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Samples from SPACE

Osiris-Rex returns to Earth with secrets from another world

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OSIRIS-REx is due to arrive at Earth from asteroid Bennu on 24 September 2023

The rock hunter RETURNS

As OSIRIS-REx becomes the latest spacecraft to bring back samples from another world, **Ezzy Pearson** examines how these missions help reveal our Solar System's history

NASA'S GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB, NASA'S GODDARD SPACE FLIGHT CENTER

On 24 September, NASA's OSIRIS-REx mission will finally arrive home, the culmination of its seven-year-long journey to asteroid Bennu and back. The Origins Spectral Interpretation Resource Identification and Security – Regolith Explorer, to give OSIRIS-REx its full title, will be carrying with it an estimated 250g of dust and pebbles which it carefully gathered from the asteroid's surface back in October 2020.

This precious cargo is being eagerly anticipated by planetary geologists around the globe, as it will be one of just a handful of pristine samples taken directly from another Solar System body. That may not be the case for long, though. Recent years have seen the number of such sample-return missions increase, heralding a new age for this particular field of space science.

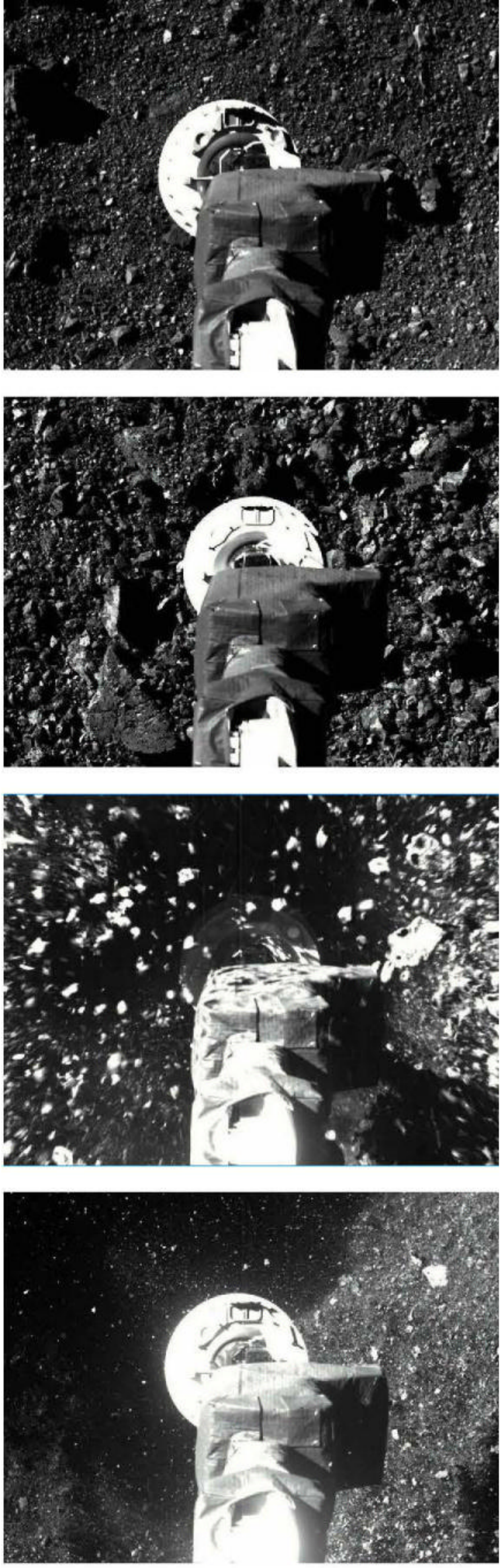
These missions provide a hugely important piece in the puzzle of understanding our Solar System's history. Four and a half billion years after its creation, our Solar System is still littered with the remnants of planets that never came to be, in the form of comets and asteroids like Bennu. Astronomers have spent centuries staring at these distant objects, while more recently orbiters and lander missions have offered a closer look. To really understand these space rocks, however, requires the use of advanced equipment that can only be found in labs here on Earth.

