KOBE SHINFUKUHARA KURUWANOZU
神戸 新福原廓之図

Art Research Center Collection, Ritsumeikan University (arcUP8328)

This ukiyo-e depicts the red-light district that used to exist in the Shin-Fukuhara area of Kobe. People are enjoying a lively evening out on the night with the full starry sky, the moon and the cherry blossoms. Though space is still what most of us can only look up, it may not be too long before people are able to live on other planets while viewing the Earth from afar...

Art Research Center, Ritsumeikan University holds a huge collection of ukiyo-e and has made their database available to the public.

See below for more information:
https://www.arc.ritsumei.ac.jp/e/database/

RADIANT

Division of Research, Ritsumeikan University

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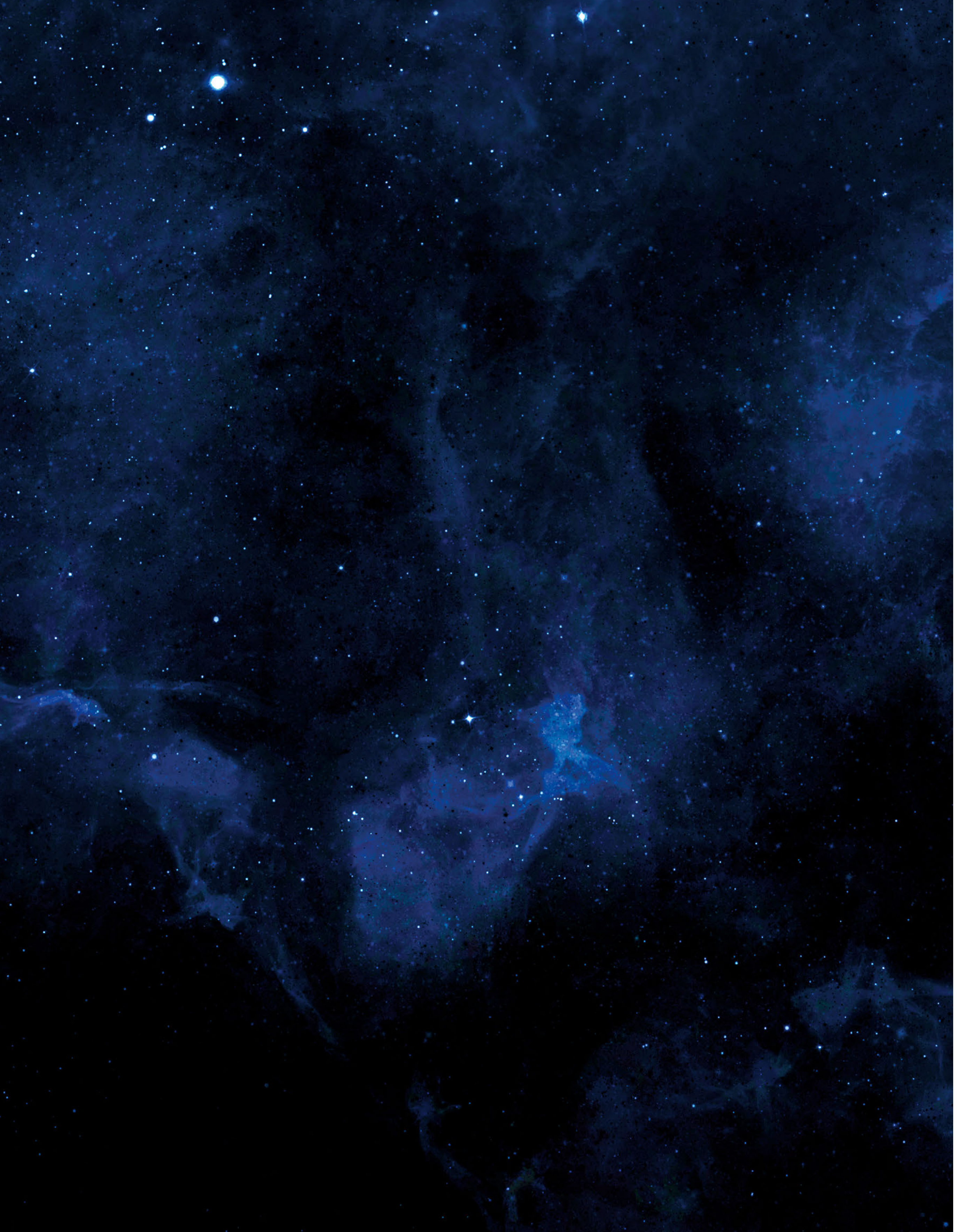
RESEARCH REPORT

FEATURE

SPACE & EARTH



RADIANT

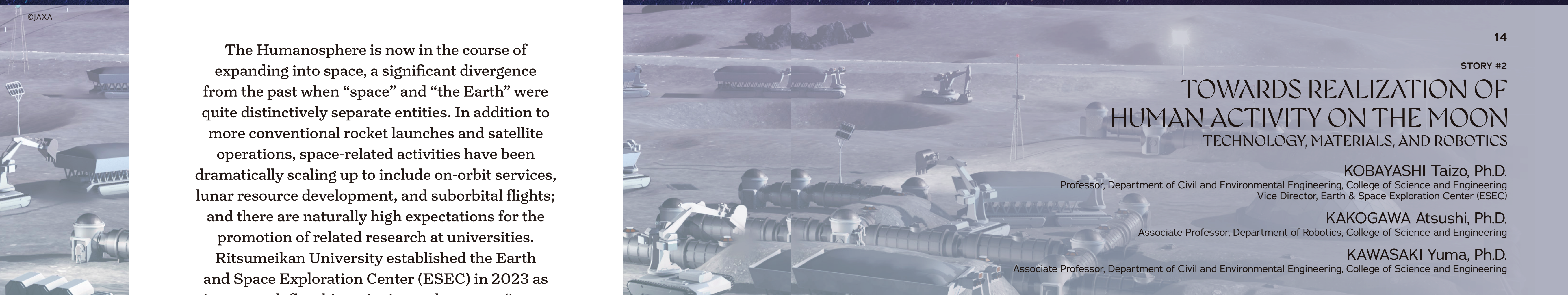
RITSUMEIKAN UNIVERSITY

RADIANT is an adjective that means to
“shed light” or “shine brightly.”
We used this meaning so that
the research results of Ritsumeikan University
can be a step towards
creating a bright future and
helping to shed light
upon the world in the future.

FEATURE

SPACE & EARTH

The Humanosphere is now in the course of expanding into space, a significant divergence from the past when "space" and "the Earth" were quite distinctively separate entities. In addition to more conventional rocket launches and satellite operations, space-related activities have been dramatically scaling up to include on-orbit services, lunar resource development, and suborbital flights; and there are naturally high expectations for the promotion of related research at universities. Ritsumeikan University established the Earth and Space Exploration Center (ESEC) in 2023 as its research flagship as it aims to become a "next-generation research-intensive university." As a pioneering research organization in Japan dedicated to the expansion of the Humanosphere into the Moon and other planets as well as to the development of infrastructure for space exploration bases, approximately 30 researchers within the University are engaged in research activities in earnest on a wide range of themes on a daily basis. And what is more, research in the field of space is interconnected also with climate change and other global issues facing humanity. In this issue, we introduce some of our researchers whose interest encompasses space in a broader context.



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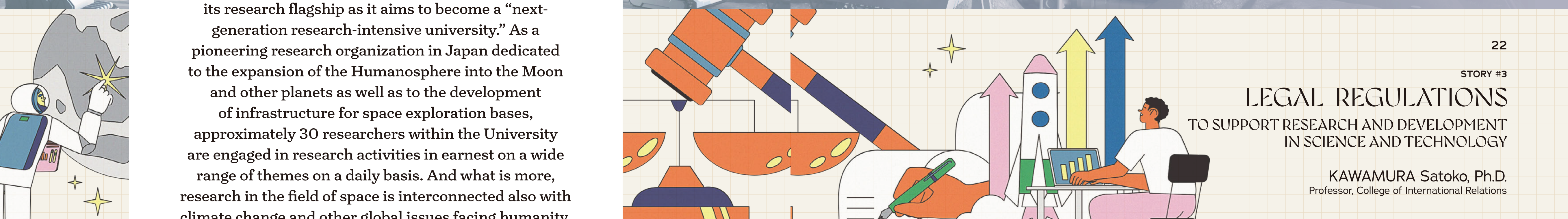
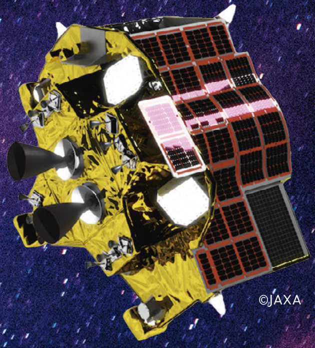


ACCOMPLISHMENTS OF MOON SNIPER SLIM AND FUTURE PROSPECTS FOR LUNAR EXPLORATION



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The Smart Lander for Investigating the Moon (SLIM), developed by Japan's space agency JAXA, became the first lunar lander to achieve an autonomous landing within just 100 meters of its target in early 2024. This breakthrough captivated researchers and space enthusiasts alike. Equipped with a near-infrared multi-band camera, SLIM provided high-resolution images of the lunar surface and made the exciting discovery of olivine within a lunar rock, offering new insights into the Moon's geology.

The project brought together a team of prominent scientists, including Professor Kazuto Saiki, Director of the Earth and Space Exploration Center (ESEC) at Ritsumeikan University, along with Associate Professor Hiroshi Nagaoka and Assistant Professor Yusuke Nakauchi, both affiliated to the Research Organization of Science and Technology, Ritsumeikan University. Their contribution—the near-infrared multi-band camera, SLIM's sole scientific instrument—is now helping to analyze SLIM's findings. The team is also working on cutting-edge observation technologies for future space missions.

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Research Introduction

SAIKI Humanity is entering a new phase of space exploration, one that goes beyond the brief Apollo-era visits to the Moon. Now, with private companies involved, we are on the verge of sustainable exploration of both the Moon and Mars. This era could mark a turning point in human history as we learn to utilize extraterrestrial resources.

As the head of ESEC, my goal is to support this transformative period with the power of science. ESEC will not only focus on space exploration but also on the Earth itself. Our planet has experienced environmental catastrophes that could have wiped out all life forms. Given that human history is a tiny fraction of the Earth's timeline, even the near future is uncharted territory for us. At ESEC, we are committed to ensuring humanity's survival on the Moon, Mars, and here on the Earth.

NAGAOKA My research focuses on the Moon's formation, which could help us understand how the Earth and other rocky planets were formed. Since the Moon cooled and solidified much earlier than the Earth, it likely retains rocks from the early stages of the planet formation process—information that has long been erased from the Earth's surface. Analyzing the Moon's composition and the conditions during its formation will give us valuable insights into the formation of rocky planets, including the Earth.

With the U.S.-led Artemis mission bringing the prospect of manned lunar exploration closer to reality, our team is developing observation and sampling technologies to support these missions. We are preparing to analyze samples returned to the Earth while refining tools to assist landers and rovers in identifying lunar samples on-site.

