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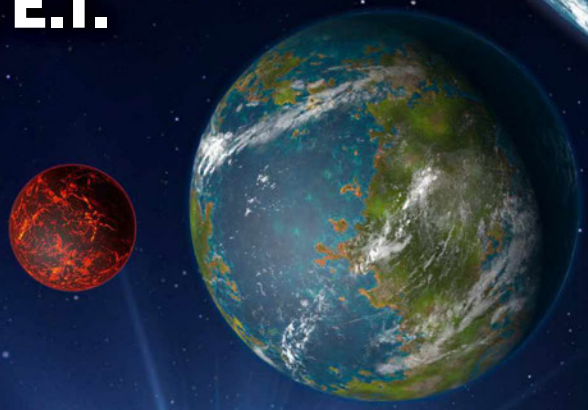

PARTICLE PHYSICS FOR BEGINNERS

THE MISSION TO SAMPLE THE MOON'S MYSTERIOUS FAR SIDE

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Like Chang'e 5 (shown, artist's impression), Chang'e 6 will return lunar surface samples – but this time they'll be from the mysterious far side of the Moon

CHANG'E 6 *journeys to the lunar far side*

China is set to return the first-ever rocks from the Moon's far side. **Jean Deville** and **Blaine Curcio** take a look at what the mission has in store

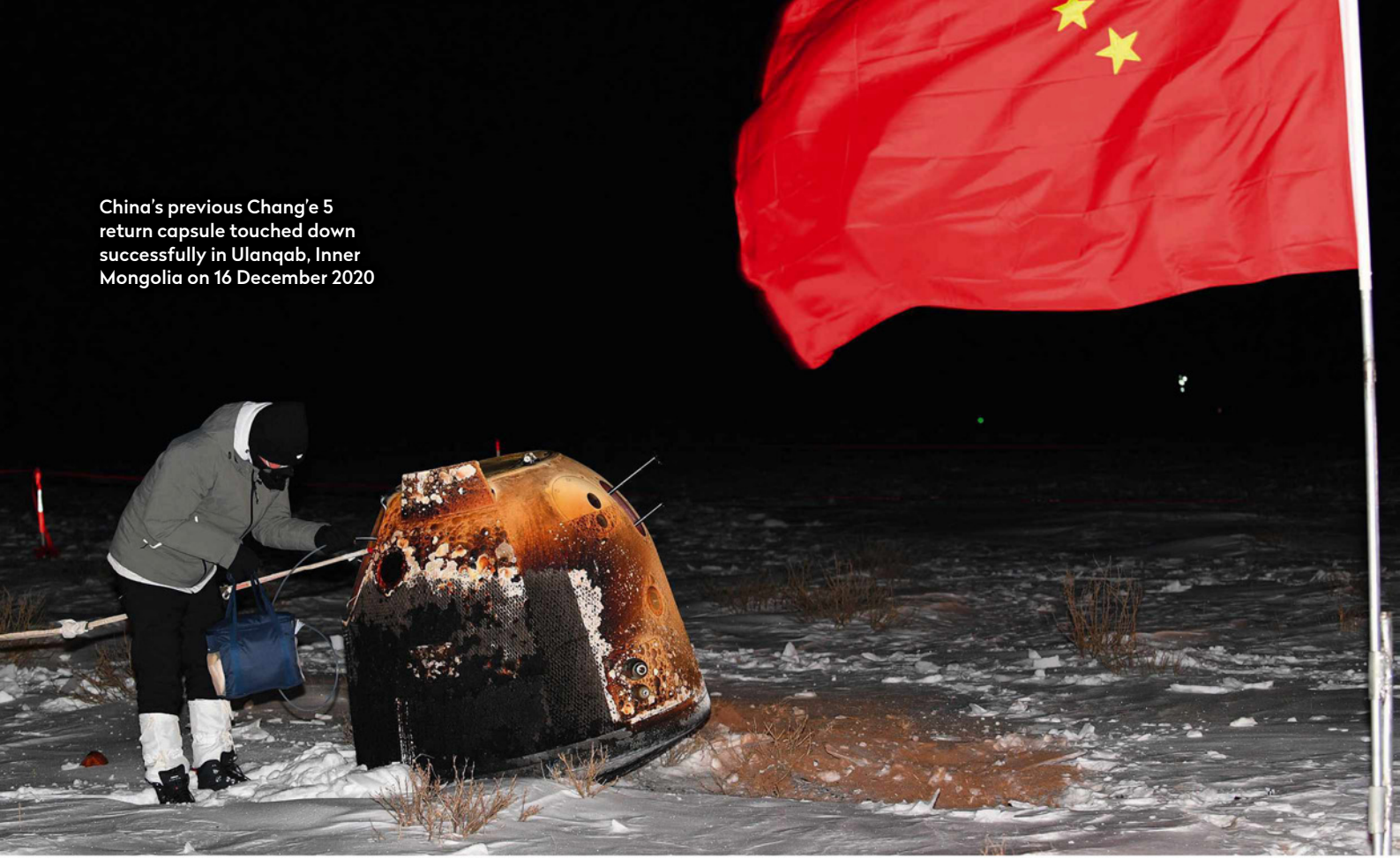
On 16 December 2020, the return capsule of the Chang'e 5 mission landed in China's Inner Mongolia Autonomous Region. It had travelled hundreds of thousands of miles from the Moon, carrying 1,731g (61 oz) of precious lunar dust. Remarkably, this represented the first lunar sample return mission since the USSR's Luna 24 brought back 170g (6 oz) in August 1976. There will be no 44-year wait this time though, as China is planning to launch its next lunar sample-return mission this year, with an expected May launch date.