Snippets of the Solar System

We have long been able, of course, to look at pieces of some asteroids that have obligingly fallen to Earth as meteorites. For decades, these have been collected, catalogued and studied to give us our current picture of the disparate worlds of our Solar System. The problem is that as soon as a meteorite enters Earth's atmosphere it's contaminated by our environment, which limits its usefulness as a source of information. Additionally, unless the meteor was seen streaking through the sky, there's usually no indication as to exactly where in space these rocks have spent the last four billion years before hitting Earth.

"My background is in geology, and one of the things our lecturers always say is it's so important to do fieldwork," says Sara Russell, head of planetary materials at the Natural History Museum. "You don't just analyse a rock; you have to know what all the rocks around it were, where it came from, what the environment was like."

This is why a growing number of space agencies are working on sample-return missions, of which OSIRIS-REx is merely the most recent. The first such missions were the Apollo landings, which in total returned an astounding 382kg of Moon rocks. Here, the fieldwork was done by human astronauts who took detailed observations and records of the landscape as they went.



▲ Hit the rocks: OSIRIS-REx's robotic arm snatches its sample in just six seconds of contact in October 2020

However, most sample-return missions have been robotic. The earliest of these were the Soviet Union's Luna 16, 20 and 24, which between them returned around 300g of material in the '70s, but ▶

▶ their primitive cameras and sensors provided only limited context. It's taken 50 years for technology to develop to the point where spacecraft can operate as effective field geologists.

This fieldwork is started as soon as the spacecraft are within sight of their intended target. When Japanese sample-return mission Hayabusa2 arrived at asteroid Ryugu in June 2018, it spent several months examining every part of the asteroid with its cameras. Six months later, OSIRIS-REx began its own observations when it arrived at Bennu.

"From that you can look at boulder size, distribution and shape," explains Russell. Specialised spectral cameras can even give some indication as to what minerals the rocks are made of. "So you can see whether the bodies are made of the same thing, or if there's a variety of different rocks."

These measurements are a vital part of the mission. For OSIRIS-REx, they fulfil the 'Resource Identification' part of its moniker by helping to analyse what potentially useful compounds and minerals can be found on asteroids, which could be mined by future space explorers. They also provide important context that geologists will call upon later. More immediately, they help the flight team pick out the ideal site to take their sample from.

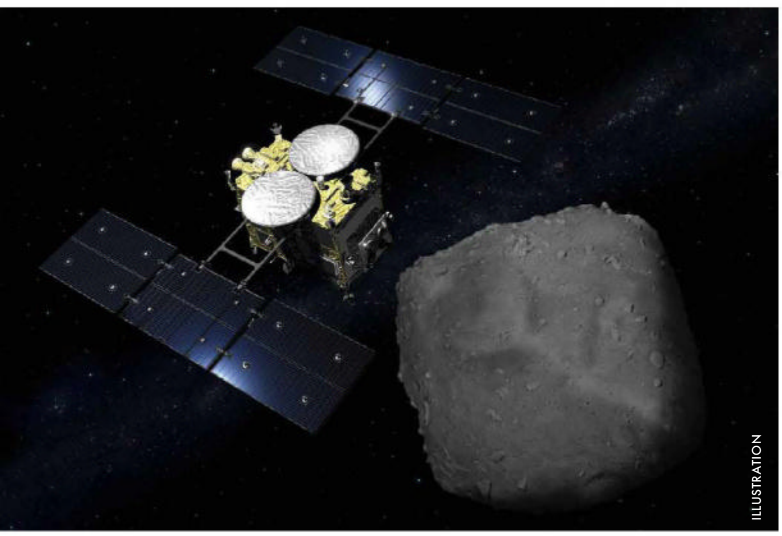
"The engineers always insist you pick the safest place," says Russell, "but the scientists want you to pick somewhere that's scientifically interesting. In OSIRIS-REx's case, they picked a dark area because that might have more organic material in it."

