

# Hitting the target on Mars

A team of scientists in Hong Kong helped the nation with its first successful mission to Mars by picking the ideal landing site for the probe's lander spacecraft. **Chen Zimo** reports from Hong Kong.



In front of Wang Yiran, a postdoctoral fellow at Hong Kong Polytechnic University, was a set of black-and-white photographs of a desolate desert — nothing but rocks, dust and craters. China's Tianwen 1 lander should have just landed in this desert on Mars. The question for her was: Where was its exact location on a planet about half the size of Earth?

The set of images was taken by the Tianwen 1 lander during its nine-minute touchdown on Mars in May and had just been received by the China National Space Administration in Beijing. However, whether the Tianwen 1 had landed successfully had yet to be confirmed or declared, as the scientists and technicians had yet to locate the lander.

The lander could be anywhere near its target landing site, which was chosen with input from Wang and her colleagues — a 20-strong team of scientists led by Professor Wu Bo in the Department of Land Surveying and Geo-Informatics at PolyU.

The team, at the invitation of the China Academy of Space Technology, had been responsible for analyzing the safest site on Mars to land the spacecraft. Such a site needed to be the flattest area with the gentlest slope. The team's analysis was vital as it could make or break the mission to the Red Planet because there was no ground control during the landing, as the distance between Earth and Mars make it impossible to control the spacecraft's descent in real time via radio signals. The event was described as "nine minutes of terror".

Wu's team stood out during the mission with their innovative topographic mapping and geomorphological analysis techniques as well as experiences. They had helped mapping and evaluating landing sites on the moon for China's Chang'e 4 lander in 2019 and the Chang'e 5 lander in 2020. The latter also carried back lunar surface samples for the first time in 44 years.

The Tianwen 1 project comprised an orbiter, a lander and a rover that was named after China's god of fire — Zhurong. The project started in 2016 and the spacecraft was launched on July 23, 2020.

Upon joining the mission, the team was prepared for any unexpected situation. The mission's research area was much larger than that of a lunar exploration, and there could be interference from the Martian atmosphere.

Wang was the only member of the PolyU team to work alongside the national astronautic scientists in Beijing for the whole project. Other team members, mainly graduates, doctoral and postdoctoral students, had to remain in Hong Kong due to the COVID-19 travel restrictions between the Hong Kong Special Administrative Region and the Chinese mainland.

Wang arrived in Beijing soon after the probe entered Mars orbit in February. Various scientific findings of Mars, captured by advanced cameras and spectrometers on the spacecraft, were sent to Beijing. After receiving the findings, Wang had to transmit them back to her colleagues in Hong Kong for analysis. She also represented the

Hong Kong team at meetings with national astronautic scientists in Beijing.

Besides the pictures captured by the Tianwen 1, the team's previous discovery also helped find the landing area. Since 2016, the team has been doing global analysis on the Martian surface. Through the analysis, Wu and his team chose a plain, known as Utopia Planitia in the northern Martian hemisphere. It was located within the latitude ranging from 5 to 30 degrees north on Mars, sunny, low in elevation and flat in terrain for landing and operations.

The team's first major worry was the weather on Mars. The planet's notorious giant dust storms were looming as the hemisphere entered summer. The storms would block the sunlight that powers the spacecraft and disrupt communications with Earth. In June 2018, horrific weather put down the United States' Opportunity rover, which did not respond to any signals before the National Aeronautics and Space Administration stopped trying in February 2019. So the Hong Kong team was on a very tight schedule — they had only about six weeks to conduct a thorough survey of the initial targeting landing zone of 12,600 square kilometers of the plain, which is 11 times the size of Hong Kong, or two-thirds that of Beijing. The image files and data piled up reached 100 gigabytes.

## New algorithms developed

Technical challenges followed. The planet's atmosphere, although much thinner than Earth's, still affects the reflection of light and blurs the images, and the algorithms the team had at that time could not meet the requirements for the operation.