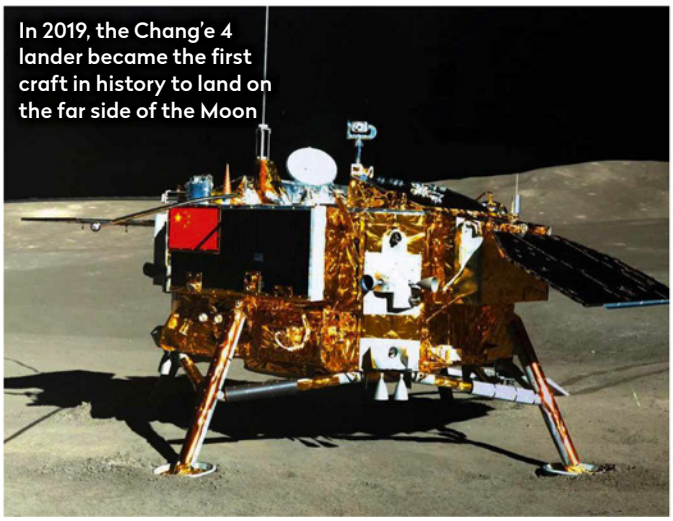
Chang'e 6 is bound for the far side of the Moon and will be humanity's first sample from the region, representing an important symbolic, scientific and possibly strategic win for the rising space power. The mission was originally a back-up for Chang'e 5 and is composed of four independent modules: the lander, the ascender, the orbiter and the return vehicle, with an estimated total mass of 8,200kg (18,077lb). It will launch from the Wenchang Space Launch Centre on China's current most powerful rocket, the Long March 5.

Once Chang'e 6 enters lunar orbit, the lander will separate from the orbiter vehicle and descend to the lunar surface, performing a fully autonomous soft landing in the South Pole–Aitken (SPA) Basin, a 2,500km-diameter (1,550 mile) impact crater on the far side of the Moon. It is understood to be the largest, deepest and oldest crater on the Moon (4.2–4.3 billion years), with an unusual ▶