Rock of ages

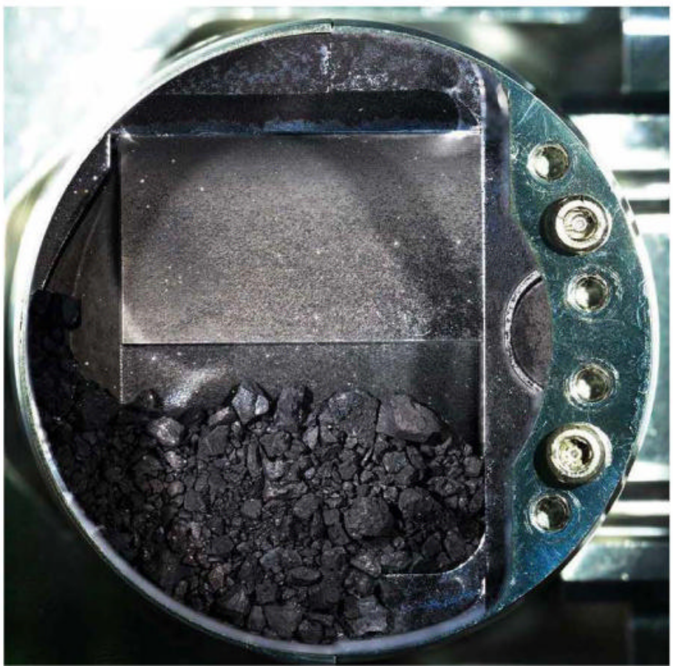
Organic materials are the carbon-based chemicals which form the building blocks of life. It's thought that asteroids were responsible for bringing these chemicals to the early Earth.

"We know that meteorites collected here on Earth contain a whole zoo of organic materials," says Russell. The problem is, Earth is even richer with organic materials, which meteorites come into contact with as soon as they enter our atmosphere.

▲ Apollo 14's Edgar Mitchell, Stuart Roosa and Alan Shepard are shown lunar samples gathered during their mission



ILLUSTRATION

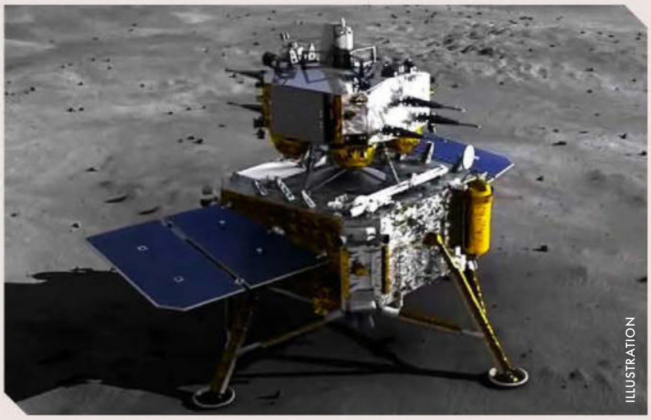


▼ Hayabusa2 (left), Japan's six-year mission to asteroid Ryugu, returned a 5.4g sample in December 2020 (right)

NASA X 2, JAPAN AEROSPACE EXPLORATION AGENCY X 2, CNSA, JAXA, NASA/JPL-CALTECH

Future missions

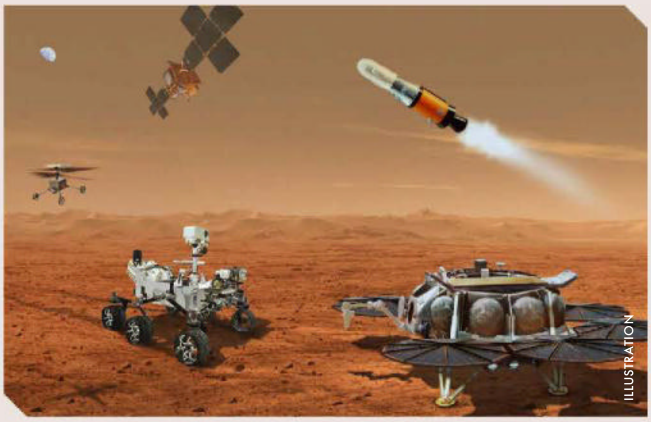
A slew of sample-return missions are set to launch in the coming decade



Chang'e 6, CNSA, 2024
China aims to collect 2kg of material from the Moon's far side, a region from which we have no samples. The lander can collect material up to 2m down, where it should be protected from solar and cosmic radiation. The craft was originally a back-up to Chang'e 5, which returned a nearside sample in 2020.