To reduce the interference of the Martian atmosphere in the images, Morgan Liu Wai-chung, another postdoctoral fellow in the Hong Kong team, used his expertise to improve the algorithm. The new algorithm could reconstruct the 2D images sent back by the probe into 3D models to reproduce the scene of the Martian surface despite atmospheric interference. The algorithm was also able to reconstruct detailed topography from a single image or multiple images captured by cameras.

Moreover, Wang and her teammates optimized the AI-based algorithms that can tell craters and rocks apart in high-resolution images. The previous algorithms, although they had been used in lunar explorations, were not exactly suitable for the Martian surface as craters on Mars had worse weathering than those on the moon due to the Red Planet's atmosphere.

The improved algorithms developed by PolyU greatly accelerated the laborious toil, which turned out to cover 670,000 craters, more than 2 million rocks, and hundreds of volcanic cones over the target landing region. Without the new method, the tasks would have taken years to complete. In 2013, it took a dozen PolyU students more than three months to hand-pick all the potential obstacles within a much smaller landing area of the Chang'e 3.

Pressed for time, the entire team worked as if it were in a relay race. "Everybody was forever ready to answer calls and to take over the work," Wang said.

During the mission, Liu slept only four hours a day, the least among the team members. But his hard work paid off as Liu managed to come up with one of the world's most accurate and detailed models of the targeting landing zone on Mars at the moment. The high-resolution cameras on board Tianwen 1, self-developed by China, with a resolution of about 0.7 meters — 10 times that of the cameras of the Chang'e 2 — also contributed to Liu's work.

The team's stress peaked the night before the due date. The final data amount was so overwhelming that the next-to-last researcher in the relay race stayed up all night for the outcome. Others volunteered to stay in the lab to lend a helping hand when needed.

When Wang, the last team member to pass on the baton, put together the results and submitted them to Wu the next morn-

ing, the professor was left with only three hours to analyze all the results and present them to the authorities in Beijing.

Based on the data from the team, Wu recommended to Beijing the three safest oval-shaped areas within the targeting landing zone. He analyzed the pros and cons of the options, using data, diagrams, and clear logic to make the case.

"Neat and deft. Well done," Wang heard a senior official on the spot commenting on their plan. Everyone seemed satisfied.

"I'm aware that a scientist's sturdy strength, accumulated over decades, can be fully projected under such an extreme situation," Wang said.

Beijing picked area No 16 — the least risky one found by the team. It signaled the team had accomplished its mission. Wang, however, had to wait for orders until the big day — the landing.

Upon receiving the first group of images sent back to Earth after the landing, Wang, with her familiarity with the iconic impact craters, instantly recognized the locations of the craters shown in the picture. Her contribution had helped to significantly narrow down the search for the lander using the cameras on the Tianwen 1 orbiter.

Wang's hitting the target was no coincidence. When she was assigned to help locate the lander, the demanding 27-year-old scientist trained herself to memorize the features of the entire landscape, until each crater became as familiar as the "faces of friends".

Then came the big announcement from the country's space agency: "The lander of China's Tianwen 1 mission landed successfully on Mars in the early morning of May 15". The coordinates of the landing site were 25.1 degrees north and 109.9 degrees east.

Pulling off the orbiting, landing and roving on the Red Planet with just one mission marked a milestone in China's deep-space planetary exploration. It made China the second country after the United States to land and operate a rover on Mars.

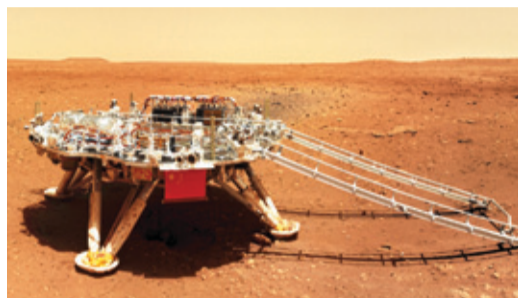
## Eyeing new heights

Back in Hong Kong, Wu and his team members were overjoyed. "The Tianwen 1 mission is a mega project, and we're only a small part of the efforts of thousands of people in supporting the mission's accomplishments. All of my team members were fully dedicated to the undertaking over the past months," he said.

