

On Sunday morning, Japan's Hayabusa2 space probe dropped a capsule from space, delivering an asteroid sample to Earth.

The capsule "streaked through the atmosphere at high speeds before deploying a parachute," Charlotte Jee writes for MIT Technology Review. At 4:37 a.m. local time, the capsule, containing up to several grams of rock, dust, and debris, landed in the red desert sand of the Australian Outback town of Woomera, 280 miles north of Adelaide.

A recovery team, led by the Japan Space Agency (JAXA), deployed a helicopter before sunrise to locate and collect it. They carried the capsule by hand into a facility to be cleaned and dismantled, exposing the interior sample container, Masaki Fujimoto, deputy director general of JAXA's Institute of Space and Astronautical Science, said during a news conference.

The event marks the end of a six-year, 3.25 billion-mile mission in space. Its team of scientists hopes to unravel the mysteries of our solar system's early days—asteroids provide hints about the "ingredients" in planets, astronomers say—while also exploring the origins of life on Earth. JAXA scientists hope to have collected at least 0.1 grams of asteroid debris to do so. Analyses this week will reveal if they met that goal.

The sample originated from Ryugu, a dark, carbon-rich asteroid 180 million miles away from Earth. After launching in 2014, Hayabusa2 reached Ryugu in June 2018. From there, it spent 18 months circling the 0.6-mile-wide diamond-shaped asteroid, making remote observations. Hayabusa2 also released several small robots onto Ryugu to collect data, images, and ultimately scout its craggy face for potential sampling sites. Unlike traditional rovers on wheels, Hayabusa2's robots traversed Ryugu's rubbly surface by hopping.

"The whole robot can rotate, kick the surface and then jump," Yuichi Tsuda, Hayabusa2 project manager at JAXA, told NOVA.

In February 2019, after identifying a safe spot for a pinpoint landing between closely spaced boulders, the Hayabusa2 team made its first attempt to collect a sample by having a sampling device on the belly of the spacecraft lightly touch down on the asteroid, firing a projectile, and collecting the resulting ejected material with a "catcher" at the top of the sampling device. "I remember the scream of my Japanese colleagues when we knew this was a success," Patrick Michel, a co-investigator of the Hayabusa2 and NASA's OSIRIS-REx asteroid mission told NOVA.

Then, in July 2019, the spacecraft went back for more rocks and rubble. This time, it collected the first-ever subsurface sample from an asteroid, extracting material from an artificial crater made by firing a copper projectile into Ryugu's surface.

From these samplings, the JAXA team aimed to collect a total of 100 milligrams of "carbon-rich soil and rock fragments," Dennis Normile writes for Science Magazine. "Just how much material was collected won't be known until the sample container—the 'treasure box'—is opened in clean room facilities in Tokyo this week," Normile writes.

Ryugu is a carbonaceous, or C-type, asteroid. Space rocks of this kind are abundant in our solar system, generally dwelling in the asteroid belt between Mars and Jupiter. But some, like Ryugu, orbit closer to the sun, roughly between Earth and Mars. These are considered "near-Earth asteroids." They contain hydrates (inorganic salts that contain water molecules) and

organic materials—Ryugu is one of the darkest asteroids researchers have ever found, “its inky complexion a result of all the carbon trapped in organic compounds smeared across its surface,” Daniel Oberhaus writes for WIRED. Scientists suspect that when asteroids like Ryugu pummeled a proto-Earth billions of years ago, they may have helped kick-start life by delivering the necessary building blocks.

While life on Earth uses only 20 amino acids, “we see many more in asteroids,” Jamie Elsila Cook, co-investigator for the NASA Astrobiology Institute at the Goddard Center for Astrobiology, said during an OSIRIS-REx mission press conference in October. (Like Hayabusa2, NASA’s OSIRIS-REx aims to bring an asteroid sample back to Earth.) “We know they’re present in carbonaceous meteorites, so they’re extraterrestrial compounds vital to life here on Earth.”

Meteorites that land on Earth originate from asteroids. We can get a peek at what asteroids contain when they bump into each other, break apart, and send debris crashing to Earth—what we call meteorites. But having traveled through Earth’s atmosphere to eventually crash land on its surface, meteorites are both cooked to a crisp and corrupted by terrestrial chemistry.

“Sending a probe to a still-orbiting asteroid is the best way to collect a clean sample,” Oberhaus writes.

Sampling Ryugu and other asteroids directly can also help us gain a broader understanding of our solar system. “By understanding better how and why Ryugu gained its current appearance, we’ll have a more comprehensive model for how solar system bodies form and develop,” planetary scientist Paul K. Byrne writes for the Conversation.

Hayabusa2 follows in the footsteps of Hayabusa, the world’s first asteroid sample return mission, which JAXA launched in 2003. Due to a failure in the Hayabusa spacecraft’s collection mechanism, only a few micrograms—about 1,500 individual grains—of dust from Itokawa, an oblong and stony (S-type) asteroid, made it back to Earth in 2010.

“Hayabusa was like Apollo 13; it was a successful failure,” OSIRIS-REx scientist Bashar Rizktold told NOVA. “I mean, they had so many things go wrong, yet they still managed to get the spacecraft back to Earth.”

Like Hayabusa2, NASA’s OSIRIS-REx mission, which successfully grabbed a 2-pound sample from asteroid Bennu in October, hopes to unravel mysteries of our solar system by analyzing asteroids’ ingredients. (While Hayabusa2 scientists had no means to measure their sample remotely, OSIRIS-REx is equipped with cameras, whose images helped discern the substantial size of the Bennu sample days after its collection.) A diamond-shaped carbonaceous asteroid covered in boulders, Bennu looks like Ryugu’s half-sized twin. Some scientists posit that the two come from a single parent body that was struck by another space rock millions of years ago, and broke into tiny pieces, which gravity helped reform into individual asteroids.

But there’s a major difference between Bennu and Ryugu: While OSIRIS-REx has detected minerals inside Bennu’s rocky surface that contain the remnants of water, an important ingredient for life, Ryugu appears to be parched.

Given the Hayabusa2 and OSIRIS-REx mission scientists’ common goal, the two teams have worked together over the past couple of years. “Two science missions isn’t just twice as good,”

Heather Enos, OSIRIS-REx deputy principal investigator, said in a 2018 press release. “It’s two times a factor of ‘X’ as good! You’ve got so much talent, information and diversification within the teams that your knowledge base can explode.”

And with some scientists, like Patrick Michel, participating in both Hayabusa2 and the OSIRIS-REx mission, there’s hope that lessons learned from the Ryugu sample analysis can be applied to the eventual study of rock and dust from Bennu, which the OSIRIS-REx spacecraft will drop down to the Utah desert in September 2023.

By then, as part of its post-Ryugu “bonus mission,” Hayabusa2 will be well on its way to a large red asteroid named 2001 CC21, which it will fly by in July 2026. Next, the craft will swing back around Earth to eventually rendezvous with the tiny asteroid 1998 KY26, a mere 1/30th the size of Ryugu, in 2031. Despite the asteroid’s small size, measurements taken on Earth hint that KY26 may have something Ryugu does not: water.

Hayabusa2 has one more asteroid sampling device onboard, and as the mission nears its end over a decade from now, the probe may deliver yet another asteroid sample to Earth.