"Perseverance is going to do so much for us," says Kennda Lynch, an astrobiologist at the Lunar and Planetary Institute in Houston, Texas.

The machine is a beefed-up version of the Curiosity rover, which gripped the world when it landed on Mars 8 years ago in a nail-biting 7-minute manoeuvre. After a journey of roughly 500 million kilometres, Perseverance will hit the Martian atmosphere travelling at around 19,500 kilometres per hour. It will deploy a parachute and then a 'sky crane' system — similar to that used by Curiosity — that will fire retrorockets to slow it down as it approaches the planet's surface. Unlike Curiosity, the spacecraft has an autopiloting system to detect obstacles such as big rocks, and guide it to a safe location.

Once Perseverance lands, engineers will spend around 90 days remotely checking all of its systems to make sure they're in working order. The rover probably won't begin rolling in earnest until May, when it will strike out on its six wheels to explore Jezero Crater, which lies about 3,750 kilometres from Curiosity's landing site.

Jezero means 'lake' in several Slavic languages. More than 3.8 billion years ago, a river flowed into the 45-kilometre-wide crater, and lake waters filled it[1]. Images suggest that along the crater's rim, carbonate minerals settled out and hardened into rock[2]. That's exciting because on Earth, ancient carbonate rocks hold some of the oldest known evidence of life, including fossilized bacterial mats known as stromatolites[3].

If Martian life ever existed, Jezero's carbonates are a good place to look for it. "We've not explored an environment like this before," says Tanja Bosak, a geobiologist at the Massachusetts Institute of Technology in Cambridge who is working on the mission. Evidence of life could come in the form of actual fossils, or in chemical or geological signatures of organisms that once lived in the rocks.

Tools of the trade

The rover is loaded with instruments that make it a true field geologist — and truly international. They include a pair of zoomable cameras that can spot a fly from the other side of a sports field; a Spanish-built weather station; a Norwegian-built radar to scan layers of soil and rock beneath the planet's surface; and an advanced version of a laser instrument carried on Curiosity, which will probe rocks to study their chemical make-up. "Who doesn't love a camera with a laser that zaps rocks?" says John Grunsfeld, a former NASA astronaut who led the development of Perseverance when he ran the agency's science office from 2012 to 2016.

Perseverance is also pioneering because it carries two microphones, which will not only reveal the winds and other sounds of Mars for the first time, but will also be able to listen for engineering problems in the motors or wheels, Grunsfeld says. And it has a 1.8-kilogram helicopter named Ingenuity, which it can deploy to scout ahead for places where the rover could roll. If the mission is successful, Ingenuity will be the first craft to make a controlled flight on another planet.

There and back again

But the workhorse of Perseverance is its robotic arm, which can stretch to scrutinize rocks up close, and then drill out samples and store them in tubes in the rover's belly. The mission will stash these samples until a future spacecraft can retrieve them and bring them back to Earth. NASA and the European Space Agency plan to bring those rocks back to Earth by 2031 so that scientists can study them in sophisticated laboratories — although only a small part of the funding has yet been committed.

"Returning samples will be the first time we will have done a round trip to Mars," Grunsfeld says. "That's important because it's a metaphor for human space flight. Most astronauts who go to Mars are going to want to come back."

As a step towards that long-term exploration, the rover will use one of its instruments to attempt to produce oxygen from Mars's carbon dioxide atmosphere. Future human astronauts might be able to do the same, to make oxygen to breathe or produce rocket fuel to get home.

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The space missions that snatch pieces of other worlds

NASA is about to grab its first taste of Mars. On 30 July, its Perseverance rover launched to the red planet — the first step towards fulfilling a long-standing dream of planetary scientists. If all goes to plan, Perseverance will arrive in February 2021 and drive around, collecting samples of rock that, one day, other spacecraft will pick up and fly back to Earth. The rocks will become the first samples ever returned from Mars (see page 15).

They will join a priceless collection of cosmic material brought back from other planetary bodies, including the Moon and an asteroid. These samples have reshaped scientific study of the Solar System.

Without planetary missions, the only way scientists can directly study rocks from other worlds is to analyse meteorites that have fallen to Earth, but such events are rare, says Queenie Hoi Shan Chan, a planetary scientist at Royal Holloway University of London in Egham, UK.

So space agencies go to a lot of trouble to collect fragments of the Moon, Mars and other worlds. In well-equipped laboratories, researchers looking to understand these samples can apply tools and techniques that aren't available on a small spacecraft, Chan says.

The first and largest collection of samples comes from the Moon. Between 1969 and 1972, a dozen astronauts in NASA's Apollo programme brought back 382 kilograms of lunar rocks (see 'Sampling the Solar System'). Studies of those samples have rewritten scientific understanding of the Solar System.

"When Apollo 11 landed on the Moon, many considered that our small moon had formed cold," says Donald Brownlee, an astronomer at the University of Washington in Seattle. "This turned out to be spectacularly wrong." Studies of the rocks showed instead that the Moon was hot at its birth, more than 4.5 billion years ago, and covered with an ocean of molten rock.

