The robotic lunar rover developed for the Google Lunar XPrize by Team Hakuto led by Kazuya Yoshida.

GETTING ROVERS, CRAB-WALKERS AND MICROSATELLITES INTO SPACE

A LEADING SPACE ROBOTICS LAB IN JAPAN is driving the development of technologies and missions aimed at accelerating the utilization of space in the vicinity of Earth.

In 2010, the first ever sample of material from an asteroid was successfully returned to Earth after the seven-year Hayabusa mission. In the years leading up to the launch, Tohoku University's Space Robotics Laboratory (SRL), working closely with the Japan Aerospace Exploration Agency (JAXA), developed and ground-tested the robotic sampling apparatus that would make the mission possible.

"Our challenge was to devise a way to sample an unknown material from the surface of the asteroid in microgravity with few controls," explains Kazuya Yoshida, a professor and the lab founder. "We trialled and tested many ideas, and eventually settled on a 'touch-and-go' mechanism with a high-speed projectile to eject material from the asteroid surface for collection."

Although ultimately successful, this mission was brought back from the edge of failure numerous times, as is often the case for space missions launched from anywhere in the world. But in this case, it was saved by the help and perseverance of the Hayabusa operation team in adjusting and reprogramming the controls.

"The Hayabusa mission had many challenges — unforeseen sensor readings caused software failure during the final approach to the asteroid, the projectile failed to fire as planned, and the ion engines ceased functioning on the way back to Earth," recalls Yoshida. "However, by devising backup plans and reprogramming, the team managed to overcome all of these challenges. Despite the difficulties, miraculously the mission was a complete success, exceeding all expectations."

That experience spurred renewed levels of activity out of SRL, which has since become a key player in Japan's burgeoning space industry.

TOWARD MINING ASTEROIDS

SRL's expertise in space-ready, extra-hardy robotics for microgravity deployments attracted the interest of Asteroid Mining Corporation (AMC), a UK-based enterprise seeking to be a pioneer of a future asteroid-mining industry.

"Asteroids are really interesting as potential resources of critical minerals," explains Mickaël Laîné, who is an assistant professor at SRL and chief robotics engineer at AMC. "Each asteroid is unique, but could, for example, contain many times the platinum-group elements available on Earth — which are essential in processes such as hydrogen conversion. The first step in developing an asteroid-mining industry is to recover samples from prospective objects, just as we would on Earth. This is where SRL comes in, with our development of a hexapod robot for sampling in microgravity."

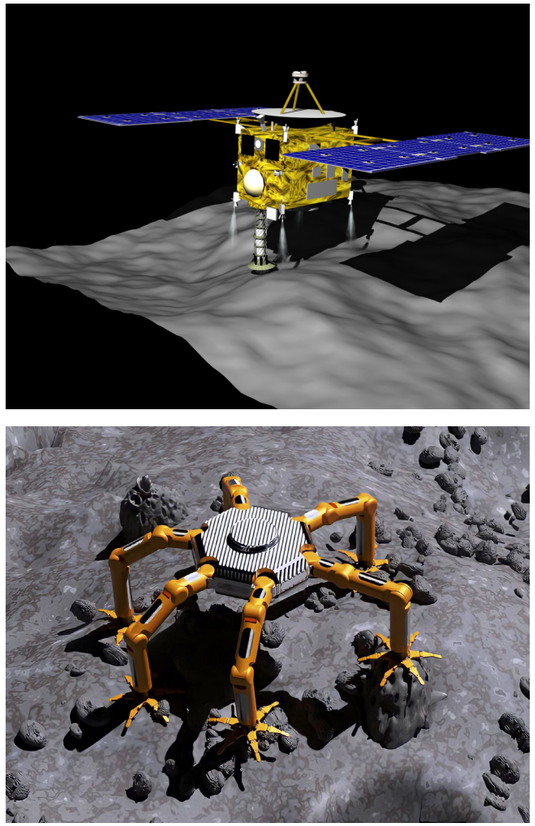
Laîné's crab-like, six-legged robot, called the Space Capable Asteroid Robotic Explorer (SCAR-E), is just over 1 metre across when in action and is designed for positive grip and locomotion over rough terrain in near weightlessness. At 12 kilograms, it is light enough to be deployed on missions similar to Hayabusa, and is designed to carry a 5 kilogram payload of instruments, sensors and other experimental devices.

"SCAR-E is being designed as a universal platform that will allow many different groups to collaborate on future missions to explore asteroids," says Laîné. "Our first prototype is near completion and will soon go into ground-based testing."

USING MICROSATELLITES

SRL has been developing microsatellites in the 50 kilogram class for more than two decades as part of its space technology research activities. Since the launch of its first satellite in 2009, the SRL has put more than ten microsatellites into orbit using piggy-back launch opportunities organized by JAXA. SRL is now turning its attention to establishing a 'working satellite' programme aimed at making near-Earth space accessible as a commercial and experimental resource.

"Through our new start-up ElevationSpace Inc., we're applying our experience in microsatellites to offer new capabilities such as recoverable return capsules, which will allow scientists to conduct zero-gravity experiments in near-Earth space cheaply and quickly," says Toshinori Kuwahara, who is an associate professor at SRL and the chief technology officer in the start-up.



▲ A simulation of Hayabusa touching down on the asteroid Itokawa (top); Space Capable Asteroid Robotic Explorer (SCAR-E), a crab-like, six-legged robot that can grip and walk across surface of an asteroid (bottom).

Such return capsule satellite missions will make it possible to perform experiments that are impossible on Earth, such as the crystallization of proteins in microgravity. Kuwahara also expects that the capability could be used for biological experiments and even drug development. The ability to conduct such experiments will become increasingly important with the imminent decommissioning of the International Space Station in 2031.

"Such microsatellites require high-performance thrusters and accurate orbit control, but must also be lightweight, and the return capsules need to be heat shielded but also to be discoverable on return," says Kuwahara. "We're currently in the process of building the first engineering models."

SHOOTING FOR THE MOON

Fresh from the success of Hayabusa, SRL entered the Google Lunar XPrize contest in 2010, which was created to spur affordable access to the Moon and the development of business models around lunar transportation. The only entry from Japan, a small robotic rover developed by Yoshida's Team Hakuto is capable of being deployed from a light spacecraft, and was one of five finalists. Although no Moon missions were launched under this competition, the project spawned another SRL start-up, ispace Inc.

"After Lunar XPrize, we turned our attention to the lunar lander," says Yoshida, who is technology advisor at ispace. "We launched the first ever private Moon mission on a SpaceX launcher in December 2022. Unfortunately, the Hakuto-R lander crashed on the final descent, but we're already working on second and third missions with a focus on improving the navigational guidance control."

Yoshida is also leading an ambitious project under the Japanese government's broad-ranging 'Moonshot R&D' programme aimed at establishing a self-evolving autonomous swarm robot system to develop lunar bases and resources.

"We want to take our Moon ambitions further by creating artificial-intelligence-driven robots that could be used to construct a lunar outpost," says Yoshida. "This is definitely a 'moonshot' goal, but we have the technology and expertise here at SRL to give it a good shot. We're a world-leading institute of space robotics research, and through our various start-ups, research and mission activities, we will continue to be a driving force in near-Earth space exploration in Japan and globally." ■

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