NAKAUCHI Infrared spectroscopy is one of the most powerful techniques for identifying and analysing the composition of planetary materials. By observing how substances interact with infrared light, we can determine their makeup and even select return samples from the Moon or other planets. My team is developing an advanced infrared spectroscopy camera for use on future lunar landers. However, lunar exploration faces a unique challenge: space weathering. The Moon's surface is constantly bombarded by solar wind, cosmic rays, and micrometeorites, which alter the optical properties of its rocks. To accurately interpret reflected light spectra from the lunar surface, we must first understand how space weathering affects these readings. Interestingly, lunar exploration has hinted at water production on the Moon caused by space weathering.

Our goal is to further explore this phenomenon through experiments simulating the solar wind's impact on rock surfaces.

An image CG of SLIM observing rocks using MBC (in originally envisaged landing posture).

Moon Sniper SLIM: The World's First High-Precision Moon Landing

NAKAUCHI The Smart Lander for Investigating the Moon, or SLIM, was a high-precision lunar landing demonstration mission designed to achieve a pinpoint landing on the Moon. In past lunar explorations, dating back to the Apollo program, a successful landing meant touching down within a range of a few to several dozen kilometres from the target. That was the technical limit of accuracy. However, SLIM drastically reduced that margin, aiming to land within a 100-meter radius.

SLIM was launched on September 7, 2023 (JST), and reached the Moon using a low-propellant trajectory. Once in lunar orbit, it began observing the surface while confirming that all its instruments were functioning properly. It then initiated its descent, using image-based navigation—one of the mission's key technologies—to determine its precise location. Just before landing, SLIM was set to release two small rovers: one designed to hop across the lunar surface for exploration, and the other that could transform and roll around to capture images of the lander and its surroundings.

SLIM targeted a landing site at 13.3°S, 25.2°E, on the Moon's southern side. Near this location lies a crater named SHIOLI, which has captured the interest of scientists due to its relatively fresh condition. Based on data from Japan's Kaguya lunar orbiter, we believe this area could reveal valuable information about the Moon's interior.

In the early hours of January 20, 2024 (JST), the three of us anxiously watched SLIM's landing from JAXA's mission control, monitoring its progress on the Quick Look screen. Since SLIM was navigating autonomously, there was nothing we could do but wait for the outcome. SLIM's altitude gradually decreased, and to our relief, it successfully touched down on the Moon! However, the altitude readings continued to fluctuate, and the data soon showed that SLIM was sinking into the lunar surface, eventually coming to rest in what appeared to be an upside-down position.

SAIKI Amid the chaos of trying to make sense of the situation, the operations team reached out to us. With everything happening so quickly and uncertainty still lingering, they asked if we wanted to proceed with capturing images using the multi-band camera (MBC) that we had meticulously developed and installed on SLIM. Despite the unexpected circumstances, the opportunity to gather valuable data was still on the table.

NAKAUCHI After SLIM went into hibernation for the first time, we discovered that during the landing, it had been automatically taking images every few seconds. Incredibly, one of those images captured a thruster that had detached from the main body, and we immediately realized it was the cause of the abnormal landing posture.

First High-Resolution Image Taken on the Lunar Surface

NAKAUCHI Our MBC was an infrared observation camera equipped with band-pass filters to observe 10 different wavelengths. It was the only scientific observation device installed on SLIM, the landing demonstrator.

SAIKI One of the challenges with the MBC was that it had to be the first domestic camera of its kind to include an autofocus mechanism. While autofocus is not necessary for shooting from orbit, it becomes essential when we want to shoot images of rocks both near and far from the landing site. Another challenge was to make the camera smaller. Since SLIM cannot move after landing, we needed a way to adjust the view of the surroundings. Rather than making the entire camera move, which would be too heavy, we opted to tilt only the mirror attached to the camera.

NAKAUCHI From orbit, the resolution for lunar surface imaging was limited to about 30 centimeters, which meant that smaller rocks were not visible. We hoped that landing on the Moon would allow us to capture rocks as small as 10 to 15 centimeters, but without knowing the precise locations of suitable targets, we designed the camera to focus within a range of 1.5 to 30 meters.

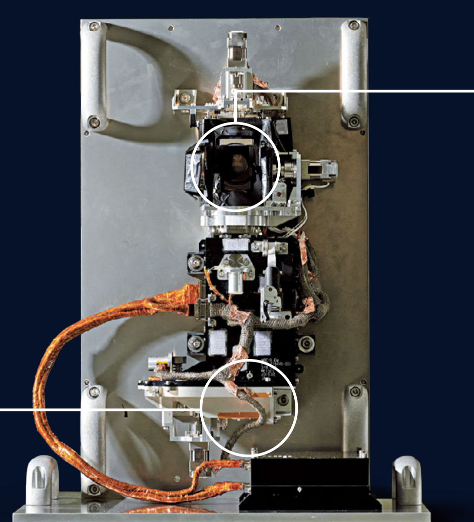
When we were asked if we wanted to start shooting, we were taken by surprise and quickly began preparing for the operation. At that time, SLIM was running on its main battery, as the solar panels were not generating power. We had to complete the imaging before the battery ran out. With the battery life uncertain, we compressed a task that usually takes five hours into just 45 minutes. Despite the time constraint, we successfully operated the camera and captured images of the area around the landing site. We identified several scattered rocks and selected six for detailed observation.

SAIKI It was decided that the six rocks would each be named after six different breeds of dogs. We could have used letters of the alphabet or numbers, but we thought it would be better to use common nouns that are easy to remember, in order also to avoid a mix-up. We thought it would be appropriate to use names that would intuitively convey differences in size, as we could guess that the rocks in the foreground were smaller and those in the distance were larger. At first, I suggested using names of fruits, but no one in the MBC team was interested. Then I suggested using names of dogs instead, and everyone started naming the different breeds.

NAKAUCHI Shortly after the images were shot to get an idea of what is going on around the landing site, the main battery ran out of power and SLIM was switched to the solar-panel operation mode before going into hibernation, but it was unable to generate power from the panels. Normally, after capturing a few images, we would immediately start analyzing which rocks to examine more closely. However, due to time constraints, we were unable to proceed further. Communication with SLIM was then lost for a week or so. During this time, we were able to confirm from images sent by the small rover, which had detached during the landing, that SLIM had landed upside down.

On January 28 (JST), communication with SLIM was restored, and 10-band spectroscopy was carried out this time for each rock, bringing the total number of rocks that were observed to 10. One of the rocks, named "Akitainu," is about 20 meters away from the SLIM main body, but a clear, high-resolution image of it has been made available to the public*. Everything came together successfully, including the precise landing and the effective focus of

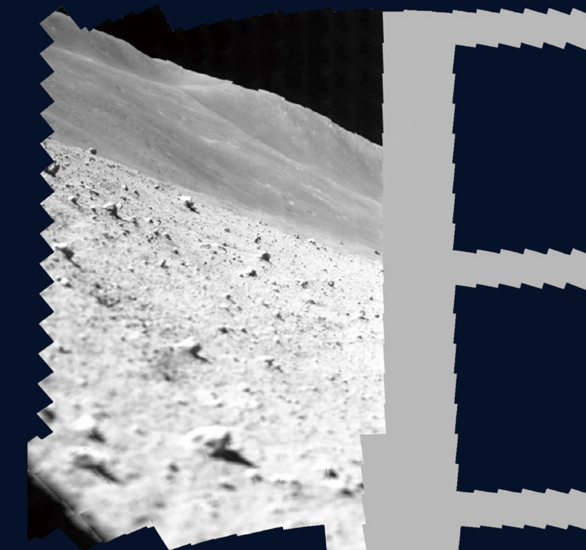
The near-infrared image sensor is at the bottom, and the filter turret above it is equipped with band-pass filters for 10 different wavelengths.



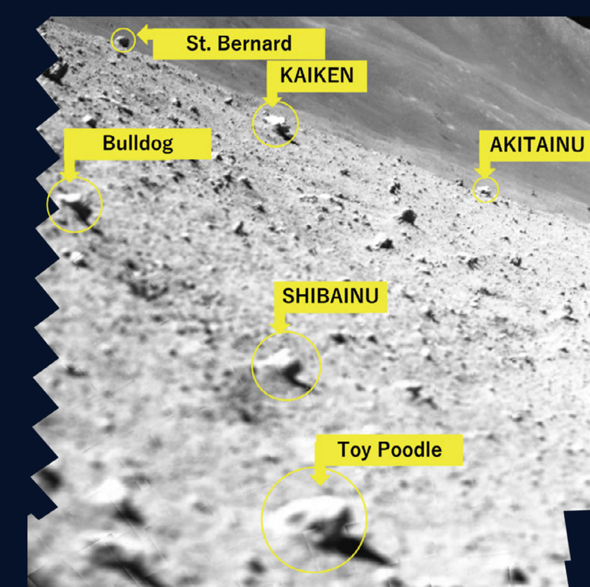
For weight reduction, the camera captures images of what is reflected in the mirror that tilts up and down, left and right.

The multi-band spectroscopic camera packs a complex mechanism of a tiltable mirror, autofocus mechanism, and filter turret into a 4 kg body. (Shown here is an engineering model (ground test model) made exactly like the flight model.)

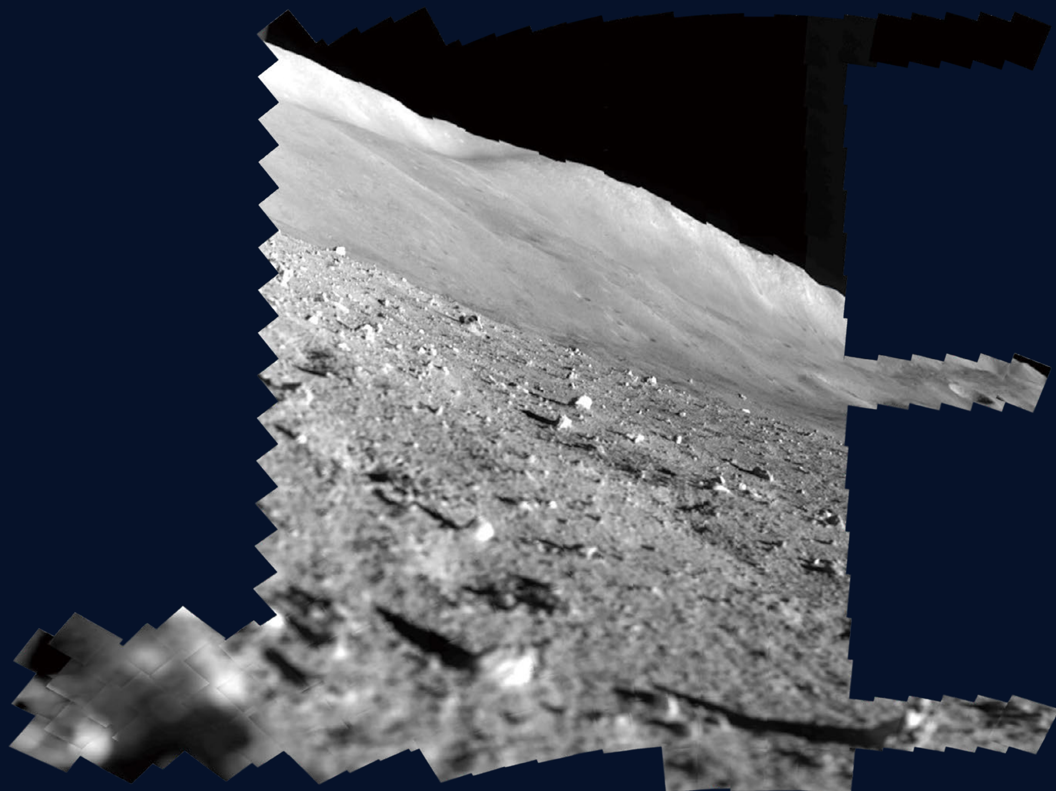
*Institute of Space and Astronautical Science (ISAS) https://www.isas.jaxa.jp/en /topics/003675.html



A scanned mosaic image taken immediately after the SLIM landing, created by combining 257 low-resolution images. Gray areas are those omitted due to operational time constraints.