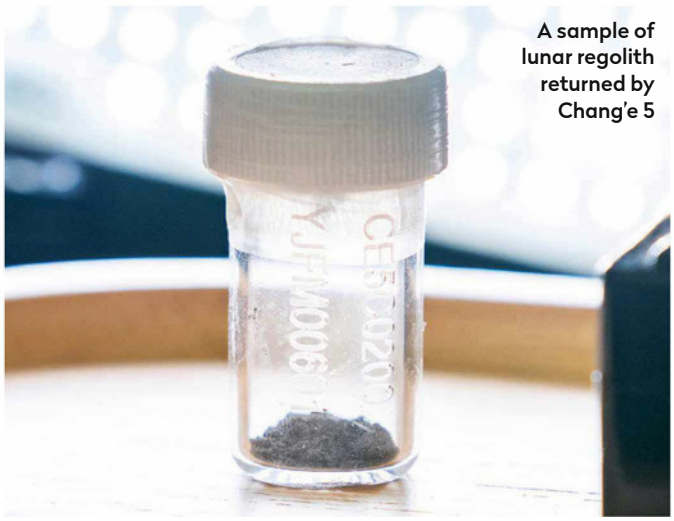
ILLUSTRATION: XINHUA/ALAMY STOCK PHOTO

China's previous Chang'e 5 return capsule touched down successfully in Ulanqab, Inner Mongolia on 16 December 2020





In 2019, the Chang'e 4 lander became the first craft in history to land on the far side of the Moon



A sample of lunar regolith returned by Chang'e 5

▶ geochemical composition that is different from the rest of the lunar surface.

To date, China's Chang'e 4 lander and rover are the only spacecraft to have touched down on the lunar far side. It's been surveyed by several lunar orbiter missions, but as the Soviet and US missions of the '60s and '70s remained on the near side, no samples have ever been retrieved from the region.

The samples Chang'e 6 collects will enable further study of the region's composition, giving scientists a much better understanding of the formation of the Moon. The impact that created the SPA is also believed to have excavated deep into the lunar crust, which could potentially provide insights into the geological composition of the lunar interior.

> ***"China's Chang'e 4 lander and rover are the only spacecraft to have touched down on the lunar far side"***

Once on the surface, the Chang'e 6 lander has a drilling capacity of up to 2m. The lander is expected to scoop up around 2kg (4.4lb) of material (about the same as the previous mission) which it will transfer to the sample-return container using a robotic arm. This will then be stored in the ascender, which will launch from the top of the lander and rendezvous with the orbiter. The samples will then transfer to the return vehicle to head back to Earth. When they are 5,000km (3,100 miles) from Earth, the return vehicle will separate from the orbiter ready for atmospheric re-entry. Parachutes will carry the capsule through its final stages to land in Siziwang Banner, Inner Mongolia.

While the Chang'e 5 mission lasted 22 days, Chang'e 6's duration is expected to be 53 days,

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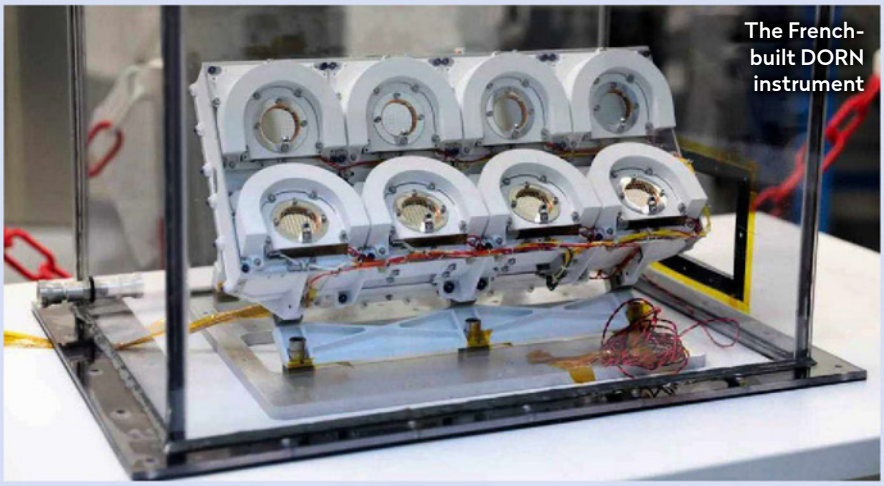
International instruments

Collaboration is an increasingly important aspect of lunar exploration



The French-built DORN instrument

In April 2018, the China National Space Administration put out a call for international partners to submit proposals for experiments Chang'e 6 could carry to the Moon. A total of 10kg (22lb) of payload mass was available and the following four were selected.

DORN (Detection of Outgassing Radon)
An alpha spectrometer that will study the transportation dynamics of radon and other elements between the lunar soil, known as regolith, and the exosphere, the Moon's extremely thin atmosphere. The instrument is being provided by the French Research Institute of Astrophysics and Planetology (IRAP).