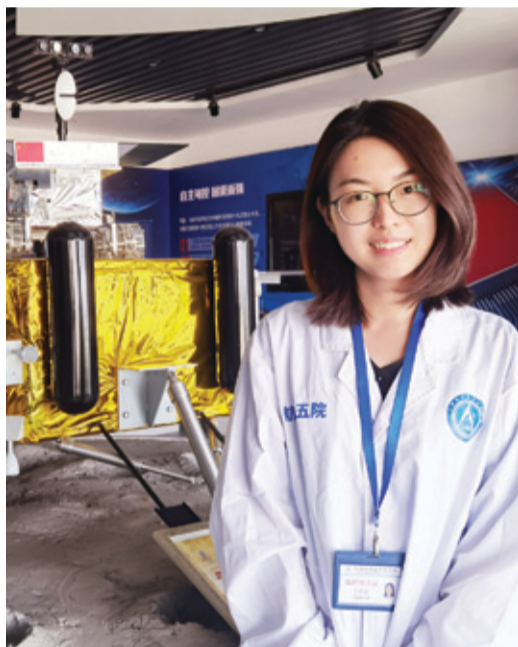
The Hong Kong research team was also impressed that the Tianwen 1 lander ended up landing right near the center of the area — an engineering feat that turned their findings into reality.

Their jubilation and pride were shared by the PolyU staff and Hong Kong's scientific academia. Since 2004, scientists from the university have participated in the nation's space programs. Along with Wu's team, another PolyU team, led by Professor Yung Kai-leung, associate head of the Department of Industrial and Systems Engineering, developed a surveillance camera fixated on the Tianwen 1 lander. It was set to monitor the landing and photograph the surrounding Martian environment.

The surveillance camera weight of 390 grams — the equivalent of two iPhone 11s — would have to withstand an impact force about 6,200 times the force of Earth's gravity. "I'm so glad it did not break into parts," Yung said in jest at a press confer-



The photo released by the China National Space Administration shows the landing platform of China's first Mars rover Zhurong. PHOTOS PROVIDED TO CHINA DAILY



