This Long March-7 rocket carried a cargo craft to the Tiangong-2 space lab in April.

VCG/GETTY

RISING STAR

Science is reaping the benefits of China's investment in space.

BY JANE QIU

Time seems to move faster at the National Space Science Center on the outskirts of Beijing. Researchers are rushing around this brand-new compound of the Chinese Academy of Sciences (CAS) in anticipation of the launch of the nation's first X-ray telescope. At mission control, a gigantic screen plays a looping video showcasing the country's major space milestones. Engineers focus intently on their computer screens while a state television crew orbits the room with cameras, collecting footage for a documentary about China's meteoric rise as a space power. The walls are festooned with motivational slogans. "Diligent and meticulous," says one. "No single failure in 10,000 trials," encourages another.

For director-general Wu Ji, this 19.4-hectare, 914-million-yuan (US$135-million) campus represents the coming of age of China's space-science efforts. In the past few decades, Wu says, China has built the capacity to place satellites and astronauts in orbit and send spacecraft to the Moon, but it has not done much significant research from its increasingly lofty vantage point. Now, that is changing. "As far as space science is concerned," he says, "we are the new kid on the block."

China is rushing to establish itself as a leader in the field. In 2013, a 1.2-tonne spacecraft called Chang'e-3 landed on the Moon, delivering a rover that used ground-penetrating radar to measure the lunar subsurface with unprecedented resolution. China's latest space lab, which launched in September 2016, carries more than a dozen scientific payloads. And four additional missions dedicated to astrophysics and other fields have been sent into orbit in the past two years, including a spacecraft that is conducting pioneering experiments in quantum communication.

These efforts, the work of the CAS and other agencies, have made an impact well beyond the country's borders. "The space-science programme in China is extremely dynamic and innovative," says Johann-Dietrich Wörner, director-general of the European Space Agency (ESA) in Paris. "It's at the forefront of scientific discovery." Eagerly anticipated missions in the coming decade include attempts to bring back lunar samples, a joint CAS–ESA project to study space weather and ground-breaking missions to probe dark matter and black holes.

But despite the momentum, many researchers in China worry about the nation's future in space science. On 2 July, a Long March-5 rocket failed during the launch of a communications satellite, raising concerns about an upcoming Moon mission that will use a similar vehicle. And broader issues cloud the horizon. "The international and domestic challenges are formidable," says Li Chunlai, deputy director at the CAS's National Astronomical Observatories in Beijing and a senior science adviser on the country's lunar programme. China is often sidelined in international collaboration, and in recent years it has had to compete with the United States for partners because of a US law that prohibits NASA from working with China. Within China, the government has not conducted strategic planning for space science or provided long-term financial support. "The question is not how well China has been doing," says Li. "But how long this will last."

REACHING FOR THE MOON

China's entry into the space age started with a song. In 1970, the country's first satellite transmitted the patriotic tune 'The East is Red' from low Earth orbit. But it was only after the cultural revolution ended in 1976 that the nation made serious progress towards establishing a strong presence in space. The first major milestone came in 1999 with the launch of Shenzhou-1, an uncrewed test capsule that marked the start of the human space-flight programme. Since then, the country has notched up a series of successes, including sending Chinese astronauts into orbit and launching two space labs (see 'Earth orbit and beyond').

"China's space programme has made tremendous advances in a short period of time," says Michael Moloney, who directs boards covering aerospace and space science at the US National Academies of Sciences, Engineering, and Medicine in Washington DC. And science has progressively become a bigger part of missions run by both the China National Space Administration (CNSA), which governs lunar and planetary exploration, and the China Manned Space Agency. The country's newest space lab, Tiangong-2, for example, hosts a number of scientific payloads, including an advanced atomic clock and a $3.4-million detector called POLAR for the study of γ-ray bursts — blasts of high-energy radiation from collapsing stars and other sources.

The country's first lunar forays — orbiters launched in 2007 and 2010 — were more engineering demonstrations than scientific missions, but that changed with the first lander, Chang'e-3. The mission made China the third nation to accomplish a soft landing on the Moon. More importantly, Chang'e-3 touched down in an area that had never been studied up close. Radar measurements and geochemical analyses unveiled a complex history of volcanic eruptions that could have happened as recently as 2 billion years ago[1]. "It has really helped to bridge the gap in our understanding of the Moon's past and deep structure," says study leader Xiao Long, a planetary geologist at the China University of Geosciences in Wuhan.

> **"AS FAR AS SPACE SCIENCE IS CONCERNED, WE ARE THE NEW KID ON THE BLOCK."**

The results have captured the attention of planetary scientists in other countries. "There is an urgent need to determine the precise age and composition of the Moon's youngest volcanism," says James Head, a specialist in planetary exploration at Brown University in Providence, Rhode Island. This might soon be possible. As early as December, the Chang'e-5 spacecraft will launch on a mission to return samples from near Mons Rümker, a region known to host volcanic rocks much younger than those obtained from the Apollo landing sites. "It would be a fantastic addition to lunar science," Head says.