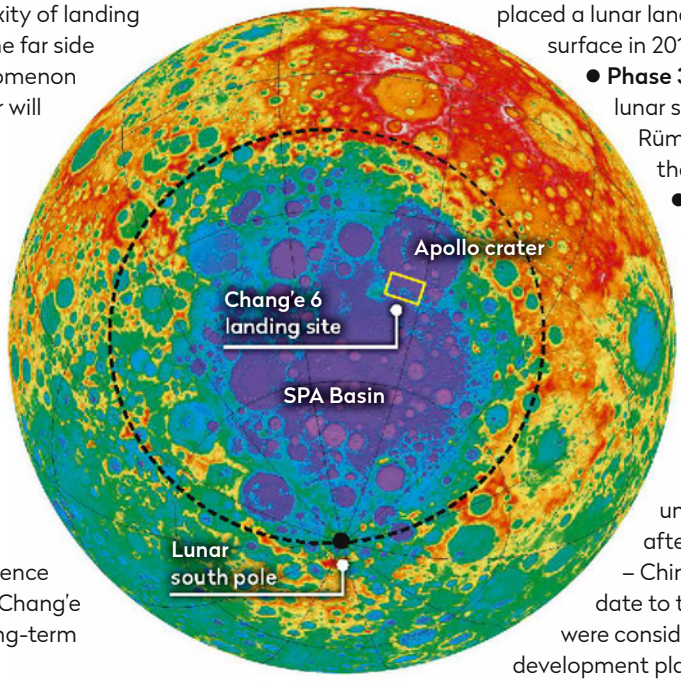
INRRI (INstrument for landing – Roving laser Retroreflector Investigations)
INRRI is a passive laser retro-reflector that will be available for future lunar missions to use for optical range-finding. It is being built at the SCF Lab in Rome, Italy.

NILS (Negative Ions on Lunar Surface)
A mass spectrometer to measure the negative ions that are emitted from the lunar surface due to its interaction with the solar wind. The NILS instrument is the brainchild of the Swedish Institute for Space Physics.

ICUBE-Q
A cubesat that aims to detect traces of ice on the lunar surface. It is being constructed by the Islamabad Institute of Science and Technology in Pakistan, with co-operation from Shanghai Jiao Tong University.

largely due to the added complexity of landing on the far side of the Moon. As the far side never faces Earth, due to a phenomenon known as tidal locking, the lander will communicate with the Chinese teams on the ground using the Queqiao-2 relay satellite.

The nascent lunar Queqiao satellite constellation is a key part of China's long-term lunar plans. It will support the upcoming Chang'e 7 and 8 missions as well as Chang'e 6, and helps pave the way for the upcoming International Lunar Research Station (ILRS), a joint Chinese–Russian megaproject planned for the 2030s, which will aim to establish a long-term presence on the lunar surface. This makes Chang'e 6 an important part of China's long-term space programme.



▲ **The far side: Chang'e 6 is aiming for the SPA Basin where it will land on the southern edge of Apollo crater**

