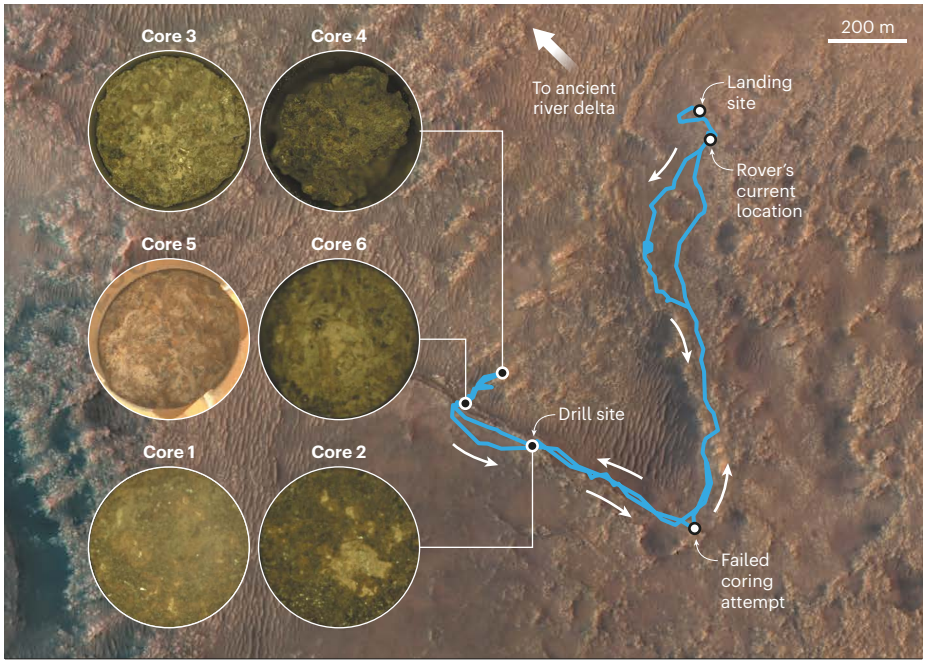
SAMPLING MARS

NASA's Perseverance rover has drilled and collected three pairs of rock samples in Jezero Crater on Mars, the first Martian rocks ever intended to be brought back to Earth for scientific analysis. The rover will soon head to its ultimate destination, an ancient river delta, to look for signs of past life.



NASA/JPL-CALTECH

Geophysical Union by Eva Scheller, a geologist at the California Institute of Technology in Pasadena — contain organic molecules, probably produced through non-biological processes, such as those seen in some Martian meteorites.

Pressure mounts

All told, Perseverance is supposed to collect at least 30 rock, dirt and atmosphere samples. It will lay them down in one or more places for future missions to retrieve, in what could be the first sample return from Mars. Getting the cores to Earth will be an elaborate process requiring another rover to pick them up, a rocket to launch them into Mars orbit, and a spacecraft to capture them and fly them back to Earth; this would happen no earlier than 2031. NASA and the European Space Agency are collaborating on the plan, and NASA announced last month that it had chosen a contractor to build the rocket that will lift the samples into Mars orbit.

"I'm just super-excited that we're finally taking the first steps towards collecting and hopefully bringing back samples from Mars," says Meenakshi Wadhwa, a planetary scientist at Arizona State University in Tempe and NASA's principal scientist for the Mars sample-return programme.

Despite the rover's success so far, pressure is mounting for it to get to the long-awaited delta. Perseverance is making its way there now as quickly as possible; last month, it set a record for long-distance driving on Mars, travelling more than 240 metres in a day. Even so, it probably won't get to the delta until April.

Time is of the essence because Perseverance has only about one Earth year remaining to meet the timetable for accomplishing its main to-do list: get to the delta, collect samples there and drive up onto the crater rim to place them somewhere for pick-up. The rover is now retracing its steps towards its landing site: once it gets there, it will detour around the dune-filled region to reach the delta. Perseverance is working at a much faster pace than NASA's previous Mars rover, Curiosity, which has been exploring Gale Crater since it landed in 2012. "We have to keep on moving," Bosak says.

Although operations have mostly been smooth, some small glitches have occurred, besides the initial failed attempt to collect a rock core. In December, some pebbles fell out during a coring attempt and jammed some of the mechanisms in the rover's sampling equipment. Engineers eventually got Perseverance to shake the pebbles loose to fix the problem. And in recent weeks, says José Antonio Rodríguez Manfredi, principal investigator of the rover's weather instrument at the Centre for Astrobiology in Madrid, surprisingly strong winds kicked dust and small pebbles into several of the rover's wind sensors, damaging them.