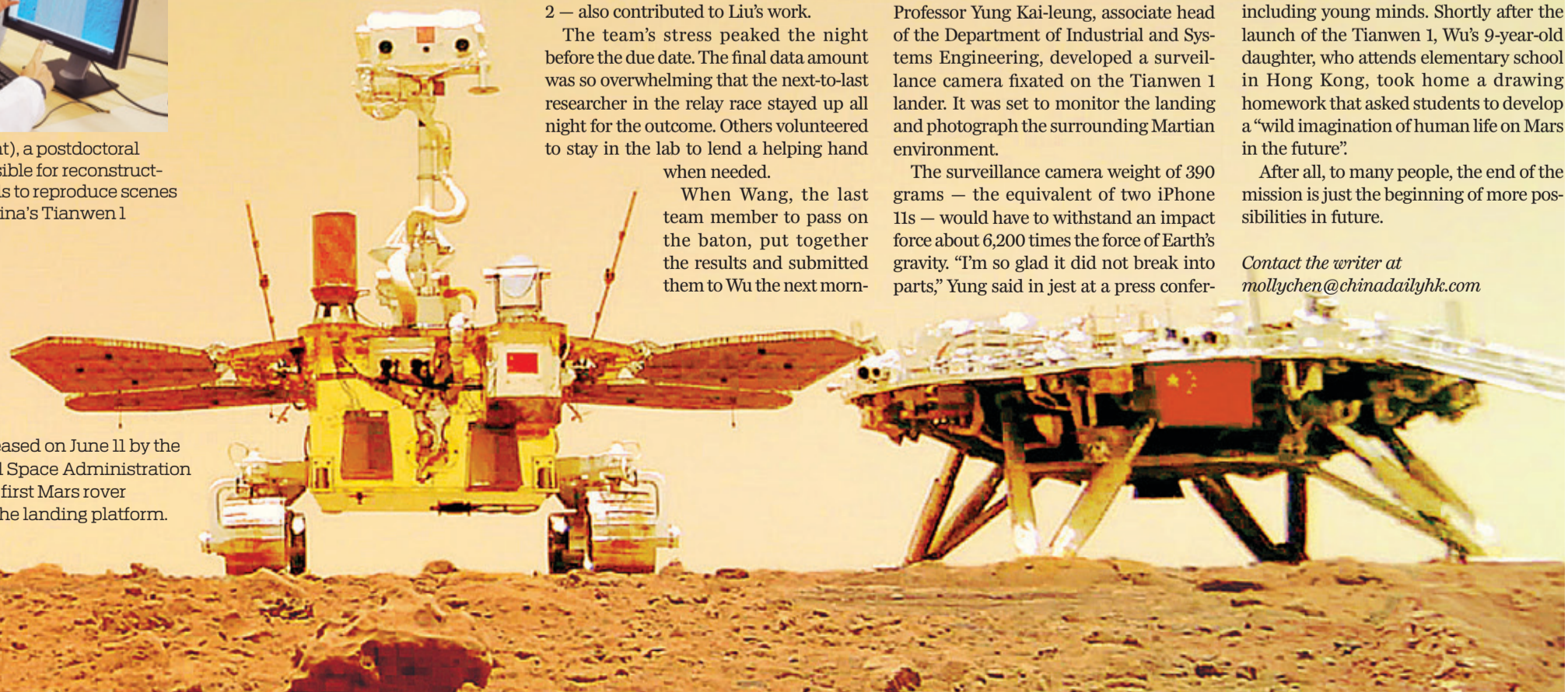
Wang Yiran, a postdoctoral fellow at Hong Kong Polytechnic University's Department of Land Surveying and Geo-Informatics, stands next to a model of the Mars probe Tianwen 1 at the China Academy of Space Technology in Beijing.



Wu Bo (left) from PolyU led the team that helped mapping and evaluating landing sites on Mars for China's Tianwen 1 lander.



Morgan Liu Wai-chung (right), a postdoctoral fellow at PolyU, was responsible for reconstructing 2D images into 3D models to reproduce scenes of the Martian surface for China's Tianwen 1 mission.



This photo released on June 11 by the China National Space Administration shows China's first Mars rover Zhurong with the landing platform.

ence in May celebrating the event.

"Given more time, we could have done it better," Liu said, adding he had gone to bed an hour early to celebrate the successful landing.

For Wang, being a part of the nation's space program is more like a reward for a scientific researcher than a call of duty. The researcher from Shandong province began her doctoral studies in Hong Kong in 2016, just as the Mars project began. The world-class space project, a highlight of her doctoral and postdoctoral days, was her perfect graduation gift. If she is offered another ticket to such missions, she will definitely oblige. "I can't see a single reason for me not to. It'll be a gift. Why not take it?"

"We're not only witnessing history, we're part of history," Wang recalled Wu's inspiring notes when he heard the big news.

For Wu, he is now eyeing another feat — setting his sights on the next possible national space project, such as China's explorations of the near-Earth asteroids scheduled in the next five years or collecting samples from Mars in a decade's time.

The success of China's Mars probe has heightened the expectations of mankind, including young minds. Shortly after the launch of the Tianwen 1, Wu's 9-year-old daughter, who attends elementary school in Hong Kong, took home a drawing homework that asked students to develop a "wild imagination of human life on Mars in the future".

After all, to many people, the end of the mission is just the beginning of more possibilities in future.

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