Hoping to revive SLIM, whose batteries had been disconnected immediately after landing without the solar cells generating power, rocks were named after dog breeds for possible future observation.



©JAXA/ Ritsumeikan University/ The University of Aizu

A scanned mosaic image taken after SLIM was restored following the solar cells being exposed to sunlight again. Note that the direction of the shadow is reversed from the scanned mosaic image immediately after landing.

the MBC. I was truly relieved when we completed the multiband spectral imaging of all 10 rocks.

SAIKI Near-infrared spectroscopy has previously been used to observe the regolith on the lunar surface. Since near-infrared light penetrates only a short distance into minerals, we had to rely on a technique where light reflected from one particle could pass through another to observe the surface. This is the first time we have been able to perform near-infrared spectroscopy on the surface of a solid rock at a high spatial resolution. We anticipated that the surface of lunar rocks, which are roughened by space weathering, would reflect and transmit infrared light similarly to lunar regolith. Based on this expectation, we proposed and successfully implemented a near-infrared camera. It is gratifying to see that our results matched our expectations.

Further analysis of the images revealed that one of the rocks contained a chunk of olivine, measuring a few centimeters in size. Olivine is a major component of the Earth's mantle. While we will need to conduct future analyses to determine if this olivine has a composition similar to those on the Earth, this discovery could provide valuable insights into the Moon's formation process.

Lunar Polar Exploration Project

SAIKI SLIM will be succeeded by the Lunar Polar Exploration Mission (LUPEX), a joint effort between JAXA and the Indian Space Research Organization. One of LUPEX's primary objectives is to explore a crater at the Moon's south pole, specifically its permanently shadowed regions where sunlight never reaches. In the 1990s, exploration by an American spacecraft indicated that these shadowed areas might contain water ice. Later in 2007, Japan's KAGUYA lunar orbiter became the first spacecraft to successfully examine the bottom of Shackleton Crater, one of those craters with a permanent shadow, which is 21 kilometers in diameter and located near the exact south pole. The topographical information it provided at that time revealed that the interior of the crater was in a permanently very low-temperature state below 90K. At such low temperatures, ice would not easily evaporate, suggesting it may have been preserved for hundreds of millions of years.

If water can be found on the Moon, it could be split into hydrogen and oxygen through electrolysis, bringing us closer to sustaining human activities on the Moon. LUPEX aims to investigate the quantity and distribution of water on the Moon. The mission plans to descend into these permanently shadowed regions to confirm the presence of water ice and, if found, to take core samples for in-situ analysis.

The Artemis 3 campaign, which aims to return humans to the Moon for the first time in decades, is currently in progress with collaboration from over 40 countries, including the United States. Candidate landing sites for Artemis 3 are located on small ridges around the craters at the South Pole of the Moon with the permanent shadow, including Shackleton Crater. In other words, the Artemis campaign is also an attempt to get to the Moon's water resources.

Given that the Sun is low on the horizon at the lunar poles, a spacecraft landing in these regions might receive no sunlight at all if not precisely positioned. In this context, the pinpoint landing technology developed by SLIM has set a crucial precedent for future polar exploration missions like LUPEX.

Further Future beyond LUPEX

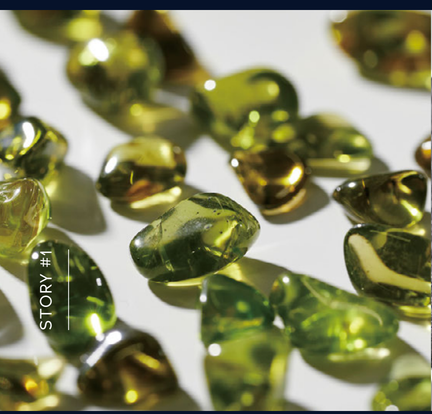
NAGAOKA Following SLIM and LUPEX, Japan is now investigating further lunar exploration possibilities using rovers. We are actively involved in these efforts. Meanwhile, there are more and more foreign missions exploring the Moon, such as South Korea's KPLO mission, which is continuing observations with an orbiter. India's Chandrayaan-3 lander successfully landed in the South Pole region for the first time shortly before SLIM. Other countries are also planning missions to the South Pole to search for water.

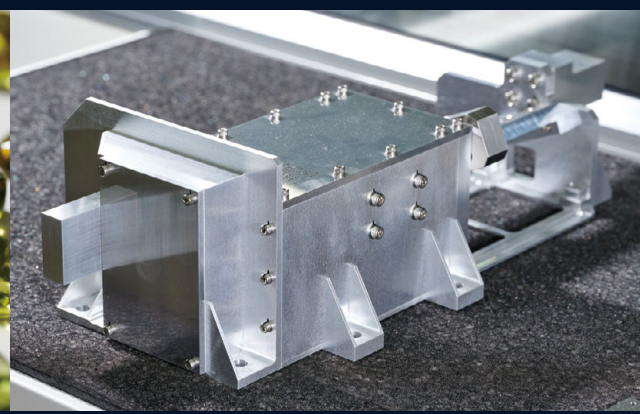
We are currently working to develop new scientific observation techniques and equipment for use in Japan's future Moon landers and manned pressurized rovers that are expected to follow LUPEX. One such device is a grinder for scraping the surface of rocks. We need to scrape the surface of rocks to flatten them, in order to study the very fine rock structure using spectrometers and learn how the rocks were formed.

NAKAUCHI Grinding on the Moon is very different from grinding on the Earth. On the Earth, water is used to wash away chips and cool the surface of grindstones and rocks that has been heated by friction. On the Moon, however, we have to develop a method of grinding without water. This is because even if we could obtain water ice from the permanent shadow, it would sublimate in the vacuum environment. In addition, the rocks on the lunar surface are known to be quite hard, and the existing grinding tools would be ineffective due to considerable wear on the tool side. We are currently working with Tokyo University of Agriculture and Technology and grindstone manufacturers to conduct experimental development for tools that can withstand the hardness of lunar rocks.

NAGAOKA Further exploration of water on the Moon is also in progress. I am involved in developing MoMoTarO, a radiation detector designed to locate water in lunar soil using neutron and gamma rays. At Professor Kobayashi's laboratory at the College of Science and Engineering, a fellow member of ESEC, we are testing this detector with simulated lunar soil and a radiation source to replicate the lunar surface's radiation environment and assess its ability to detect water content.

Looking ahead, human exploration of the Moon is on the horizon. JAXA, Toyota, and other private companies are currently developing a manned pressurized rover with the goal of transporting astronauts to collect samples. Using handy, compact analyzers, the astronauts will perform analysis in the field, identify and collect samples of high scientific value, and bring them back to the Earth. We are currently working to develop a portable laboratory package that can be installed on a manned pressurized rover, equipped with multiple handheld analyzers. Our future objective is to use artificial intelligence to analyze data in the field and determine if samples are worth bringing back to the Earth, thereby contributing to sample return missions.





Left: Olivine, a mineral thought to be abundant in the lunar mantle. (Shown here is olivine found in the upper mantle of the Earth.)
Center: MBC's structural test model used during vibration testing of the SLIM main body.
Right: The electrical circuit block controlling MBC. Weighs approx. 4 kg, together with the block for the camera proper. (Shown here is an engineering model.)

As the Frontrunners of Lunar-Resource Science

SAIKI I am not only in the current quantities of water and mineral resources but also in their origins, the processes by which they were gathered, their future behavior if left undisturbed, and the potential for sustainable human use. Gaining insights into these aspects is crucial for developing the humanosphere, a key objective of ESEC.

NAGAOKA The lunar samples hold a wealth of information that is unique and not found on the Earth. I think it is important to develop analysis and curation facilities to accumulate this kind of information. At the moment, NASA has a virtual monopoly on the lunar return samples, but I would like to see the establishment of comparable facilities in Japan so that we can analyze, store, and pass on the samples to future generations.

NAKAUCHI I strive to remain a pioneer in my field and enhance the feasibility of our projects so that people will say, "If ESEC is involved, the project will succeed." In Japan today, the development time from project launch to actual deployment is becoming shorter and shorter, but I want to create an organization that can develop the technology and equipment it deems necessary in advance, just as researchers involved with NASA do. This forward-thinking approach will ensure that we are well-prepared and can consistently deliver successful outcomes.

SAIKI When people start living on the surfaces of the Moon and Mars, not only scientists and engineers, but everyone will have a connection with space, and the purpose of going into space will be infinite. At ESEC, we are committed to advancing space exploration through collaboration with experts from diverse fields. Our goal is to position ESEC at the forefront of the evolving wave of space exploration and development.

SAIKI Kazuto, Ph.D.

Professor, Research Organization of Science and Technology
Director, Earth & Space Exploration Center (ESEC)

Specialties: Planetary Geology, Mineralogy, Volcanology
Research Themes:
1. Development of new methods for geological exploration of the Moon and planets
2. Elucidation of the structural differentiation process of the Moon and planets and chemical substance transfer phenomena near the lunar and planetary surfaces
3. Volcano Observation and Volcano Disaster Prevention

NAGAOKA Hiroshi, Ph.D.

Associate Professor, Research Organization of Science and Technology

Specialties: Planetary Science (Planetary Exploration and Meteoritics, in particular), Space Radiation Physics
Research Themes:
1. Developments of science instruments for planetary exploration
2. Studies for the origin and formation process of terrestrial planets based on geochemical and mineralogical analyses for meteorites and returned samples, and remote sensing data analyses

NAKAUCHI Yusuke, Ph.D.

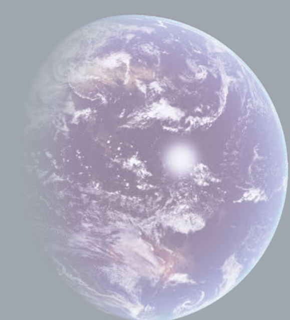
Assistant Professor, Research Organization of Science and Technology

Specialty: Planetary Science (development of near-infrared spectroscopic camera for planetary exploration, space weathering on the Moon and planets)
Research Themes:
1. Development of Vis-Near Infrared Spectrometer for planetary exploration space crafts.
2. Laboratory simulation of space weathering and water formation caused by solar wind proton on lunar and planetary surface.

TOWARDS REALIZATION OF HUMAN ACTIVITY ON THE MOON

TECHNOLOGY, MATERIALS, AND ROBOTICS

Space development has three phases. Phase one focuses on the scientific observation and exploration, phase two comprises the building and maintenance of the humanosphere, and phase three concentrates on building a living environment and the realization of a worthwhile life. We are mainly focused on phase two. Several places on the Earth and in space are uninhabitable by humans. Our goal is to explore these uncharted areas and make them habitable for humans. Professor Taizo Kobayashi, Associate Professor Atsushi Kakogawa, and Associate Professor Yuma Kawasaki of the College of Science and Engineering have been working on unmanned construction technology to build the infrastructure essential for human survival, including the first lunar base on the Moon's surface.