Perseverance's sidekick, the tiny helicopter named Ingenuity, continues to plug along. Researchers intended it to make five flights over 30 days. But it has so far made 19 flights and travelled more than 3.8 kilometres. If the craft continues to survive, it will be used to scout routes that the rover might take once it gets to the Jezero delta to collect more cores.

"The delta samples will be spectacular," Bosak says. "I can't wait. I really can't wait."

ASTEROIDS, HUBBLE RIVAL AND MOON BASE: CHINA SETS SPACE PLAN

In the next five years, the nation hopes to launch a robotic craft to an asteroid and two lunar missions.

By Elizabeth Gibney

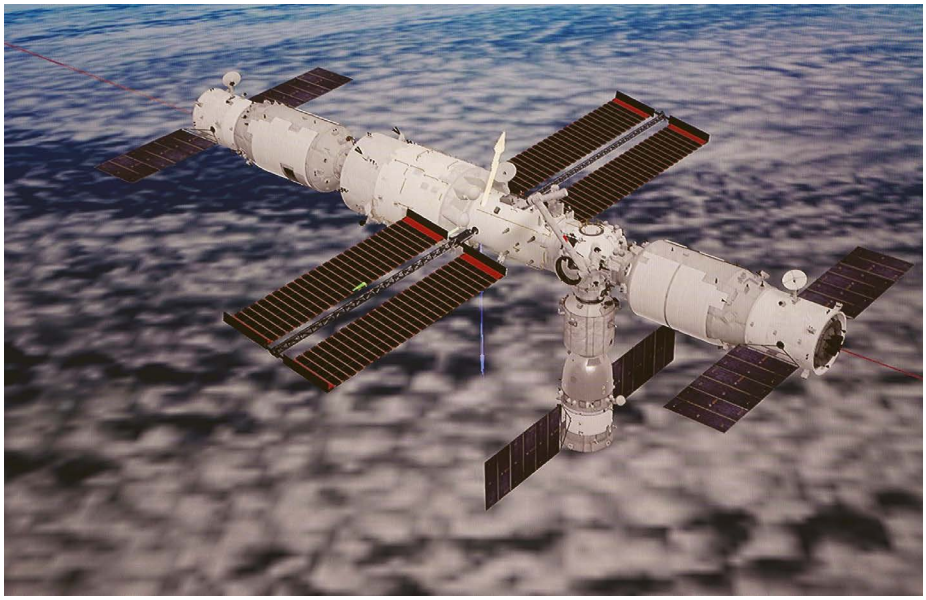
China has had a bumper few years in space exploration, and its ambitions are about to get bolder. The China National Space Administration has released an overview of its plans for the next five years, which include launching a robotic craft to an asteroid, building a space telescope to rival the Hubble and laying the foundations for a space-based gravitational-wave detector.

The missions were highlighted in a white paper, 'China's Space Program: A 2021 Perspective', released last month. The plans continue the country's trend in emphasizing missions with science at their heart, rather than technology development and applications, says Shuang-Nan Zhang, an astronomer at the Institute of High Energy Physics in Beijing. "This is a very good sign," he says. "It's a continuous increase in investment in exploration of the Universe."

Nature looks at five of the most ambitious projects.

Visit an asteroid

China aims to launch asteroid probes to sample near-Earth asteroids and study icy comets that have asteroid-like orbits. The mission, which will probably be named ZhengHe after a Ming-dynasty Chinese explorer, would be the country's first to visit an asteroid, and could launch as soon as 2024. It will follow in the wake of Japan's successful Hayabusa asteroid missions and NASA's OSIRIS-Rex, which is



China's Tiangong Space Station, which is under construction.

XINHUA/EYEVINE

due to return space rocks to Earth next year.

ZhengHe will fly for ten years, first landing on an ancient asteroid known as HO3 or Kamo'oalewa, which loops around Earth as a quasi-satellite. Scientists hope that studying it will give them an insight into conditions in the early Solar System. ZhengHe will anchor itself on the asteroid before scooping up its sample, according to a correspondence published in *Nature Astronomy* last year (T. Zhang *et al*. *Nature Astron*. **5**, 730–731; 2021). ZhengHe will return to Earth's orbit in 2026 to drop off its spoils, which will parachute to the ground. The craft will then sling-shot around Earth and Mars and travel to comet 311P/PANSTARRS in deep space.