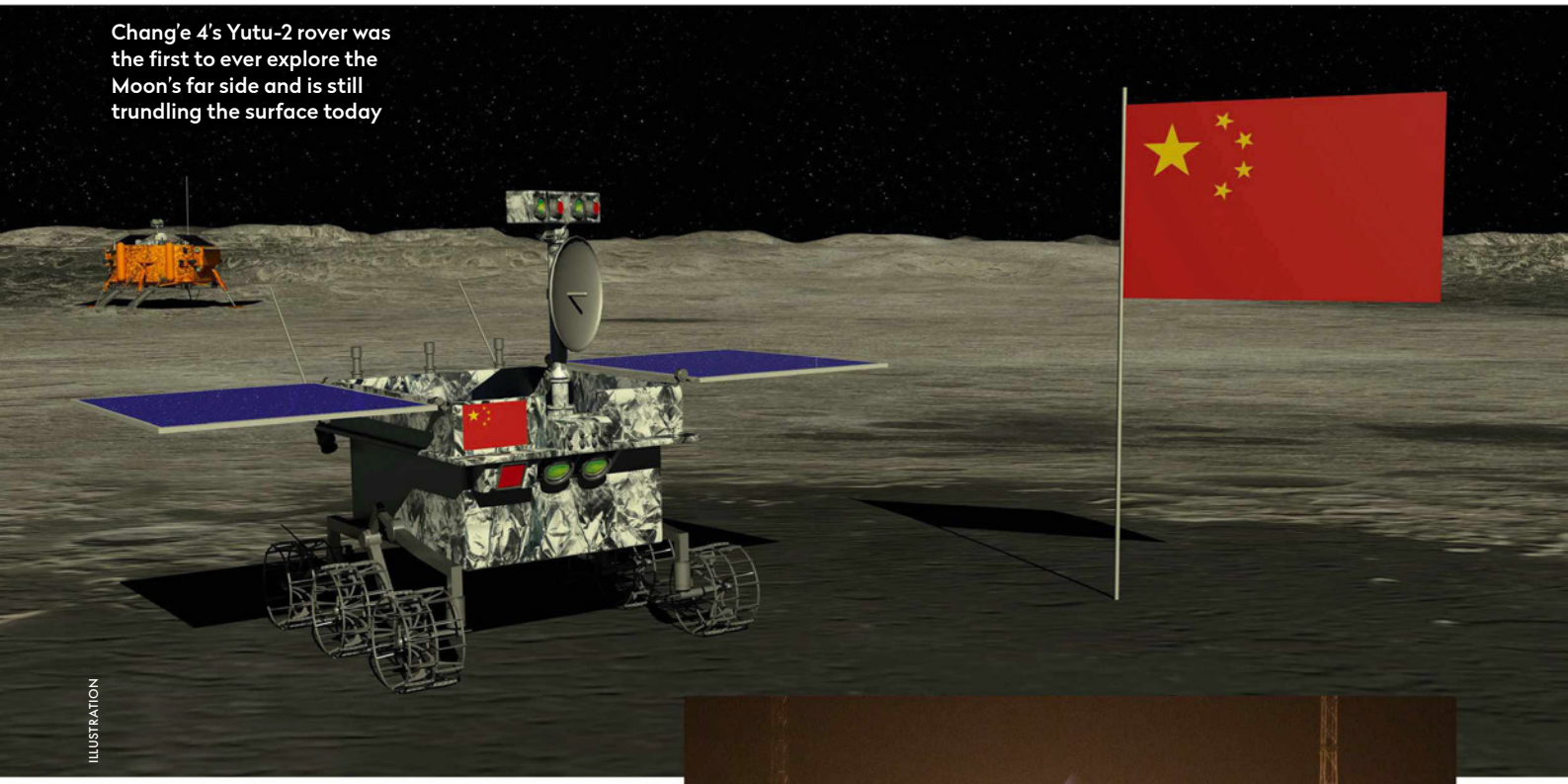
The bigger picture

China's lunar exploration efforts are managed by the China Lunar Exploration Program (CLEP), a sub-unit of the China National Space Administration (CNSA). The programme consists of four phases:

- **Phase 1:** Chang'e 1 and 2, which reached lunar orbit in 2007 and 2010, undertaking mapping and remote sensing missions.
- **Phase 2:** Chang'e 3 and 4 (plus Queqiao-1), which placed a lunar lander and rover on the Moon's surface in 2013 and 2018.
- **Phase 3:** Chang'e 5, which collected lunar samples in the Moon's Mons Rümker area in 2020 and returned them to Earth.
- **Phase 4:** Chang'e 6, 7 and 8, which will aim to develop technologies for long-term exploration of the Moon, and prepare for China's future lunar station, the ILRS. The last two missions are expected to fly in 2026 and 2028 respectively.

Despite not formally starting until 2004 – more than 30 years after the US's first Apollo missions – China's lunar exploration interests date to the early 1990s, when proposals were considered under a national high-tech development plan known as Program 863. But lunar plans only formally began after China orbited their first astronaut, Yang Liwei, in 2003. Since then, the country has seen five consecutive successful missions, each helping to "cross the river by feeling the stones" – a Chinese phrase for navigating a complex situation by small, measured steps.

