SPACE

# Goodbye Rosetta

**During its lifetime, the comet chaser transformed our understanding of the solar system – but its afterlife may have much to teach us too. RICHARD A. LOVETT reports.**

When the European Space Agency's Rosetta spacecraft was launched in March 2004, nobody expected it to end its 12-year sojourn by falling gently to the surface of a comet, like an autumn leaf. With its solar panels giving it a wingspan of 32 metres, one thing it was never intended to be was a lander, even in the incredibly low gravity of a comet. Rather, its mission was simply to rendezvous with a comet called 67P/Churyumov-Gerasimenko and shadow it as it dived close to the sun, observing the changes that occurred as the comet warmed.

But as the mission drew to a close, the scientists decided to go out with a gentle crunch. On 30 September, the spacecraft ended its mission in a slow-motion crash, snapping increasingly detailed images as it drew ever closer to its demise. By the end, said Holger Sierks, principal investigator for Rosetta's main camera, these "super-duper" images were so close-up that resolutions were down to millimetre level. "This the first time the comet has been imaged at this resolution," he said, when the spacecraft was still more than a kilometre above the surface.

It was a suitable finale to a mission that has been rich in drama since the beginning.

En route to the comet, the three-tonne spacecraft bounced through the inner solar system like an interplanetary pinball, gaining gravitational kicks from three close encounters with Earth and one with Mars. It flew by two asteroids and spent nearly three years in hibernation mode when its trajectory carried it so far out from the sun that its solar panels couldn't provide enough power to keep its computer fully functional.

When it reawakened, the spacecraft braked into orbit around the comet, mapped the surface for a couple months and deployed a lander to take detailed measurements of the surface. But things didn't go quite as planned. The lander was supposed to affix itself to its landing site by firing a pair of "harpoons" designed to hold it in place in the comet's miniscule gravity. Instead, it bounced. And bounced.

As Paul Weissman, a planetary scientist at the Planetary Sciences Institute, Tucson, Arizona, later joked, it didn't just make the first-ever landing on a comet – "it landed three times". When it finally came to rest, it was in the shadow of a cliff where its solar panels couldn't get enough power to complete all of the intended tests (though it was able to finish many during the two-and-a-half days before its batteries failed).

But the science was even more dramatic than the landing.

Rosetta draws its name from the Rosetta Stone, a tombstone-sized slab of granite whose inscription allowed archaeologists to translate Egyptian hieroglyphs – opening a vast new realm of historical understanding. The name fits: comets are widely believed to be remnants of the early solar system that have spent billions of years deep-frozen in its cold outer reaches. Then some random tug of gravity sends them plunging inward for us to observe.

Artist's impression of Rosetta shortly before hitting Comet 67P/Churyumov–Gerasimenko on 30 September 2016.

CREDIT: ESA / ATG MEDIALAB

"We're pretty certain that we really are looking back at the formation period of the solar system," says Bonnie Buratti, a planetary scientist from NASA's Jet Propulsion Laboratory in Pasadena, California, who was part of the Rosetta team.

One goal was to test a theory that Earth's water was brought to us by a "rain of comets" late in our planet's formation. Rosetta's instruments measured isotope ratios in water escaping from the comet for comparison to those in Earth's oceans. The water didn't match. That meant our water must have come from elsewhere, possibly different types of comets, or from ice-containing asteroids.

THE SPACECRAFT DEPLOYED A LANDER. BUT THINGS DIDN'T GO QUITE AS PLANNED.

Another find was that the comet's surface is peppered with pits whose cliff-like walls offer a glimpse into the subsurface, just as roadcuts and cliff faces do on Earth. Intriguingly, these walls were studded with boulders, one to three metres in diameter.

Nicknamed "dinosaur eggs", these boulders offer clues to how the comet was formed – that may also apply to the origin of protoplanets that later coalesced into planets. They lend support to what is called the pebble-accretion model, in which protoplanets are formed not from cascading collisions of ever-larger pieces, but from large numbers of primordial "pebbles" that somehow come together in comet-sized agglomerations.

Before this mission, adds Buratti, "our idea of how the solar system formed the planets was very shadowy. There was dust, and then miraculously planetesimals formed. [Now] you can find the progression of how these were put together".

When the decision was made to end Rosetta's mission with a crash landing, one of the goals was to make sure its final

**Snapping photos until the last moment, Rosetta captured this wide-angle shot of comet 67P at a distance of 22.9 kilometres.**

CREDIT: ESA / ROSETTA / MPS FOR OSIRIS TEAM MPS / UPD / LAM / IAA / SSO / INTA / UPM / DASP / IDA

trajectory provided the best-ever views of these boulders.

And there really wasn't that much to lose by ending the mission this way, says project scientist Matt Taylor. The comet was rapidly receding from the sun, carrying the spacecraft with it. Already there wasn't enough power to keep all of its instruments running and the data transmission rate had dropped by 90%. The only other option would have been to put the spacecraft back into hibernation mode and hope it could be revived again years from now as it drew back towards the sun on the comet's next close approach. It was a classic bird-in-hand choice. "This was the option where we'd maximise the science," Taylor says.

But while Rosetta has finally come to rest, the mission is far from over. "We've analysed only like 5% of the data," says Art Chmielewski, Rosetta's US project manager. And to date, he adds, scientists have been looking only at data from their own instruments. Now they'll be coming together in groups to share information. "There's years of hard work ahead," he says.

Taylor agrees. "The spacecraft may end, but the science will continue."