Martian Moons eXploration (MMX), JAXA, 2024
Following Hayabusa2's success, Japan is looking further afield to Mars's tiny moon, Phobos. MMX will spend several months conducting a detailed study of Phobos before collecting up to 10g of material. After making several fly-bys of the smaller moon, Deimos, it will head back to Earth, arriving in 2029.

Artemis III, NASA, 2026
The first of many planned human missions to the Moon is bound for the lunar south pole, where NASA hopes to set up a permanent base. Samples taken by the crew and other support missions will be analysed not just for their scientific value but for any resources that future Moon-dwellers could use.



Mars Sample Return, NASA/ESA, 2030s
Since 2021, NASA's Perseverance rover has been collecting dozens of samples from the Martian surface. NASA and ESA are planning a pair of follow-up missions to collect them: a surface lander to gather the tubes and launch them into orbit, and an orbiter to catch them and return them to Earth in around 2033.

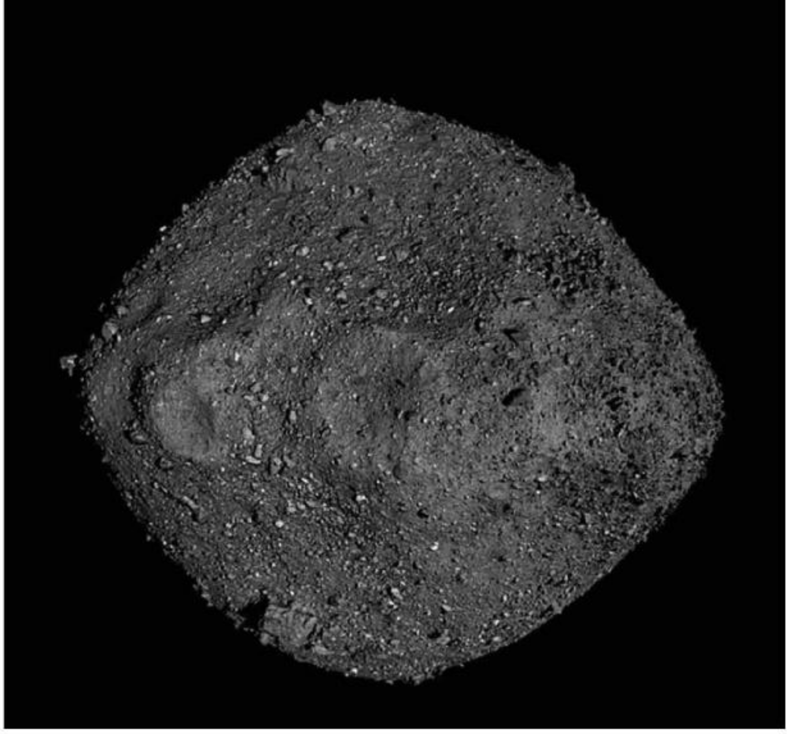
"There's a lot of controversy about which of these are due to contamination and which are indigenous."

Keeping the sample free from contamination is a prime concern, so as soon as the sample is taken it's sealed inside a special return capsule for the journey back to Earth. As well as protecting the sample from Earth's biology, the capsule insulates the precious space dust so it remains at a stable temperature even through the scorching heat of re-entry.

"Most sample returns come from places that have not been hot for billions of years," explains Russell. "We don't want them to start having chemical reactions or similar, so keeping them cool is really important. And also challenging when you're dropping them from space!"