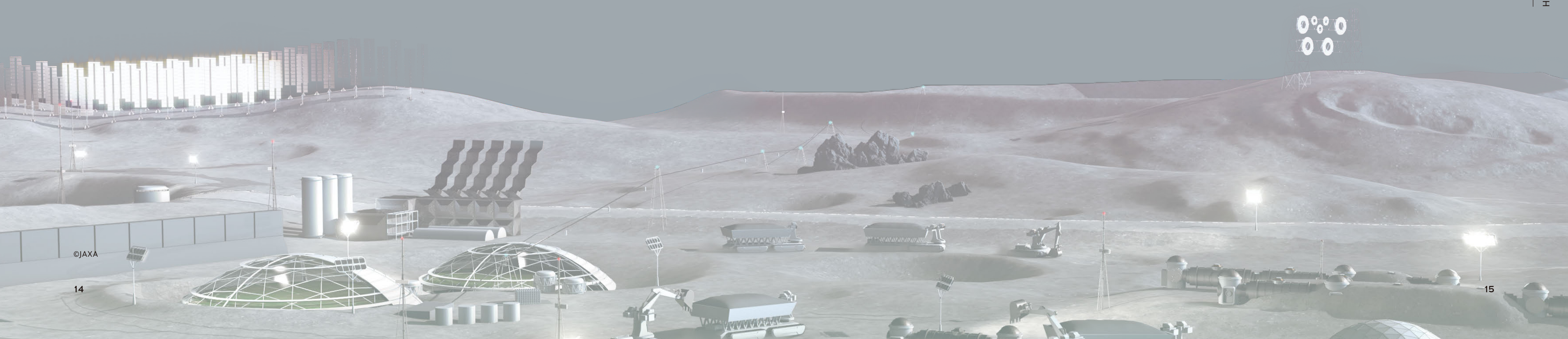
Research Introduction

KOBAYASHI The construction of a lunar base was only discussed in manga and science fiction. However, with humanity seeking new spheres of activity and survival, lunar base construction has been recently considered a realistic goal. Residential areas for human habitation, research facilities, ports for transport vessels, and access roads for these essential facilities can be expected to be constructed on the Moon.

The lunar surface is covered with fine grains called "regolith." However, only limited information is available on the characteristics of the regolith, including its thickness and firmness. This information is essential for lunar base construction.

As a researcher specializing in geotechnical engineering, I am conducting basic research on the soil mechanical characteristics (such as stiffness, compressibility, and strength), the design and operation of lunar and planetary probes, the development of lunar soil investigation equipment, and the design of facilities to be constructed on the lunar surface.

KAKOGAWA In addition to space, several locations on the Earth are not fit for human inhabitation, such as deep waters and deep caves with low oxygen concentrations. Access to locations, such as the deep ocean with high water pressure, environments with high heat and toxicity (such as volcanoes), or the polar regions with extremely low temperatures, is hindered even with the



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right equipment or vehicles.

Additionally, narrow artificial spaces, such as gaps between buildings and infrastructure are inaccessible. We use hardware and technology to research and develop robots capable of performing tasks that are physically impossible for humans to perform in these extreme environments.

In my lab, we also focus on social implementation. For example, we are conducting outdoor field experiments on robots that can move forward and backward to inspect the complex winding sewer pipes.

KAWASAKI Ordinary concrete is prepared by mixing sand, gravel, cement, and water, and is allowed to harden through a hydration reaction. Sand, gravel, water, and limestone, which are the raw materials for cement, are mostly natural resources. The depletion of sand resources has been a major concern worldwide. I have succeeded in creating a new type of concrete that uses powder made from discarded concrete, instead of sand, and polysaccharides of plant cell walls instead of cement. This concrete is hardened through heating and compression.

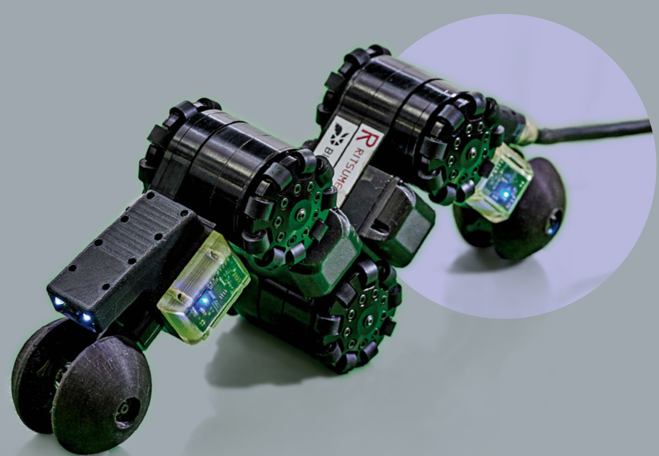
Heating increases the viscosity of the polysaccharides, which then function as a glue to hold the powder together when pressure is applied. Some polysaccharides may require high temperatures and high pressures to increase their viscosity. However, we have developed a mixture that can be used at room temperature (approximately 20 degrees Celsius). The flexural strength of the resulting material was higher than that of ordinary concrete.

Currently, I am working on the development of "lunar concrete," which uses simulated lunar regolith as an aggregate instead of recycled concrete. We have already succeeded in creating a hardened body through pressurization and are currently working to improve its performance by changing the type of polysaccharide and the mixing ratio with regolith for potential utilization as building and paving materials on the Moon.

Civil Engineering Works on the Moon

KOBAYASHI I am working with Associate Professor Kakogawa to develop an unmanned lunar surface investigation robot. In particular, I have specifically requested him to develop a rover and a manipulator (robot arm). Our goal is to attach a bucket to the end of the robot arm for automatically performing tasks, such as leveling and excavation on the lunar surface, similar to a hydraulic excavator used on the Earth. Currently, we are in the process of developing and testing a model that is operable on the ground.

KAKOGAWA Although we are exploring the potential use of robots on the Moon, much of the new technology has not been developed. The currently implemented technological innovation comprises a combination of existing technology. As there are many hurdles in an extreme environment, we do not actively incorporate cutting-edge devices with high-performance central processing units but use the "Karakuri" mechanism involving low-tech devices. The major limitation of using the system on the Moon is the distance between the Earth and the Moon. Remote manual operation from the Earth is challenging due to the time lag in communication. The system must be capable of autonomous operations. We are about to test automatic operations. We also want to ensure high reliability so that it can be entrusted with exploration, surveying, and other tasks not only on the Moon but also in places on the Earth that are inaccessible to humans, such as the ocean floor and polar regions, as well as in harsh environments.



In-pipe inspection robot: a robot for inspecting corrosion and aging states with cameras while navigating itself through pipeline with an inner diameter of 4 in (approx. 100 mm). The robot can navigate itself through bends, vertical and T-junctions and can generate traction forces of 30 kgf or more. It was found to be capable of navigating itself through up to 19 bends.

Unmanned exploration robot for lunar surface geotechnical investigation (breadboard model). The robot is equipped with the following components: (1) a positioning and surveying system for micro-topography measurement, (2) an active seismic exploration system to investigate subsurface stratigraphy, (3) a radiometric density meter for soil density measurement, and (4) a plate loading and shear testing tool to evaluate the deformation and strength characteristics of lunar regolith.

KOBAYASHI So, we are aiming to create a dual-use robot that can be used both in space and on the Earth.

Now let us hear from Associate Professor Kawasaki, who is developing a concrete material that can be used as a building material and a paving material. This concrete material is a hardened substance that does not rely on water and cement, which are difficult to obtain. The novel concrete is developed using regolith, which is abundant on the lunar surface, and a small amount of water that can be procured on-site.

KAWASAKI Yes, I have already succeeded in producing the hardened material using the same method as that used for recycled concrete, which involves heating and compression. I have presented it at public events, such as the Golden Expo held in Tsukuba City in April 2024. The challenge, however, is to find a source for the plant-based powder. As water is not completely unnecessary, another concern is its availability on the Moon. Materials that cannot be obtained on the Moon may have to be sourced from the Earth although we may consider producing them on-site in the future.

KOBAYASHI The production of lunar concrete would be one way to effectively utilize water on the Moon and I think that could be a selling point.

KAWASAKI Most of my research is focused on applications both on the Moon and on the Earth. In addition to the lunar regolith, we are also considering the use of desert sand, which cannot be used as a material for conventional concrete because the grains are too uniform in size, as well as the use of debris from natural disasters and even coffee powder, as raw materials. As countless potential plant materials can be used as a source of polysaccharides, we are investigating the optimal sources to increase strength and/or the effect of the combination of multiple materials on the properties of the final product. The manufacturing process also requires further research. Currently, the material is mixed, placed in a mold, and compressed to produce a brick-like, rectangular, hardened body. However, to

Hardened specimen developed using simulated lunar sand.

pave the lunar surface, methods, such as a vibrating press, which is similar to the method of asphalt paving on the Earth, must be considered. The effect of harsh environments, such as meteorite impacts and huge temperature differences, ranging from 100 degrees Celsius during the day to –180 degrees Celsius at night, must also be tested.

KAKOGAWA We still have a lot of issues to address related to adapting to the lunar environment. Currently, we are at the stage of ground testing. The air, stable temperatures, and low radiation in these testing conditions provide a fairly simple and tractable environment. However, the Moon's surface is completely different from the Earth's surface with no air, low gravity, high cosmic radiation, and powdery regolith. Having said that, low gravity has its advantages, such as the ability to lift heavy objects with smaller motors than those used for lifting on the Earth.

The absence of air and space radiation, however, is a major problem. This is because most robots use reduction gears to amplify the torque of the motor, which almost always contains lubricating oil. In an extremely low-pressure environment, such as a vacuum, fluids can easily evaporate and leak outside. Additionally, robots on the ground use various sensors and electronic circuit boards to accurately control their position and speed. Space radiation can damage these components.

For construction applications, excavators and cranes can be used. However, general construction equipment is powered by hydraulic actuators. Hydraulic oil, like lubricant, evaporates and is lost in a vacuum environment and leaks out. Nowadays, electric motors are being used in construction machinery on the Earth, and yet the power of electric robots is considerably lower than that of hydraulic robots. Hence, the performance of electric robots on the Moon must be verified.

To Build a Lunar Base and Pavement

KOBAYASHI To explore the Moon and build a lunar base, the geological and geotechnical conditions of the lunar surface must be understood. Our robot is approximately one meter wide and weighs approximately 100 kilograms. This robot performs 3D geological and geotechnical investigations and records the results on a three-dimensional map. Additionally, this robot is equipped with devices for positioning and surveying, seismic testing, shear testing, load testing, and radioisotope (RI) density measurement. These tools enable us to visualize the subsurface environment.

To recreate the lunar surface environment, we are conducting experiments using a lunar regolith simulant, which artificially reproduces the size, weight, and chemical composition of soil particles. The slag produced as a byproduct in metal smelting plants resembles lunar regolith. As the slag is abundantly available, large-scale experiments can be conducted. This plant has an area of several hundred square meters where the slag has accumulated up to a depth of several meters. We have obtained permission to use the slag to create the required terrain. We hope to create a crater and other lunar-like environments in this terrain soon and test the rover.