With ever more ambitious and higher-profile missions, China has built up a world-class space infrastructure, becoming a highly regarded potential partner for space programmes across the world. But any country with a substantial lunar programme ▶



Chang'e 4's Yutu-2 rover was the first to ever explore the Moon's far side and is still trundling the surface today

ILLUSTRATION

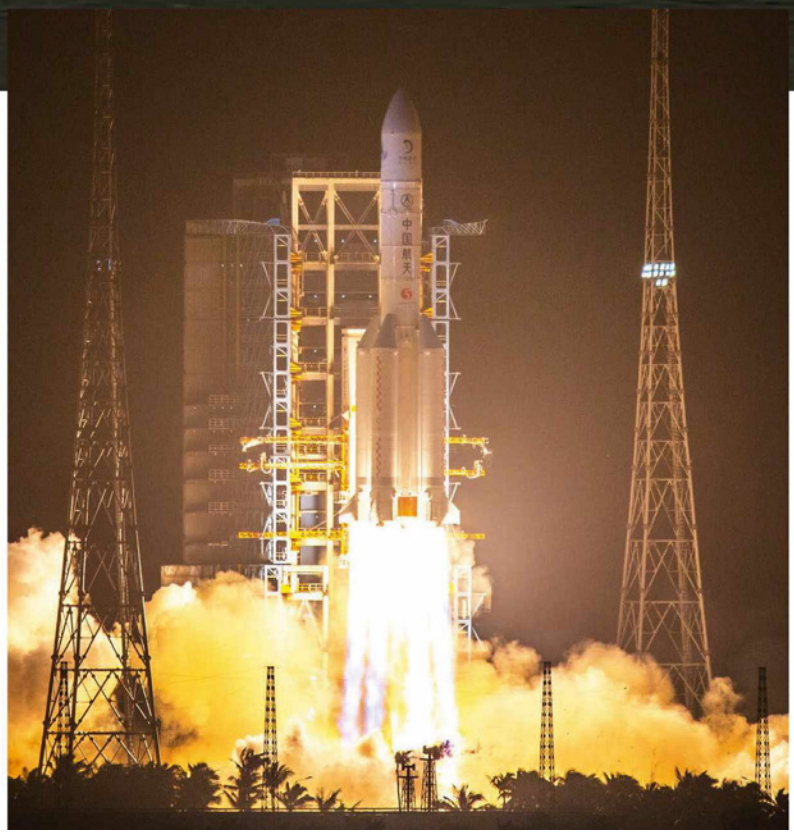
▶ needs good reasons for embarking on such a programme. Lunar missions cost billions of dollars, present a significant risk and occupy many of a country's brightest technical minds. China's reasons are sometimes opaque but seemingly manifold, including scientific progress, resource utilisation, international diplomacy and soft power.

Why the Moon matters

Scientific advancements form a pivotal aspect, with a focus on advancing the understanding of lunar geology, geochemistry and topography. These in turn can provide valuable information on the early history of the Solar System and Earth. The Moon's proximity to Earth is also a key enabler for China to develop space-based technologies in areas such as biology, medicine and astronomy.

Resource exploration is another key driver of China's lunar endeavours. China is very interested in the potential presence of ice in the permanently shaded regions at the Moon's poles – an interest shared by other major space powers. This common interest is reflected in recent and upcoming missions from the US, China, India and others targeting the lunar south pole. Notably, ice can be harvested for water, oxygen and hydrogen, the latter two serving as a rocket propellant combo. The Moon is also known to have noteworthy concentrations of helium-3, a rare resource crucial for nuclear fusion.

Additionally, China envisions the Moon as a potential source for substantial economic development. While obviously to be taken with a grain of salt, in late 2019, prominent Chinese space industry figure Bao Weimin proposed the creation of a new space economy he dubbed "the Earth–Moon Economic Zone", projecting an economic output of up to $10 trillion by 2050.



▲ Chang'e 6 will blast off from Wenchang on a Long March 5 rocket, just like Chang'e 5 in 2020

As for diplomacy and soft power, several previous Chang'e missions have featured instruments from international partners, and Chang'e 6 will have four scientific instruments on board from France, Italy, Sweden and Pakistan, adding a diplomatic dimension to the missions.