Towards a lunar base

Not content with returning the first lunar samples to Earth since the 1970s, China approved three more lunar missions in December, all focusing on the Moon's south pole, where the country is considering building a lunar base.

Chang'e-7, set to launch in 2024, will carry out a detailed survey of the Moon's south pole, including mapping the distribution of ice in its shadowy craters. Chang'e-6 will follow, aiming to bring back polar soil samples. The ice is a treasure trove for scientists, who can use it to study the Moon's history, and for prospectors, who hope to use it as rocket fuel and to supply lunar bases.

Work will also begin on Chang'e-8, which is not scheduled to fly until 2030; this will test "core technologies" for a crewed international lunar research station — the focus of China's lunar programme beyond 2025. Russia and China will sign an intergovernmental agreement on building a research base together "as soon as possible this year", said Wu Yanhua, vice-administrator of the China National Space Administration, at the press conference to launch the white paper. He stressed, however, that the venture was open to all nations.

Wu added that China wants to broaden and deepen international collaboration, including on lunar exploration; on China's space station, Tiangong, which is under construction; and on planetary exploration.

Mars and beyond

China made its first leap into interplanetary space with the Tianwen-1 orbiter, which dropped a lander containing the Zhurong rover on Mars in May. According to the white paper, China will complete research for sending a craft to Mars to sample rocks and return them to Earth. This mission could launch in 2028. (NASA's Perseverance rover collected the first Mars rocks in 2021; see page 18. The agency hopes to bring them back to Earth as part of a joint mission with the European Space Agency (ESA), launching in 2026.)

"Deep space is certainly another area where China sees there are a lot of opportunities."

The white paper also lays out China's plans to eventually probe farther into the Solar System. The next five years will see the completion of key research for a mission to explore Jupiter and its ocean-filled moon system. Press reports suggest that this mission could launch as early as 2029 — meaning that it would join ESA's JUICE and NASA's Europa Clipper mission, scheduled to fly in 2023 and 2024, respectively. "Deep space is certainly another area where China sees there are a lot of opportunities for scientific breakthroughs," says Zhang.

The country has also set its sights on exploring the boundary of the Solar System. China's funding agencies have yet to confirm this, or the Jupiter mission, but "a mention in the plan is certainly helpful", says Zhan Hu, an astronomer at the National Astronomical Observatories in Beijing.

A new Hubble

China also plans to launch a space telescope called Xuntian, whose name means 'survey the heavens'. This will image in the same wavelengths — ultraviolet, visible and infrared — as those used by NASA's Hubble Space Telescope.

Slightly smaller than Hubble, Xuntian will not quite match its predecessor's resolution; but, at any one time, Xuntian will capture a patch of sky 300 times larger. That will allow it to probe a much greater volume of the Universe than Hubble, says Zhan, who works on Xuntian.

Most of Xuntian's first 10 years will be devoted to understanding the history and evolution of the Universe through a wide survey of the sky. The telescope will periodically dock with Tiangong for refuelling and maintenance. Zhan says that the team plans to deliver the telescope by the end of 2023, ready for launch in 2024. "The schedule is very tight," he says.

Spotting gravitational waves in space

China wants to further develop plans to launch a space-based gravitational-wave detector, called Taiji, in the early 2030s. If launched then, it would be the first of its kind. Such a mission would observe lower-frequency waves than those seen by ground-based detectors such as Advanced LIGO, allowing it to detect higher-mass black holes, including those in the early Universe.

But the experiment would be complex: spotting ripples in space-time will mean detecting shifts of just a few trillionths of a metre in the distances between three spacecraft, positioned 3 million kilometres apart in the shape of a triangle.

An initial pilot satellite, called Taiji-1, completed its mission successfully in 2019, and researchers now hope to fly a two-satellite mission in 2024–25 to test the necessary precision technologies. This will "remove all the technical obstacles" for the ultimate Taiji mission, says Yue-Liang Wu, a physicist at the University of the Chinese Academy of Sciences in Beijing.

ESA has for a long time been planning its own gravitational-wave observatory, LISA, and has already flown a successful pathfinder. But LISA is not scheduled to launch until 2037. Together, the two networks could be used to measure the Hubble constant, which describes the expansion of the Universe, with much greater accuracy than ground-based detectors can, say researchers behind the mission.