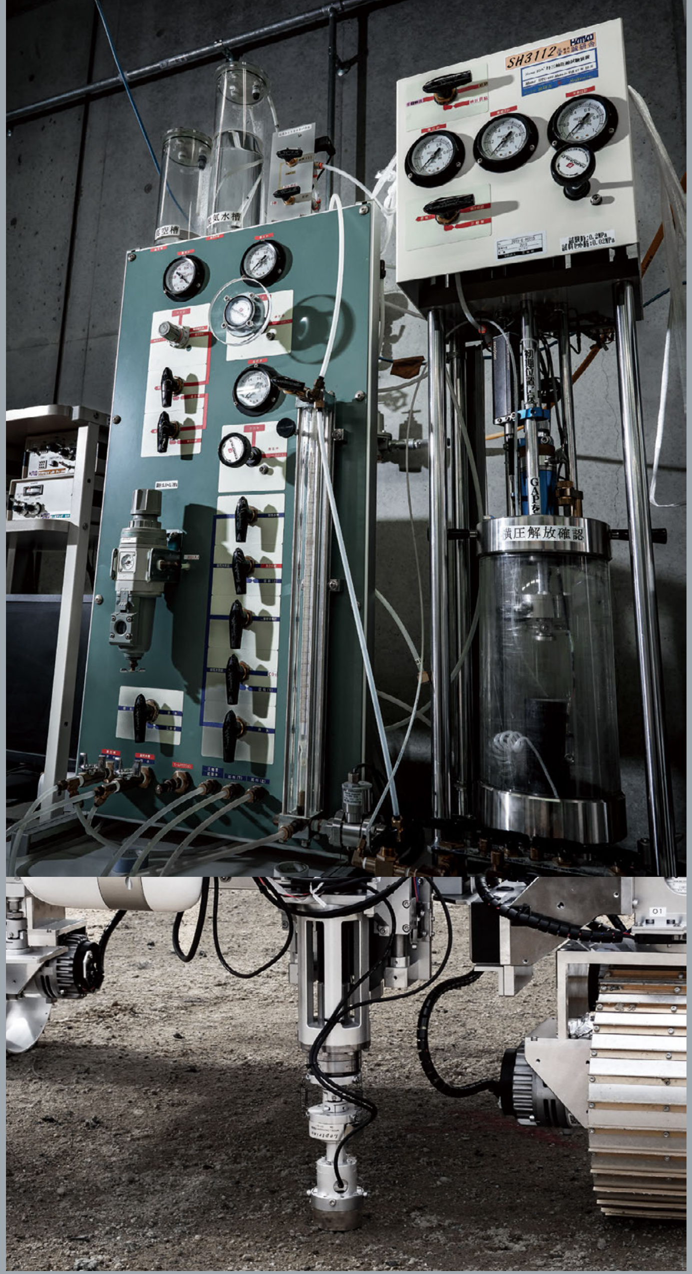
KAKOGAWA To achieve autonomous driving, I would like to conduct experiments where we attach a camera or LiDAR (Light Detection And Ranging) to the robot and let the robot estimate its position.

KOBAYASHI I have heard that construction machinery manufacturers are also starting to place cameras or LiDAR on their machines for position estimation.

KAKOGAWA Exactly. But the primary difference between our challenge and theirs is that the cameras and LiDAR may not withstand cosmic radiation for our project. We may need to consider a different method that does not rely solely on optical technology.

Additionally, estimating the position and drawing a map are two completely different challenges. It is difficult to build a mechanism into a robot that allows it to move autonomously while drawing a map. On the Earth, you first establish a reference point and then measure the coordinates from that point. On the Moon, however, the first question is how to create a reference point as the surface of the Moon is a uniform gray color with few variants in appearance. It may be better to use an artificial reference point. We are currently investigating the type of color or the placement of these reference points.

There is also a method of drawing a map called simultaneous localization and mapping, which allows the robot to determine its position and draw a map simultaneously. The robot detects its environment and decides its move. As it moves, the robot acquires more information about its environment and uses that to update the map. When the map is updated, it can ascertain its po-



Top: Triaxial compression test apparatus: A laboratory setup used to evaluate the deformation and strength characteristics of soils. A cylindrical soil specimen is subjected to all-around confining pressure while applying axial loading, enabling precise measurement of stress-strain relationships and volume changes during deformation.
Bottom: Plate loading and shear testing tool(breadboard model): A testing device mounted on exploration rovers to measure deformation and strength characteristics of the lunar and planetary surfaces. It features two primary functions: (1) a plate penetration to obtain load-settlement relationships for assessing soil stiffness, and (2) a plate rotation under constant pressure to obtain shear stress-shear deformation relationships for evaluating soil strength.

sition within that map and subsequently decide its next move.

KAWASAKI I am still at the stage of considering the best type of materials. Hence, it is hard for me to think about specific uses on the Moon like you two. But, if we are thinking about using them for paving and construction, I think we would first need equipment to produce large quantities of concrete on the Moon.

I mentioned earlier the idea of using a vibratory press to apply pressure. As the Moon has low gravity, compacting the material is challenging using the weight of the press. A macadam roller with teeth would render the finished surface uneven although it is useful to apply some pressure to the material. Alternatively, instead of laying the material directly on the lunar surface and applying pressure, a precast method can be used where several small bricks are prepared in advance and then assembled on-site. In this case, we would build a pressure factory, and the mixing, heating, and pressurizing of the material would be done in that facility.

In the United States, NASA is working with a private construction company to carry out Project Olympus, which aims to use 3D printing to construct living spaces on the Moon and Mars. Currently, they are in the stage of performing simulations on the Earth. Based on my information, they hope to complete the preparations by landing on the Moon by 2026. In the future, the most appropriate construction method can be selected depending on the type and size of the required object.

What We Should Consider for the Future

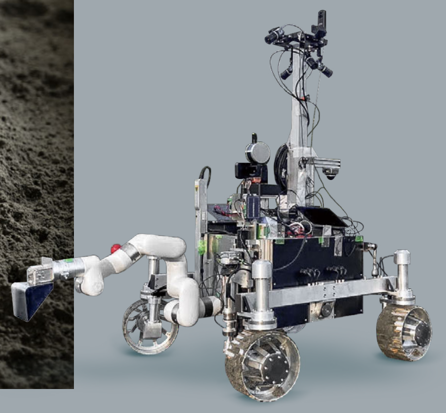
KOBAYASHI Until now, the value of lunar exploration was centered on scientific exploration to reach the Moon and unravel the mysteries of its origin and evolution. However, to make the Moon a humanosphere, we are required not only to conduct scientific exploration but also to consider how to utilize the Moon's resources and how to make use of scientific data. Research institutions in Japan and overseas, including JAXA, are gradually starting to talk about ideas based on data, such as how to use the water discovered on the Moon. However, several of these ideas have not been transformed into more concrete plans. I think the difference between an idea and a plan is whether it is based on a proper investigation. To build structures on the Moon, an on-site investigation and a design theory are needed. As a civil engineering researcher, I intend to continue my research on the lunar surface and pursue structural design theory.

Some of the researchers at the Earth and Space Exploration Center (ESEC) are developing sensors and spectrometers to explore lunar mineral resources. We would like to work with them to develop a drilling robot using science and engineering.

KAKOGAWA Currently, a limited number of organizations focus on the design and development of equipment to be installed on landers and rovers, such as observers, robots, and working machines. BKC is a huge campus, and in some cases, we use fields outside the University, such as the company that Professor Kobayashi introduced earlier. We are fortunate in terms of our field-testing environment. It is important to test robots in an environment that is similar to the actual field rather than a university laboratory. I would like ESEC to serve as a base for lunar and other planetary exploration by connecting fields in different parts of the Kansai region with BKC at the center. In the future, we can propose collaborations with colleagues overseas.

KAWASAKI At ESEC, we have researchers from various fields of Sciences and Humanities. In the future, I would like to focus not only on individual research results but also on collaboration among researchers. I would like to participate in such collaborative activities when my expertise is coveted, and I hope to develop ideas that would encourage other researchers to collaborate.

KOBAYASHI We are both engineers and scientists. We have personnel who can not only develop tools but also interpret the data for further research. I am confident that through ESEC we can add value to lunar exploration.



A model experiment investigating the dynamic interaction between a lunar lander's footpad and regolith. A circular disc simulating a footpad is dropped onto a regolith simulant, and the resulting acceleration response and settlement are measured. Calculation models are developed to predict settlements and impact loads during landing, using soil parameters obtained with the loading and shear testing tool.

KOBAYASHI Taizo, Ph.D.

Professor, Department of Civil and Environmental Engineering, College of Science and Engineering

Vice Director, Earth & Space Exploration Center (ESEC)

Specialty:
Geotechnical engineering

Research Themes:
1. Development of intelligent construction technologies
2. Hazard assessment of slope disaster using an in-situ investigation system
3. Studies on interactions between robots and lunar/planetary surfaces in space exploration

KAKOGAWA Atsushi, Ph.D.

Associate Professor, Department of Robotics, College of Science and Engineering

Specialties:
Dynamics/Control, Intelligent mechanics/Mechanical systems

Research Themes:
1. Development of new robot mechanisms and their control system
2. Actuators operable in hazardous and extreme environments
3. Field robots for infrastructure inspection and environment exploration

KAWASAKI Yuma, Ph.D.

Associate Professor, Department of Civil and Environmental Engineering, College of Science and Engineering

Specialty:
Civil engineering materials/ Construction/ Construction management

Research Themes:
1. Building of Damage Evaluation Method for RC Subject to Steel Corrosion by Monitoring with AE Technology
2. Challenge to Method of Nondestructive Evaluation of Laminated Rubber Bearing by Using AE Technology
3. Damage Evaluation Method for RC Bridge Retainer Reinforced with Steel Sheet by Using Nondestructive Test Method
4. Development of Method of Hybrid Nondestructive Examination of RC Member Subject to Steel Corrosion

LEGAL REGULATIONS

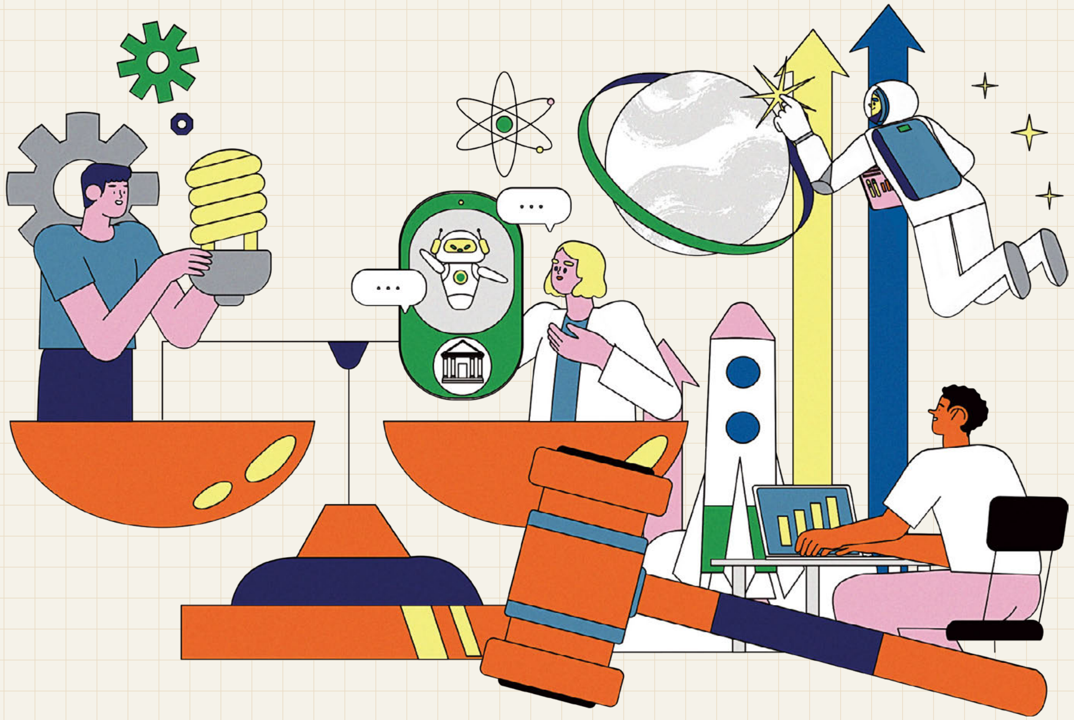
TO SUPPORT RESEARCH AND DEVELOPMENT

IN SCIENCE AND TECHNOLOGY

Since the beginning of human space exploration, several international legal frameworks have been established to ensure the equitable use of space and the fair distribution of associated risks. Satoko KAWAMURA, a professor at the Ritsumeikan University's College of International Relations and an expert in international administration and international relations, examines the application of the principles of these legal regimes to the transnational governance of emerging technologies, including space technology, artificial intelligence (AI), nanotechnology, and biotechnology. The legal regime governing space research and development (R&D) is a rare example of an international legal framework for advanced technology that has been developed from the outset through cooperation among multiple countries. Kawamura suggests that the concept of governance in space can serve as a reference for international rule-making in various advanced science and technology fields.