Longer term, the joint Chinese–Russian lunar station, the ILRS, is being touted as an alternative to the US-led Artemis programme. As of March 2024, six

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The Queqiao lunar constellation

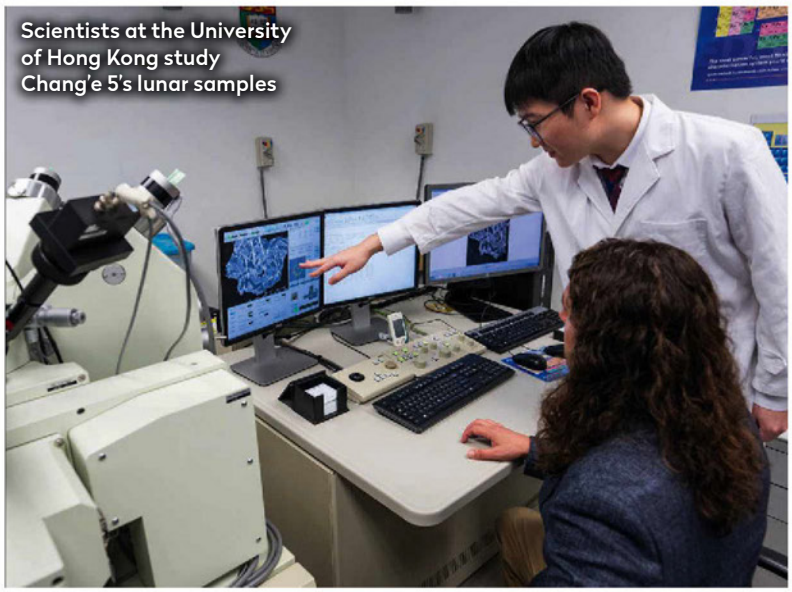
Satellites orbiting the Moon are key to operations on the far side

One of the biggest problems with landing a mission on the lunar far side is that spacecraft can't communicate directly with Earth from the surface, as the Moon itself blocks radio signals. To resolve this, China uses relay satellites to convey signals from the surface back to Earth.

The first of these, Queqiao, launched on 20 May 2018. It is in a halo orbit around the Earth–Moon L2 Legrange point, which is directly behind the Moon with respect to Earth. Queqiao helped support the Chang'e 4 mission, the first ever to land on the lunar far side when it touched down within the Von Kármán crater in January 2019. The Queqiao-2 relay satellite, launched in March 2024, is a larger craft weighing 1,200kg (2,645lb). Queqiao-2 was placed in frozen elliptical lunar orbit, meaning it can support missions across the whole of the Moon.

A future constellation of Queqiao satellites has also been proposed, which could provide not just communications but also navigation and remote-sensing services. Details are still largely unknown, but it's thought the first phase, Queqiao v1.0, could be in place by 2030. It would consist of Queqiao-2 and the future Queqiao-3, as well as the Tiandu-1 and Tiandu-2 test satellites which would fly in formation to test lunar satnav and communication technologies.

Queqiao v2.0, comprising 16 satellites, would then be deployed between 2030 and 2040, and would enable improved remote-sensing capabilities, higher bandwidth (1–10 GB/s) and better positioning resolution. The final generation, deployed in the 2040s, would have even higher performance and could also act as interplanetary relay stations.


Scientists at the University of Hong Kong study Chang'e 5's lunar samples

countries in addition to China and Russia had signed up, namely South Africa, Pakistan, Egypt, Belarus, Venezuela and Azerbaijan.

The samples themselves will also provide opportunities for international collaboration. When Chang'e 5's samples were returned to Earth, the Chinese gave domestic institutions initial priority access to them before granting access to international partners 2.5 years later. It's expected the Chang'e 6 samples will be treated the same way.

The Chang'e 5 and 6 samples give China an important bargaining chip in international space diplomacy, with NASA having applied to receive Chang'e 5 samples in late 2023 after receiving permission from the US government to do so. No doubt they and other institutions will be even more eager to get their hands on the lunar rocks Chang'e 6 brings back from the lunar far side, so they can take the first-ever look at this mysterious world that is usually hidden from our view.

Blaine Curcio (left) and **Jean Deville** (right) are co-founders of Dongfang Hour, a website (**dongfanghour.com**) and YouTube channel focused on China's space sector