FIVE YEARS

The rising fortunes of Chinese space science have come in part from efforts by the CAS, which worked through the 2000s to convince China's government to boost the scientific impact of its missions. The academy's efforts were eventually rewarded with a pot of money: the five-year Strategic Priority Program on Space Science kicked off in 2011 and provided $510 million for the development of four science satellites.

One of the missions that has yielded early results — and garnered worldwide attention — is the $100-million Quantum Experiments at Space Scale (QUESS) mission. The spacecraft launched in August 2016 and has been testing a peculiar phenomenon called entanglement, in which the quantum states of particles are linked to each other even if the particles are far apart. Last month, the QUESS team reported that it had used the satellite to beam a pair of entangled photons to two ground stations spaced 1,200 kilometres apart[2] — far exceeding an earlier record of 144 kilometres (ref. 3).

The team is also using the satellite to test the possibility of establishing a quantum-communication channel between Graz, near Vienna, and Beijing. The aim is to transmit information securely by encrypting it with a key encoded in the states of photons. "If successful, a global quantum-communication network will no longer be a science fiction," says Pan Jian-wei, a physicist at the CAS's University of Science and Technology of China in Hefei and the mission's principal investigator.

Researchers are also expecting great things from the $300-million Dark Matter Particle Explorer (DAMPE). The detector, which launched in 2015, is the most cutting-edge equipment for picking up high-energy cosmic rays, says Martin Pohl, an astrophysicist at University of Geneva in Switzerland and a co-principal investigator of the mission.

DAMPE's data could help to determine whether a surprising pattern in the abundance of high-energy electrons and positrons — detected by the Alpha Magnetic Spectrometer (AMS) aboard the International Space Station — comes from dark matter or from astronomical sources such as pulsars, says Pohl, who also works on the AMS. Because DAMPE is more sensitive than the AMS to high-energy particles, Pohl says, it "will make a significant contribution".

SCIENCE FOR ALL

The dark-matter and quantum missions launched just before the CAS's space-science funding expired. Scientists, including Wu, had to battle for continued support. The Chinese government has lately prioritized applied research, and it took intense lobbying for the better part of 2016 before researchers convinced the government to allocate an additional $730 million to the CAS for space science over the next five years. "It was not without a fight," Wu says. "But we've managed to pull it off."

The new plan, which began this year, funds a number of missions slated for launch in the 2020s, including China's first solar exploration mission and a remote-sensing spacecraft to study Earth's water cycle.

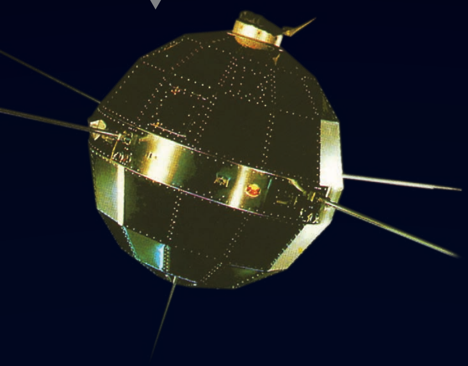
The CNSA and the China Manned Space Agency have also been ramping up their space-science efforts. One source of excitement is a $440-million X-ray telescope led by the CNSA, called Enhanced X-ray Timing and Polarimetry (eXTP). Planned for launch by 2025, the mission is being financed in part by European partners and involves hundreds of scientists from 20 countries. It is designed to study matter under extreme conditions of density, gravity and magnetism that can be found only in space — in the interior of neutron stars or around black holes, for instance.

The most innovative aspect of the satellite is its ability to simultaneously measure with high precision the timing, energy distribution

EARTH ORBIT AND BEYOND

After achieving major space-flight milestones, China has put more support behind missions with scientific aims.

1970 China launches its first satellite, Dongfanghong-1.



NSSC

1999 The launch of the uncrewed Shenzhou-1 test capsule kicks off China's human space-flight programme.

2003 Astronaut Yang Liwei flies aboard *Shenzhou-5* on China's first crewed mission to orbit.

2007 China's first lunar orbiter, Chang'e-1, is launched.

2011 China's first space lab, Tiangong-1, reaches orbit.

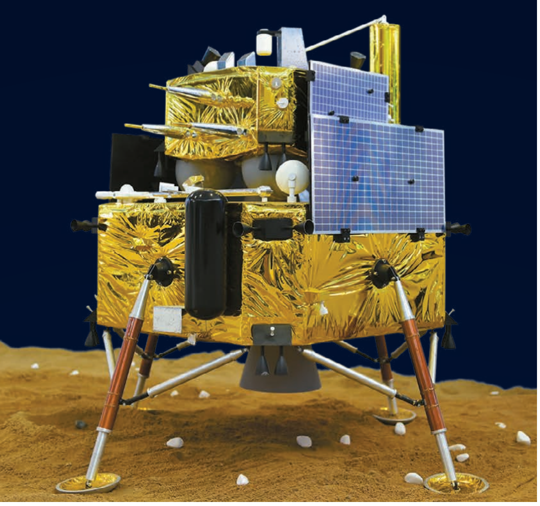
2013 The lunar spacecraft Chang'e-3 makes the country's first soft landing on the Moon.