The legal regime governing the use of outer space has been established through international discussions since the early phases of space exploration. One of the most fundamental treaties is the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, commonly known as the Outer Space Treaty or Space Charter. This treaty enshrines principles such as the freedom of outer space, the non-appropriation of space in any form, including the claim of sovereignty, the peaceful use of outer space imposing the partial demilitarization of the Earth's orbit, the common interest, and international space cooperation.

The Outer Space Treaty has been ratified even by the United States and the then Soviet Union, which were the main contenders in the intense space race. This highlights the advances in international governance of space development when compared with those in other fields of science and technology.



The establishment of international treaties related to space has been challenging owing to the increasing complexity of international relations. The last United Nations Space Treaty is the 1984 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the Moon Agreement), which provides for the demilitarization of the Moon and other celestial bodies, except the Earth, and the prohibition of the appropriation of Moon and its natural resources. Additionally, the Moon Agreement ensures the principle of freedom of space for the Moon and other celestial bodies. However, most countries, including the United States, Russia, and Japan, have not ratified the Moon Agreement due to political opposition related to the regime of exploration and exploitation.

Various issues, such as space debris management, arise with rapid space development. Additionally, rules must be established to address situations not anticipated in the earlier phases of space exploration and exploitation. For example, the emergence of numerous private space-related companies and their participation in R&D in various capacities, including public-private partnership.

Kawamura examines the type of governance needed to balance the promotion of space R&D with risk management under these circumstances. According to her, space R&D is still in a nascent stage and is continually evolving. Thus, rigid policies and legal norms can hinder free development in this domain. Additionally, she suggests that the norms and institutions also serve to protect the rights and interests of developers and non-spacefaring developing countries, ensuring fair risk distribution.

The relationship between political thought and international relations captured the imagination of Kawamura. In particular, she recalls "The origin of the idea of cooperation among people across national boundaries fascinated me. This has been considered by many thinkers since ancient times. I initially focused on *Zum Ewigen Frieden (Perpetual Peace)*, which was written by the German philosopher Immanuel Kant in the 18th century. According to Kant, whose ideas led to the modern concept of the United Nations, the principle for peace was that the civil constitution of each state should be republican.”

Kawamura admits that republicanism may not be a familiar concept in Japan. According to her, some people may mistakenly identify republicanism only with democracy or presidential systems. However, republicanism is about *res publica* (the public thing), encompassing the theory of a political system that governs a community of diverse people and the idea of citizenship upholding that system. Republicanism seeks to prevent the arbitrary exercise of power through laws and institutions and emphasizes the importance of citizens actively participating according to their abilities in the pursuit of the common good. One of the origins of republicanism can be found in the Roman Republic, where the consuls and the Senate were at the center of politics but votes on bills and other important issues were in the domain of the assembly, which comprised representatives of all citizens. “Studying the relationship between republicanism and the idea of an international community from ancient times to the present piqued my interest in global citizenship and cosmopolitanism. I specifically was fascinated by the idea of a transnational governance comprising states, intergovernmental organizations, and global civil society working together to address challenges that transcend national borders.”

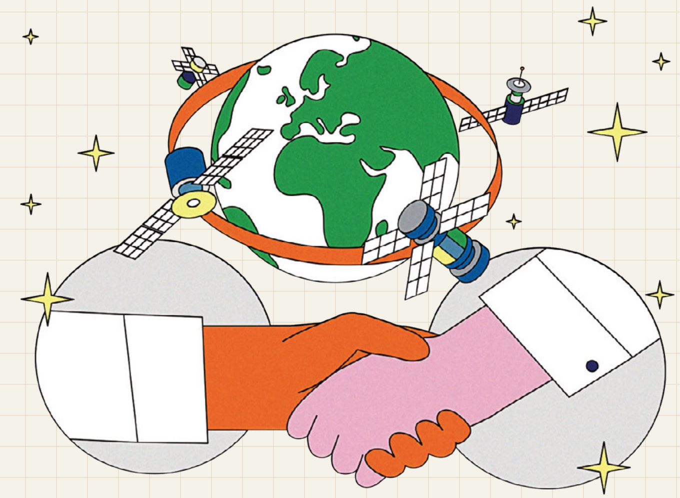
It was around this time that Kawamura met Kunihiko Tatsuzawa, who is a Professor Emeritus at Ritsumeikan University. “Tatsuzawa is an expert in international laws, especially space law. He is also well-versed in history and politics and can analyze international order from a broad perspective. I learned from him that the principles of space law are based on ancient Roman law and other European philosophy even though space law is based on a modern and advanced set of rules.” According to Kawamura, republicanism is a political philosophy that has served as an underlying theme in Western political thought from ancient times to the present. In the field of advanced science and technology, republicanism encourages entities other than the state, such as corporations, research institutions, and academia, to independently establish their norms and institutions without relying on any particular authority.

“Advanced science and technology can be both a boon and bane for humanity. This also applies to the research that Earth and Space Exploration Center (ESEC), Ritsumeikan University,” explains Kawamura. “The distinct separation of civilian and military research is impossible as evidenced by research on rockets. In the early stages of the Internet’s development, one of the main goals was to secure a military communications network. Conversely, technology developed for civilian use has been diverted for military use. However, we cannot stall development on account of the risk of misuse. Rules for harnessing science and technology must be established based on deliberation.”

Although establishing rules is important, why can’t individual states be allowed to formulate their own rules? Kawamura answers, “Because the practical application of advanced science and technology does not affect only the people of one country.” For example, several non-functional satellites, known as “space debris,” orbit the Earth. Some of these satellites are nuclear-powered satellites. In the late 1970s, one such satellite crashed in Canada. Although no human casualties were reported, radioactive debris from the impact contaminated the vast natural environment. Current technology cannot determine the exact location of space debris, except for just over 30 minutes before impact. “The need for international risk management is critical, irrespective of who launched the satellite.”

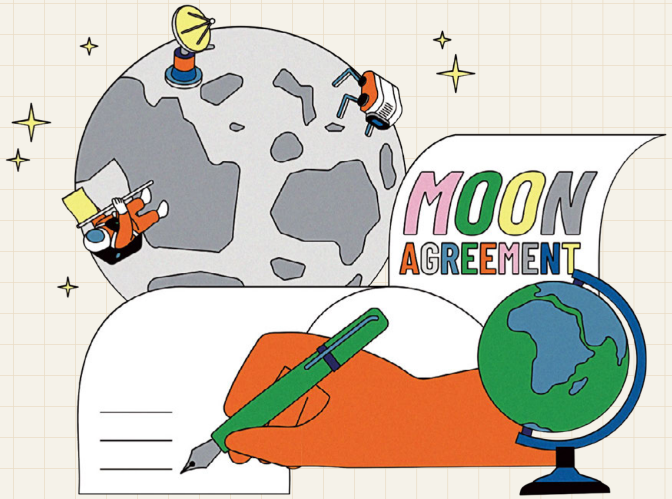
In addition to formulating rules for risk distribution, the benefits of R&D should also be fairly distributed. Fair distribution of benefits is not equivalent to equitable distribution among humans. The personnel involved in providing these benefits, such as researchers and developers, should be rewarded. For example, the financial reward of researchers and developers may vary depending on the country with poorer countries being charged less.

An example of equitable distribution is the allocation of geostationary satellite orbits in the 1980s. Geostationary satellites are a type of artificial satellite that can remain in the same position relative to the ground, as if stationary, by orbiting above the equator at the same speed as the Earth’s rotation. This type of satellite orbit is called a geostationary orbit. Only three satellites in this orbit cover the telecommunications of all areas of the Earth, except the polar regions. Kawamura explains that during the Cold War, spacefaring countries tried to place satellites in the geostationary orbit. However, the constant flying of satellites from major powers over the territory of equatorial developing countries was not welcomed by the residents of these territories. These residents considered the geostationary orbit over their territory as their natural wealth and resources and claimed their sovereignty by invoking the UN Declaration on States’ sovereign rights over their natural wealth and resources. Sovereignty over space is not recognized by the Outer Space Treaty and other developing countries opposed the exclusive rights of equatorial countries. Thus, the equatorial countries withdrew their demand but were granted recognition for the fair distribution of profits. Rules have now been established within the framework of the International Telecommunications Union to ensure a fair distribution of geostationary orbits and radio frequencies by the quinquennial world allocation plan. Equatorial countries lease their allotted orbits to other countries or engage in joint development with technologically advanced countries.



The effective enforcement of rules established even under the Moon Agreement is not guaranteed unless each state adheres to them. “This is where the difficulty of international law lies,” Kawamura points out. “However, the law has been traditionally more flexible.” Only a few countries and a limited number of spacefaring countries have ratified the Moon Agreement. One of the reasons for this is the groundbreaking phrase in the Moon Agreement that designates the Moon as “the common heritage of mankind.” The industries from the United States strongly opposed this principle, and consequently, the United States did not ratify the agreement. “Both the United States and the Soviet Union participated in drafting the agreement and agreed on the outline of the text. Hence, I believe that the Moon Agreement can be interpreted as a general principle of law. Except for resource-related points, such as not placing weapons or not conducting military exercises on the Moon, the content of the agreement can be agreed by every state.”

Recently, Kawamura has been interested in governance through public-private partnership. The management of lunar resources was a major issue during the drafting of the Moon Agreement. However, national and private organizations have been recently working together internationally to explore and exploit these resources. Lunar exploration, which has continued since the Apollo missions, has revealed that the helium isotope helium-3 is abundant on the Moon but scarce on Earth. Helium-3, which is considered to be an efficient nuclear fusion energy source, produces very little radioactive waste, and only 30 tonnes of Helium-3 can operate a power plant of 1 million Kw for a year. To use helium-3 as an alternative energy resource to oil, discussions on a mech-



anism of global governance have been actively pursued, especially in the United States, by governments, public institutions, private companies, and investors since the 1980s. Kawamura believes that these discussions can be applied not only to space but also to R&D in advanced science and technology in general.