The returning capsules are normally directed to land in deserts, as these are largely unpopulated regions with few obstacles that could damage them. Soon after arrival, they are swarmed by waiting collection teams that gather not just the capsule but also 'witness samples' of the surrounding air and soil. These – along with special plates which were in the room alongside the spacecraft when it was initially being built – help guide those looking at the samples by recording possible contaminants.

The capsule is then transported to a dedicated facility – the Johnson Space Center in Houston in the case of OSIRIS-REx – where it will be placed in a sealed box filled with inert hydrogen gas that will prevent terrestrial air from getting into the sample. ▶



▲ Thought to be a 4.5-billion-year-old remnant of the early Solar System, Bennu could help reveal how planets formed and life emerged on Earth

▶ "Trying to make sure the sample doesn't come into contact with the atmosphere is the absolute biggest thing," Russell emphasises. "That means keeping it away from oxygen and water, because those are things that will react with the sample and make it start to erode away."

Once the canister is open, the team will photograph every pebble and grain collected to catalogue what they have. Around 75 per cent of the sample will be packaged up and stored, ready for future generations of researchers to analyse, but the remaining quarter will be divided up and sent to waiting partner facilities around the world.

"We're really lucky to be getting a bit of Bennu very early on," enthuses Russell. "We're going to CT scan it – which is largely considered non-destructive – and that will give us an idea of its internal structure."

Scientific smash and grab

Alas, many of the tests will not be so kind to the sample. OSIRIS-REx is expected to collect some pebbles up to 2cm in diameter, which can be sliced up and polished so they can be looked at under an electron microscope, which gives a close-up view of the physical and chemical structure of a rock. Other tests will use lasers to precision burn parts of the sample, sniffing out the elements released in the smoke.

In fact, all around the world, teams of planetary geologists will be taking these carefully collected samples and then cutting them up, smashing them to pieces, burning them, even dissolving them in acid. But when the data from all these tests is put together, it will give us a full picture of what the asteroid is made from and how it was all structured. As we know the conditions needed for certain minerals to form, or what has to happen for a particular crystal structure to arise, all this information will help us to understand that particular asteroid's history, leading to what we see today.

Once we have that knowledge, it will be time to unleash the real power of returned samples,

▼ The Bennu sample will be put through exhaustive tests at NASA's Johnson Space Center and other institutes

NASA/GODDARD/UNIVERSITY OF ARIZONA, NASA, NASA/JPL-CALTECH/MSSS, ASSOCIATED PRESS/ALAMY STOCK PHOTO JOE VELLA/ALAMY STOCK PHOTO

Protecting Earth

Space rocks contaminating our planet is as perilous as the other way around

It's the premise of many sci-fi tales, but the threat of bringing back some alien microbe that could harm our planet is something all space agencies take very seriously. Billions of years of being bombarded with cosmic radiation have rendered asteroids safely sterile – but that's not the case on Mars.

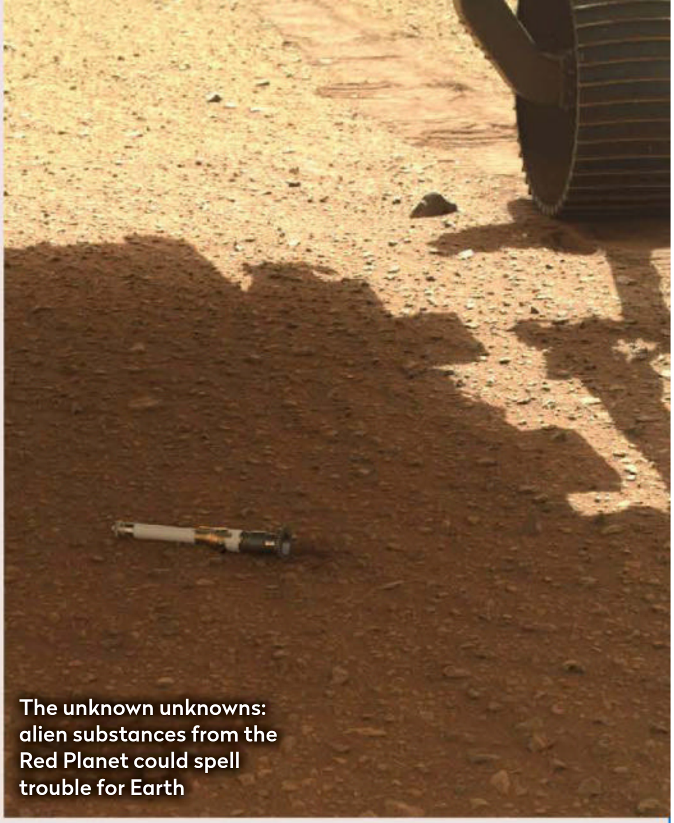
"Though we have seen no evidence for life on the Red Planet so far, it would be naïve to assume there isn't any, given it's a planet with an atmosphere," says Sara Russell.