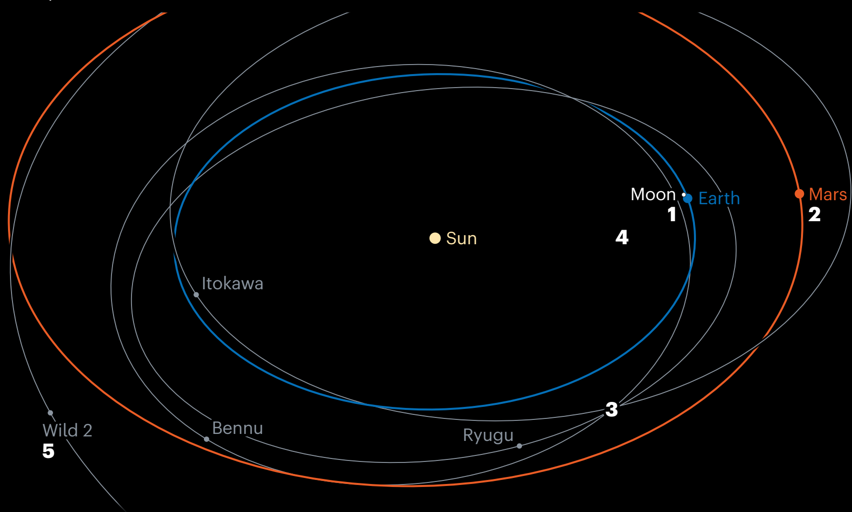
Three Soviet Luna missions, all involving robots, also brought back small amounts of Moon dust between 1970 and 1976. And China plans to retrieve some lunar samples with its upcoming Chang'e-5 mission, which could launch by the end of this year.

The Japan Aerospace Exploration Agency (JAXA) is the only space agency so far to have brought back material from an asteroid. In 2010, the Hayabusa spacecraft returned from the potato-shaped asteroid Itokawa with more than 1,500 precious grains. Studies of the material confirmed, among other things, that the most common type of meteorite that falls to Earth, called an ordinary chondrite, comes from silicate-rich asteroids such as Itokawa. Two other asteroid samples

Data story

SAMPLING THE SOLAR SYSTEM

Agencies have sent spacecraft to the Moon, asteroids and comets, and into the middle of the solar wind, to grab rocks and particles and return them to Earth. These materials have transformed our understanding of the Solar System and its bodies. The next step towards a sample-return mission, NASA's Perseverance rover, will this month head to a new frontier: Mars.



1. Moon
1969–72: NASA's Apollo missions collected 382 kilograms of Moon rocks.
1970: Soviet Luna-16 mission, 101 grams.
1972: Luna-20, 55 grams.
1976: Luna-24, 170 grams.
Future: China's Chang'e-5 probe, NASA's Artemis missions.

2. Mars
Future: Japan's Martian Moons Exploration mission could return material from the satellite Phobos as early as 2029. NASA's Perseverance rover will fill 30 tubes with rock and soil on Mars, to be returned to Earth by 2031.

3. Asteroids
2005: Japan's Hayabusa probe collected more than 1,500 particles from asteroid Itokawa.
2019: Hayabusa2 left asteroid Ryugu to bring samples to Earth.
Future: NASA's OSIRIS-REx will collect samples from asteroid Bennu.

4. Solar wind
2001–04: NASA's Genesis spacecraft collected more than 1,850 samples.

5. Comet Wild 2
2004: NASA's Stardust mission collected more than 10,000 particles of dust from Wild 2's tail.

should arrive on Earth soon. In December, JAXA's second asteroid mission, Hayabusa2, should return material from a carbon-rich asteroid called Ryugu, and NASA's OSIRIS-REx spacecraft is orbiting the diamond-shaped Bennu asteroid, in the hope of grabbing a sample in October and returning to Earth in 2023.

NASA has also grabbed material from a comet, with its Stardust spacecraft. In 2004, the mission whizzed through the tail of Comet Wild 2. On Earth, the samples it gathered turned up huge surprises.

NASA named the mission Stardust because scientists thought the comet contained ancient dust from other stars, frozen in ice for billions of years. "This idea was also spectacularly wrong," says Brownlee, the mission's principal investigator. Instead, they found the comet dust had formed close to the Sun at incandescently hot temperatures. That showed that hot materials had been transported throughout the early Solar System and somehow become incorporated into the icy body of the comet.

But returning samples from Mars is a bigger challenge than any other mission so far. The planet is farther away than the Moon and has more gravity than a comet or an asteroid, making it harder to escape the surface and get back to Earth.

NASA wants Perseverance to drill out and store at least 30 tubes of Martian rock and soil at its landing site in Jezero Crater. Long-term plans call for NASA and the European Space Agency to collaborate to send a second rover to collect those tubes and launch them into Martian orbit, and a third spacecraft to fetch them from Martian orbit and fly them back to Earth. The aim is for the samples to reach Earth in 2031.

Alexandra Witze

CHINA'S CORONAVIRUS VACCINES ARE LEAPING AHEAD

But companies could struggle to run trials in enough people to satisfy regulators.

By David Cyranoski

Chinese companies are at the forefront of global efforts to create a vaccine for the coronavirus, with more than half a dozen candidates in clinical development. Last month, Tianjin-based CanSino Biologics published results[1] from an early clinical trial showing that its vaccine is safe and can trigger an immune response.

Yet the companies could face difficulty as they try to push vaccines through phase III trials, a crucial stage of testing that is needed to prove efficacy and secure approval from regulators. These trials usually require tens of thousands of participants, and with the outbreak in China largely under control, companies are having to test their vaccines elsewhere. But researchers say they might still struggle to enrol so many participants and employ enough health-care professionals to collect data.

"The Chinese companies will need to step outside of China," says Jerome Kim, director-general of the International Vaccine Institute in Seoul. "The race is on," he says, "and it's really about who can set up in a high-risk area most quickly."

Chinese vaccine-makers will face other challenges, too. Vaccines will probably face extra scrutiny, given the country's opaque regulatory system and previous vaccine scandals, say scientists. In 2018, hundreds of thousands of children reportedly received defective vaccines against diphtheria, tetanus and whooping cough.

As the country where the first cases of the coronavirus were reported, China was fast out of the gate in developing vaccines. CanSino's offering is made from a common-cold virus,