In some cases of joint R&D between the government and the private sector, government involvement has become unnecessary with the progression of commercialization and practical application as observed in the case of Intelsat, which began as an international organization. Technologically advanced countries, such as the United States, liberalized international satellite communications. Thus, international public institutions for satellite communications could not compete with the private sector, resulting in their privatization. However, to ensure that communications essential to national security would not be disrupted in times of emergency, public services were decided to be provided by another public organization, the International Telecommunications Satellite Organization, rather than Intelsat. Although the state still plays a central role in space development, it will be substituted by the private sector in the near future. Kawamura speculates that the case of the Intelsat privatization negotiations may be useful in demarcating the roles of the private sector and the international public services.

Kawamura is also exploring legal principles, such as the prevention principle, the follow-up obligation, and the precautionary principle, which are crucial for establishing new rules and institutions that correspond to the risks associated with advanced technology. For example, the "follow-up obligation," as outlined in the Outer Space Treaty, is crucial for new technologies whose efficacy might be scientifically proven but not for technologies for which the related risk cannot be predicted, such as AI and mRNA vaccines for the coronavirus. This obligation is key to a new governance mode that balances the promotion of R&D with risk management and prepares for potential unexpected harm.

The legal framework governing space R&D has been established through cooperation among multiple countries even during times of deteriorating international relations, such as the Cold War. Kawamura notes that the accumulation of these efforts provides an invaluable precedent for establishing governance in emerging scientific and technological fields. She aims to continue her research on establishing norms and institutions that will efficiently utilize the results of cutting-edge science and technology in collaboration with researchers not only in Japan but also abroad.

KAWAMURA Satoko, Ph.D.

Professor, College of International Relations

Specialties: International Relations (Governance of Advanced Technology, International Thought), International Administration, The Law of International Relations

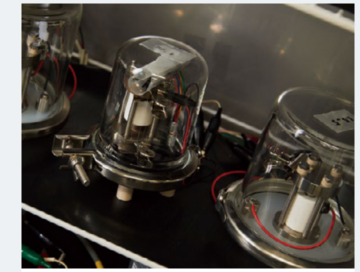
Research Theme:Research on Global and Transnational Governance for Advanced Science and Technology through Public-Private Partnership.

OTHER NOTABLE ARTICLES

[E-vol.5 WELL-BEING]

Psychology Beyond Borders

SUZUKI Hanako, Ph.D.
Associate Professor,
College of Comprehensive Psychology



[Issue#21 Decarbonization]

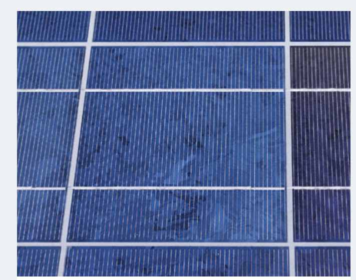
What is the Governing Factor Enhancing the Performance of Lithium-Ion and Fuel Cells?

ORIKASA Yuki, Ph.D.
Professor,
College of Life Sciences

[Issue#20 Regeneration]

Exploring Sustainable Resource Circulation Mechanisms from Bottle-to-Bottle Recycling

NAKAMURA Shingo, Ph.D.
Professor,
College of Business Administration



[Issue#20 Regeneration]

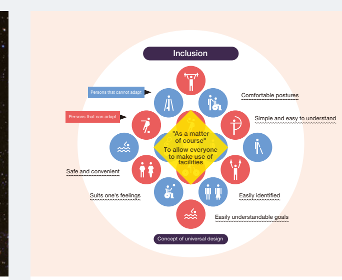
Don't Throw Them Away—Those Solar Cells Still Have Power Generating Capacity!

MINEMOTO Takashi, Ph.D.
Professor,
College of Science and Engineering

[Issue#15 SPACE]

Developing Team Behavioral Skills Through Astronaut Training

MINATO Nobuaki, Ph.D.
Professor, Graduate School of Technology Management



[Issue#3 Sports]

What type of sport facilities can allow people both with and without disabilities to enjoy sports/exercise together?

KANAYAMA Chihiro, Ph.D.
Professor,
College of Social Sciences

RITSUMEIKAN UNIVERSITY

As a comprehensive university, Ritsumeikan University has continued to bring various researchers together to cooperate and traverse the boundaries of their respective fields, create new academic areas, and develop young researchers to lead the next generation. The university, where excellent faculty and unique students come together, provides an environment where you can cooperate with people who see the world from a different point of view in order to create new things and improve yourself.

Rurikoin temple

KYOTO

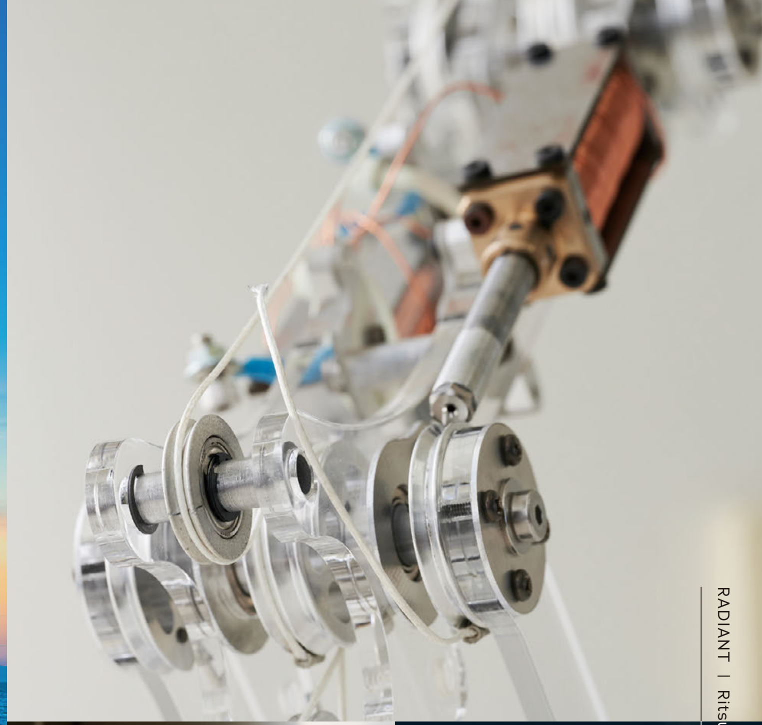
Kiyomizudera temple

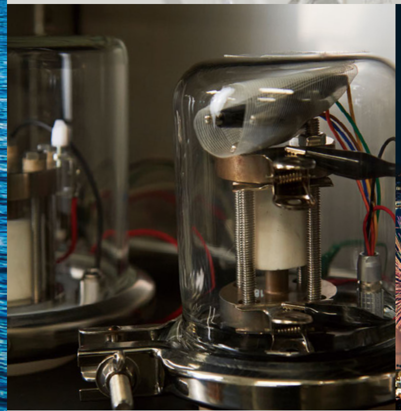
KINUGASA CAMPUS

Surrounded by numbers of cultural heritages, Kyoto with its long and deep history has been a core city of Japan since ancient times. The campus is located in a quiet area of the city where many famous temples are situated. Kinugasa campus combines tradition and innovation in a place where students are able to disseminate cutting-edge research to the world while being surrounded by Japanese tradition and culture.

SHIGA

Shirahige-jinja shrine





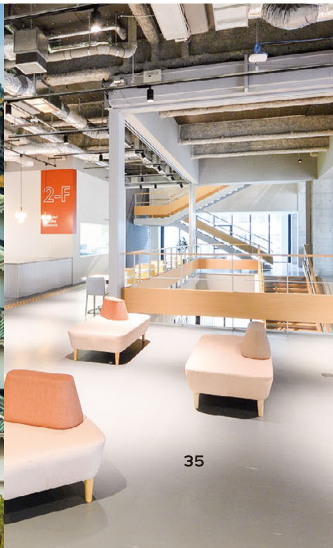
BIWAKO-KUSATSU CAMPUS

Offering top tier science education and equipped with some of the largest research facilities, Biwako-Kusatsu Campus (BKC) is a campus where students can conduct research activities that take advantage of the campus's location surrounded by nature and nearby Lake Biwa, and where numerous companies have established their own research facilities. It is an innovative campus which creates and disseminates world-class educational research, knowledge and technologies to all regions of the globe.

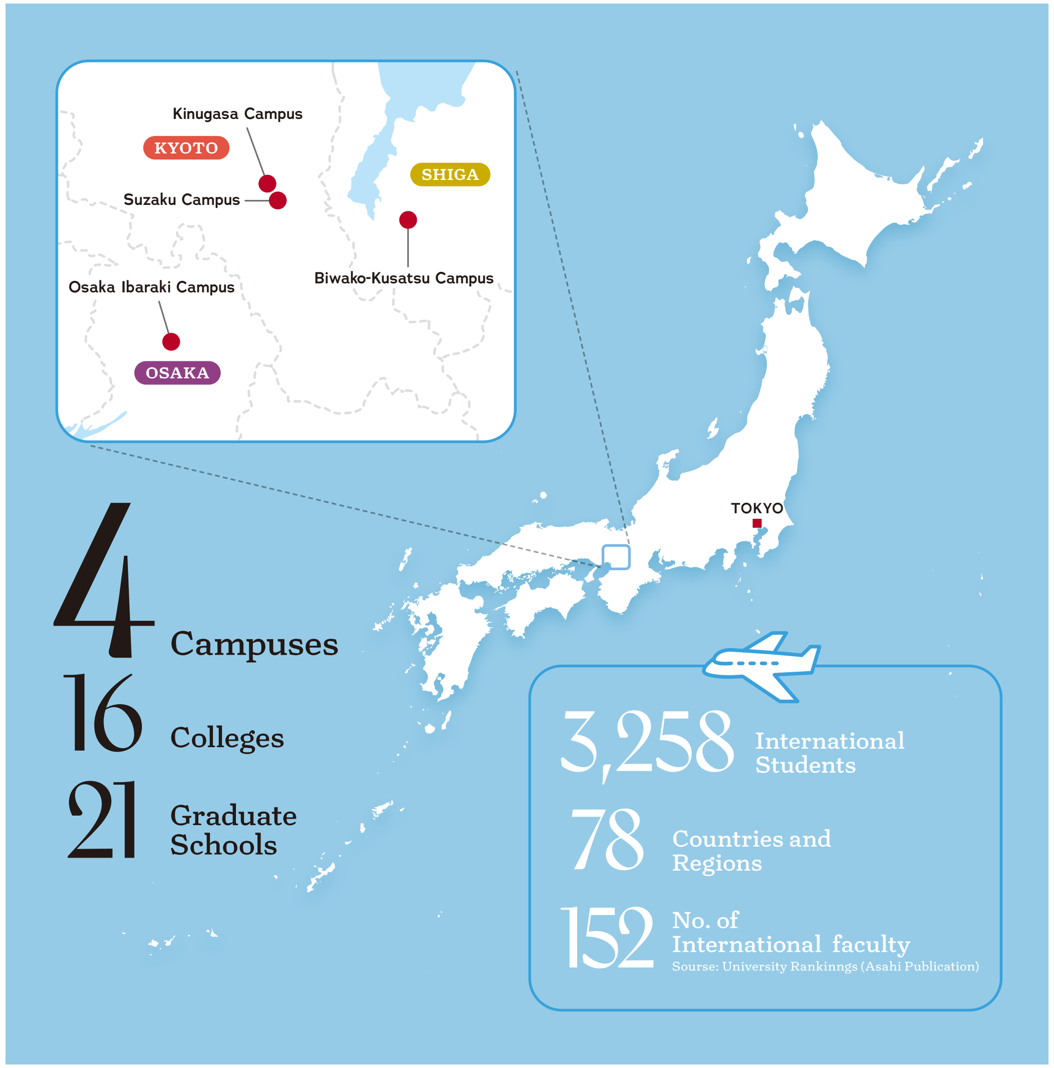
OSAKA

OSAKA IBARAKI CAMPUS

The Osaka Ibaraki Campus (OIC) is located in Ibaraki City in Osaka Prefecture. Osaka is one of the biggest international and commercial centers in Japan, and the campus is expected to facilitate collaboration with industry and government institutions, promote the Ritsumeikan Academy's activities on the frontline of social collaboration and exchange, and support the further development of students.



