary defence researchers from around the world gathered at the University of Tokyo from 7 to 11 April for a very unusual workshop.

Each space agency shared its mission's objectives, while making sure that they would coordinate with one another to get the most out of this opportunity.

Although multiple spacecraft will effectively be racing to get to Apophis first, “nobody is winning or losing”, says Michel. If the historic team-up goes according to plan, everybody will have a better understanding of how to defend the planet from killer asteroids.

Shortly after Apophis was discovered in 2004, it caused a bit of a fright. According to early orbital calculations, this 450-metre-long asteroid – big enough to cause damage on a continental scale – stood a



An artist's impression of the RAMSES mission to Apophis

defenders have more ambitious hopes: they want to send several spacecraft after Apophis to get the best look possible before, during and after the Earth flyby.

The first of the fleet is the successor to NASA's OSIRIS-REx mission. This spacecraft extracted pieces of rock from the asteroid Bennu in 2020, before returning to Earth in 2023 to drop a capsule containing them. This mission was primarily scientific, with those stolen shards being studied to understand the origin of planets and life itself. But OSIRIS-REx also helped anti-asteroid research efforts: it studied the geology of the asteroid and helped us better understand how this was being affected by sunlight, which can very gently but significantly alter an asteroid's orbit.

Planetary defence

OSIRIS-REx has since been repurposed for planetary defence. While the spacecraft was on its way back from Bennu, its operators realised they could pilot it in such a way that it could also rendezvous with Apophis. It can no longer gather samples with its extendable arm, but it could examine the asteroid with its suite of cameras and sensors.

So, 20 minutes after the sample capsule was jettisoned towards Earth, the spacecraft fired its thrusters, sending it on a circuitous trajectory around the solar system to catch up to Apophis in 2029. The mission, now named OSIRIS-Apophis Explorer, or APEX, is taking a gamble: it wasn't designed to get as close to the sun as it has been. Fortunately, its instruments are

2.7 per cent chance of striking Earth in 2029. Thankfully, follow-up observations ruled out this calamitous possibility, instead showing that it will safely pass by Earth.

However, it will get extremely close to the planet, passing below the height of geostationary satellites. Weather permitting, people in Europe and Africa will be able to see it with the naked eye, as a hastily moving glimmer. “It [will be] evening twilight skies when Apophis is brightest,” says Richard

Binzel at the Massachusetts Institute of Technology.

There are thousands of asteroids just like Apophis in near-Earth orbits yet to be discovered. If one is found to be heading our way, any mission attempting to deflect or destroy it would greatly benefit from knowing what their structure is like. Are they rigid objects that could absorb the impact of a ram-like spacecraft or rubble piles prone to chaotic fragmentation?

Apophis won't just passively pass by the planet. It is likely to shift to a slightly different orbit, while its surface geology and interior structure will be disturbed. “There is going to be seismic shaking on Apophis,” says Dani DellaGiustina at the University of Arizona. These asteroid quakes will hint at its geologic make-up.

Throughout the close encounter, a bevy of ground-based observations, including those using radar, will give us a precise measure of the asteroid's size, shape and trajectory. But planetary

450

Length of the asteroid Apophis, in metres

5 million

How far the OSIRIS-APEX craft will be from the asteroid when it starts observing, in kilometres

6

Number of months the RAMSES craft will fly alongside Apophis



holding up to the scorching heat. “Everything appears ‘go’ for Apophis,” says DellaGiustina, the principal investigator for OSIRIS-APEX.

The craft will begin observing Apophis on 2 April 2029, from 5 million kilometres away, closing the gap to just 50,000 kilometres during the 13 April Earth encounter. It will finally arrive alongside the asteroid on 5 June, and fly in formation with it into 2030, mapping out its surface. In September 2030, the craft will approach Apophis before firing its thrusters at the rock. Known as the Spacecraft Thruster Investigation of Regolith, or STIR, manoeuvre, this is designed to expose the pristine geology just under the surface of the asteroid.

OSIRIS-APEX’s mission ends in December 2030. What happens then? “We’re pretty interested in trying some daring things,” says DellaGiustina. They may prod Apophis with OSIRIS-APEX’s extendable arm or even try landing on the surface. “We would love to do something crazy, but right now, we’re just hoping to get through our nominal mission plan.” (See “Smashing asteroids”, above.)

ESA’s contribution to the fleet is the Rapid Apophis Mission for Space Safety, or RAMSES, spacecraft. Unlike OSIRIS-APEX, this is a work in progress. The preliminary design work has already been funded but awaits a critical go-or-no-go decision at an ESA gathering in late 2025. But there was considerable optimism in Tokyo that RAMSES would be green-lit.

Paolo Martino at ESA, the mission’s project manager, says RAMSES will rendezvous with Apophis in February 2029, flying alongside it for at least six months. As well as monitoring it with

Smashing asteroids

The Apophis flyby project is the latest in a series of planetary defence efforts. Like OSIRIS-REx, Japan’s Hayabusa 2 mission also returned samples of an asteroid, named Ryugu, back to Earth in 2020. And in 2022, NASA’s Double Asteroid Redirection Test, or DART, was the first ever deep-space planetary defence experiment: the spacecraft rammed into the (harmless) asteroid Dimorphos, deflecting it and proving that space rocks can be diverted away from Earth in an emergency. ESA’s Hera mission, launched in 2024, is currently heading towards Dimorphos to examine it post-DART impact.

At April’s Tokyo workshop (see main story), several other Apophis

mission ideas were floated by institutions and universities. The most eye-catching was the Apophis Cratering Experiment, or ACE. “Our mission concept is pretty simple: we impact Apophis, and OSIRIS-APEX watches and studies the way the impact makes the crater and deflects its orbit,” says Kevin Walsh at the Southwest Research Institute in Texas, one of the proposers of ACE.

Although it sounds like a miniature version of DART, ACE isn’t going to majorly change the asteroid’s orbit. By smashing into Apophis and watching it respond, the project would measure the asteroid’s internal structure and mechanical strength – albeit in a fairly dramatic fashion.

cameras, RAMSES will deploy two miniature satellites called CubeSats. One will use ground-penetrating radar to probe the interior of Apophis, while another may land a seismometer on the asteroid, says Michel.

“This kind of approach of a body of Apophis’s size occurs only once every few thousand years”

“We can take more risks with CubeSats, while the mother spacecraft remains at a safe position,” says Michel.

Beating OSIRIS-APEX and RAMSES to the punch – if it launches in 2028, as planned – will be JAXA’s DESTINY+ mission. Although its primary target is another asteroid named Phaethon, which it will reach in 2030, it will make a flyby of Apophis in early 2029, taking photographs to aid the incoming

RAMSES and APEX spacecraft, says Tomoko Arai at the Chiba Institute of Technology in Japan, the principal investigator of DESTINY+.

Assuming both RAMSES and DESTINY+ make it off the launch pad, the three-piece Apophis squadron must ensure it avoids an inadvertent destruction derby. “One coordination task is collision avoidance between spacecraft,” says Michael Küppers, an ESA planetary scientist.

But if they succeed, NASA, ESA and JAXA will get to watch Apophis transform as it wrestles with Earth’s gravity – revealing vital secrets to planetary defenders in the process.

“We have spent years considering what happens to an object when it makes such a close approach to a planet,” says Cristina Thomas at Northern Arizona University. “We finally have the opportunity to see.” ■