2015 The Dark Matter Particle Explorer (DAMPE) reaches Earth's orbit.

2016 The Tiangong-2 space lab launches, carrying 14 science experiments.

2017 China launches its first X-ray telescope, the Hard X-Ray Modulation Telescope (HXMT).

2017 China plans to launch Chang'e-5 on a mission to bring lunar samples to Earth.



LIANG XU/XINHUA VIA ZUMA WIRE

and polarization of X-ray signals, which will provide insight into a range of X-ray sources, says co-principal investigator Marco Feroci, an astrophysicist at the Institute of Space Astrophysics and Planetology in Rome. eXTP will also carry a wide-field telescope to hunt for unusual, transient signals. "Once it finds a potentially interesting source, all the other instruments will be zoomed in that direction," says Zhang Shuangnan, an astrophysicist at the CAS's Institute of High Energy Physics in Beijing, who is leading the mission. "It's the total weapon for X-ray astronomy."

Work is also progressing on projects led by the China Manned Space Agency. One is a dark-matter detector that has 15 times the sensitivity of DAMPE; it's set to be installed on China's permanent space station, which is slated for completion by 2022. There are also plans for a $730-million optical telescope to orbit near the space station. With a field of view 300 times that of the Hubble telescope, it will produce survey data that could be ideal for studying dark matter and dark energy as well as hunting for exoplanets, says Gu Yidong, a physicist at the CAS's Technology and Engineering Center for Space Utilization in Beijing and a senior science adviser to the China Manned Space Agency.

INTERNATIONAL TIES

Such projects suggest that collaboration is strengthening between the CAS and China's other agencies involved with space. And a similar spirit is reflected abroad. China's space programme "has become increasingly confident and outward looking", says Wörner. In the past, announcements were made only after a mission was successful; now, China routinely broadcasts launches as they happen. And Chinese scientists are increasingly reaching out to their international colleagues, building ties through small-scale partnerships.

Most major CAS-led missions have European partners, with collaborations initiated by researchers on both sides. But ESA hopes to establish high-level cooperation with the rising space power. In early 2015, ESA and the CAS issued a call for proposals for space-science missions. They selected a project called Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE), to be led jointly and funded with $53 million from each group. "The agencies work intimately together at every stage of the development," says Wu.

ESA and China collaborated more than a decade ago on a project called Double Star to study magnetic storms, but it was a China-led mission. Through SMILE, the agencies are testing a new, more intimate cooperation model. "It's about building trust and bridges, so we could better understand each other," says Fabio Favata, head of strategy planning and coordination at ESA. "Hopefully, this will open the way for larger-scale cooperation in the future."

A nation that is notably absent from China's current list of collaborators is the United States. In the past, China contributed key components to NASA missions. But NASA is now forbidden from such collaboration by a US law passed in 2011, and as a result China is excluded from participation in the International Space Station. On board is a product of earlier collaboration between the United States, China and a number of other countries — the AMS.

Representatives from NASA and Chinese agencies still visit each other regularly. But with no official cooperation possible, there may be some inevitable replication of effort. In March, STROBE-X (Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays) — a project similar to China's eXTP mission — was selected by NASA for further study. STROBE-X could launch by 2030, some five years after eXTP. "Having two very similar missions at the same time is not ideal," says Colleen Wilson-Hodge, an astrophysicist at NASA's Marshall Space Flight Center in Huntsville, Alabama, and a member of the STROBE-X team. "I wish there were a way we could all work together rather than competing with each other."

MOVING FORWARDS

For China's space scientists, however, the main challenge is to convince their own government of the need for long-term investment. Zhang, the leader of several astrophysics missions including eXTP, refers to the situation as "a constant state of *zhaobu baoxi*", which translates as "not knowing where the next meal will come from". "We'll be safe for another five years," he says. "But nobody knows what will happen afterwards."

Feats of engineering and exploration still get priority over science. The Chinese space station, for instance, has a budget of $14.5 billion. But even though Chinese President Xi Jinping has said that the station will be China's national laboratory in space, there is no dedicated fund for the development of its scientific payloads. The station might support science as Tiangong-2 does, providing power and communications to various experiments. But there is also the danger, Zhang says, that "it will be a house without furniture".

At China's sprawling National Space Science Center, the furniture is new, and the air still smells of fresh paint. Having secured the next bout of funding, Wu looks relaxed as he settles into a big leather armchair behind his desk. He acknowledges the institutional flaws but is optimistic about the future. "So far, so good," he says, glancing at the satellite models that line his shelves. "We can't expect things to change overnight." ■

Jane Qiu *is a freelance writer based in Beijing.*

1. Xiao, L. *et al. Science* **347,** 1226–1229 (2015).
2. Yin, J. *et al. Science* **356,** 1140–1144 (2017).
3. Ursin, R. *et al. Nature Phys.* **3,** 481–486 (2007).