RITSUMEIKAN UNIVERSITY CAMPUSES 2024



4 Campuses

16 Colleges

21 Graduate Schools

3,258 International Students

78 Countries and Regions

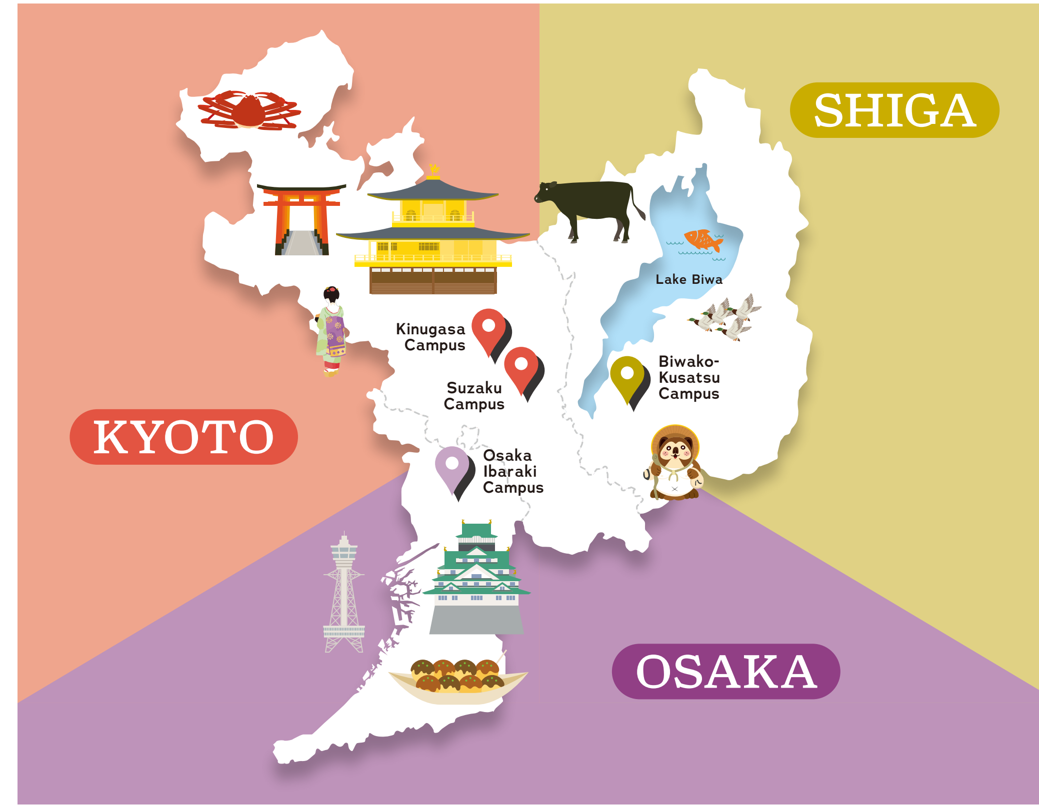
152 No. of International faculty

Sourse: University Rankinngs (Asahi Publication)

RESEARCH

6 Research Organizations	**33** Research Centers	**16** Research Institutes

CUMPUSES AND SURROUNDINGS



FACULTY 2024

838 Professors

273 Associate Professors

150 Assistant Professors

220 PDs, RAs

RANKINGS

QS World University Rankings 2025

QS WORLD UNIVERSITY RANKINGS®

3rd

Among Private Universities in Japan

THE Impact Rankings 2024

THE IMPACT RANKINGS

RANKED

15th for SDG 1	1 NO POVERTY
81st for SDG 6	6 CLEAN WATER AND SANITATION
63rd for SDG 14	14 LIFE BELOW WATER

*90th for SDG 2, 86th for SDG 15

IN THE WORLD

INTERNATIONAL PARTNERS

474 Universities and Institutions

69 Countries and Regions

ACADEMIC PUBLICATIONS

Publications in Top 10% Percentiles

72 | 7.2%

Percentage = No. of Publications in Top 10% Percentiles (Field - weighted) / No. of Scopus - indexed publications

International co-authored publications

322 | 32.2%

Percentage = No. of international co-authored publications / No. of Scopus-indexed publications

Source: Elsevier's "SciVal" (as of November 2024)

INTERNATIONAL RESEARCH NETWORK

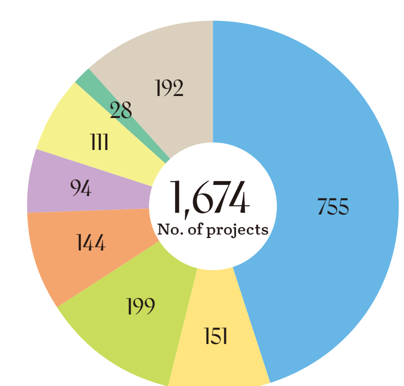
74 COUNTRIES/REGIONS 978 RESEARCHERS

USA	147	SINGAPORE	28	FINLAND	6
SOUTH KOREA	119	ITALY	28	CZECHIA	5
UK	64	CANADA	22	TURKEY	5
CHINA	59	INDONESIA	20	NEW ZEALAND	5
FRANCE	53	BELGIUM	19	HUNGARY	5
TAIWAN	50	SPAIN	16	MEXICO	5
AUSTRALIA	46	MALAYSIA	16	SOUTH AFRICA	5
GERMANY	42	AUSTRIA	14	CYPRUS	4
VIET NAM	35	INDIA	9	UAE	4
THAILAND	34	SWEDEN	9	GREECE	4
		NETHERLANDS	8	PHILIPPINES	4
		DENMARK	7	PERU	4
		MONGOLIA	7	PORTUGAL	4
		SWITZERLAND	7	ARGENTINA	3
		IRELAND	6	CAMBODIA	3

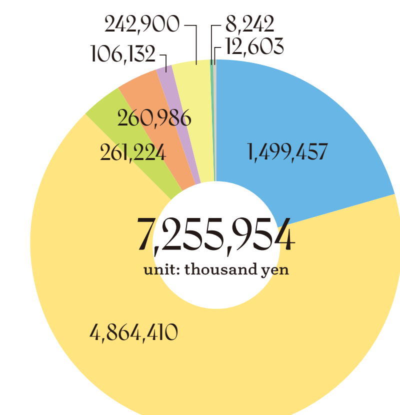
AND OTHER 34 COUNTRIES

EXTERNAL RESEARCH FUNDING 2023

No. of Projects by Funding Source



Monetary Amount by Funding Source



- Grants-in-Aid for Scientific Research (KAKENHI)
- Other Public Research Funding
- Contracted Research
- Joint Research
- Grants and Subsidies
- Private Research Funding
- Revenue from Patents etc.
- Other revenue

TOPIC

AN ASTRONAUT'S PERSPECTIVE

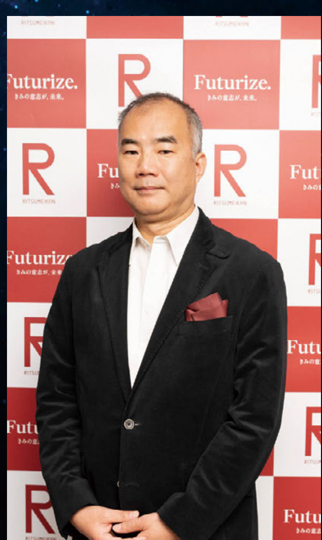
From Astronaut Soichi Noguchi, Ph.D.

Pro Vice President/Research Advisor to ESEC

At Ritsumeikan, a comprehensive academy encompassing elementary education on one hand and university on the other, space-related activities are gradually gaining momentum.
It is hoped that substantial activities can be conducted under the admirable vision of "contributing to the preservation and expansion of the humanosphere."
In addition, I would like to tell young people who aspire to be in space that now is a great time to get involved, and with career opportunities expanding, there is a lot of potential related to space in various ways.
I yearn to inspire students and researchers alike and bring international progress back to the front lines of academia.

ESEC
EARTH & SPACE EXPLORATION CENTER, RITSUMEIKAN UNIVERSITY

PROFILE



Soichi NOGUCHI, Ph.D. (Astronaut, Professor, CTO)

Dr. Soichi Noguchi graduated from the Graduate School of University of Tokyo in 1991. His first spaceflight was STS-114 on the space shuttle Discovery in 2005. He conducted three spacewalks as a lead spacewalker and became the first Japanese astronaut to perform EVAs on the International Space Station (ISS). In 2009, he became the first Japanese flight engineer for the Russian Soyuz spacecraft TMA-17. In 2020, he became the first non-American to board on SpaceX spacecraft, participating in the world's first commercial operation ISS mission (NASA Crew-1).

He was the first astronaut to accomplish three different methods of Earth entry (runway, ground, and ocean), and officially certified by Guinness World Records in two categories. He received a YouTube Creator Award with a live performance of Chopin from Space, and Distinguished Award from the Japanese Association of Qualitative Psychology for in-depth "Tojisha" Kenkyu (Self-directed Studies) on his cosmic experiences. He was inducted into the Genius 100 Visionaries by the Genius 100 Foundation, an international NPO.

He left NASA in 2022, and currently holds several prestigious positions, including President of Mirai Space Co., Ltd., Chief Technology Officer of the Institute for International Socio-Economic Studies(IISE), Executive Adviser of IHI Corporation, Sustainability Advisory committee of Mitsubishi Corporation, Project Professor at the University of Tokyo, Distinguished Fellow for Space Technology at the World Economic Forum(WEF), and Co-Chair, Astronaut Admin Committee, the International Astronautical Federation (IAF). Appointed as Pro Vice President of Ritsumeikan University and Research Advisor of the Earth & Space Exploration Center (ESEC) in 2023.

Outside of work, he enjoys cooking, camping, songwriting (Sony Music Artists), and flying airplanes and helicopters (CFII, MEI).

RESEARCH OFFICE

The Research Office has the aim of contributing to society through research exchanges, technological transfers, support of ventures, etc., utilizing the intellectual assets of the University. To centralize information on researchers at the University and their diverse external needs as well as to facilitate industry-government-academia activities more smoothly, depending on the challenges involved, we serve as an integrated point of contact for various matters associated with research.

Research Office at Kinugasa Campus

- College of Law
- College of Social Sciences
- College of International Relations
- College of Letters
- Graduate School of Language Education and Information Science
- Graduate School of Core Ethics and Frontier Sciences
- School of Law
- Graduate School of Professional Teacher Education

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Research Office at Biwako-Kusatsu Campus

- College of Economics
- College of Sport and Health Science
- College of Gastronomy Management
- College of Science and Engineering
- College of Life Sciences
- College of Pharmaceutical Sciences

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- Graduate School of Technology Management
- Graduate School of Management

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