The Perseverance rover is currently collecting a series of samples on Mars, which NASA and ESA hope to return to Earth some time in the next decade. Already there are plans for what precautions are needed to keep Earth safe.

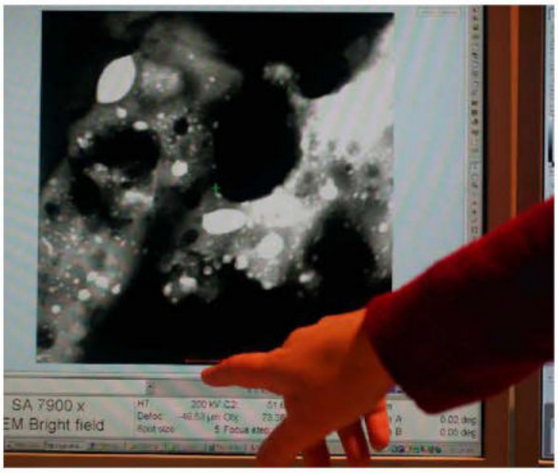
"The first samples will be taken to the US, who have taken on that responsibility," says Russell. "They'll be kept in BSL-4 biocontainment, the same level that's used to look at Ebola viruses, and will be absolutely assumed to be as dangerous until proved otherwise."

While the samples are under containment, the team will conduct tests to look for evidence of Martian biology. After this, the rocks will be bathed in gamma radiation to sterilise them without affecting their bulk chemistry or mineralogy.

"We've learned from old voyages of discovery, when Europeans explored the new world and took lots of horrible diseases with them," Russell concludes. "This is something that we have to be super-aware of, and careful not to make mistakes that we've made before."



The unknown unknowns: alien substances from the Red Planet could spell trouble for Earth



▲ Magnified particle samples retrieved from the coma of comet Wild 2 by the Stardust mission in 2004

▲ A slice of the Imilac meteorite found in the Atacama Desert in 1822 and held by the Natural History Museum

which comes not from what they look like in and of themselves, but from how they compare with what we already have. Currently, we only have direct samples from three asteroids, our Moon and a comet's tail as collected by Stardust in 2004, which is hardly a full representation of the variety that we see across the Solar System. For that, we have to turn to the vast meteorite collections at the Natural History Museum and other institutes around the world. The handful of samples taken directly from source give a vital insight to peel away at least some of the uncertainties surrounding meteorites.

"Hayabusa2's Ryugu sample looks like most chondrite meteorites," says Russell. "These are made of chondrules – tiny round blobs we think came from our protoplanetary disc. So they're frozen samples of what was there before the planets. Around eight per cent of meteorites that fall to Earth are chondrites."

There is one big difference between Earth-collected chondrites and the Ryugu sample, however. "Chondrites contain 20 per cent water, Ryugu contained 10 per cent water. The meteorites have soaked up water from the atmosphere which the sample return hadn't."

Perhaps even more exciting is the prospect that sample-return missions can visit places not represented by meteorites. Early indications suggest that Bennu could be unlike anything we have on record. With several more sample-return missions expected in the next few years, who knows what other worlds we could soon have a piece of, back here on Earth?

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press