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INDEX

Feature Article

REACHING SPACE FROM KASHIWA

東京大学大学院新領域創成科学研究科
GRADUATE SCHOOL OF FRONTIER SCIENCES, THE UNIVERSITY OF TOKYO

Feature Article

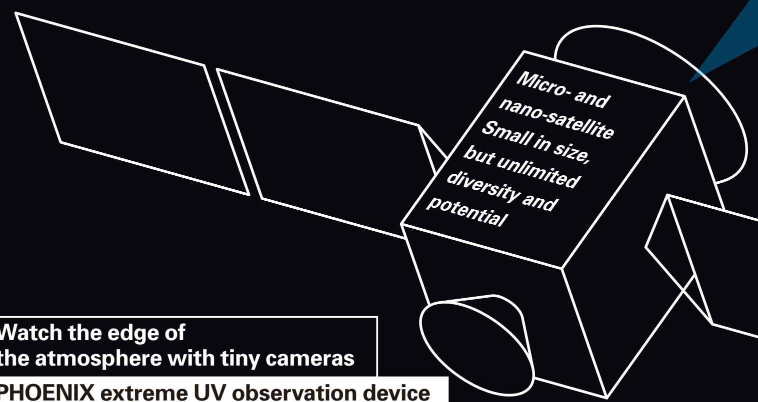
REACHING SPACE FROM KASHIWA

Space—the venue where diversity manifests. In December 2020, JAXA's Hayabusa 2 capsule returned to the Earth, and in December 2021, for the first time, a private Japanese citizen stayed on the International Space Station (ISS).
In just the past few years the scope of space research, development, and use has rapidly expanded.
Graduate School of Frontier Sciences (GSFS) is progressing into research area beyond traditional disciplines of space science and engineering linking various sectors together.
This article presents some of our efforts to foster human resources for space under the title "Reaching Space from Kashiwa," focusing on GSFS research into the field of microsatellites that have been attracting more and more interest in recent years.

(Interviews, editing, text: FURUI Kazutada)

Use water for fuel!
AQUARIUS: water resistojet propulsion system

New possibilities for satellites with new materials
Heat-resistant shape-memory alloys and titanium alloys



Watch the edge of the atmosphere with tiny cameras
PHOENIX extreme UV observation device

Aerodynamic drag turned from disadvantage to advantage
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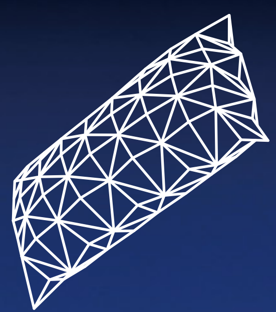

Launch small, use large
Spatial structure in space

Connecting Kashiwa and space with radio waves
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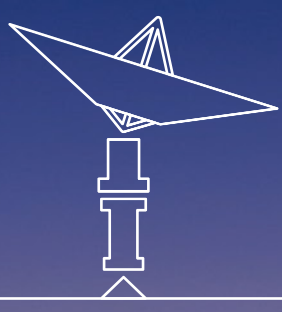


Kashiwa Campus

Learning at the frontier of space development
JAXA collaborative laboratories

Challenge in education to eliminate borders between science and engineering
DESP (Deep Space Education Program)

Lower costs and shorter development time are our strengths

Microsatellites: Hiding great potential

	Mass	Cost	Development time
Large	1 t+	¥30 billion+	5 years+
Small	100 kg–1 t	¥5 billion+	3 years+
Micro	**10–100 kg**	**Up to ¥5 billion**	**Up to 3 years**

Until now, space development has required enormous funding and needed decades to measure its efforts, thereby limiting it to national-level projects. But the situation has been changing dramatically as symbolized by the microsatellite. Since the first launch of a microsatellite in 2003, the number of launches using the surplus capacity of larger rockets has increased rapidly.

Satellites come in various sizes, and NASA's classification places the Japanese "chōkogata" satellite among the 10–100-kilogram microsatellites, although this Japanese size commonly includes the still-smaller 1–10-kilogram nanosatellites (cubeSats) as well.

A CubeSat is a satellite combining several basic units in the form of 1U cubes each measuring 10 × 10 × 10 cm (for example, 2U, 3U, etc.), and it is widely used as a standard-form microsatellite.

The strength of the microsatellite is its lower cost and shorter development time. Compared to larger satellites, which cost more than 30 billion yen, and small satellites at over 5 billion yen, a microsatellite weighing 50 to 60 kilograms can cost less than 1 billion yen. Moreover, while it is not unusual for a large satellite to take ten years to develop, completing a microsatellite in two years is not just a dream.

Microsatellites are used in such fields as communications, technical demonstrations, remote sensing, and scientific observation, but they also hold great potential in the fields of space exploration and utilization. Academic fields and areas of study that conventionally had no direct connection with space are now finding such connections.

Easier experiments and research in space

GSFS has high expectations for microsatellites as a connector that links different fields in new forays in space exploration and development. In fact, unique research and development that spans several fields is already underway.

Owing to their small size, microsatellites have found a variety of means for getting to space. Some are launched by several groups from a rocket that they have rented out, others are delivered to a space station as freight and then released into space with a spring mechanism, yet others are carried in unused corners in the payload fairing of a large rocket; all of these have resulted in greater launch frequency and lower transportation costs.

Professor SUZUKI Kojiro, an expert in aerodynamics and the leader of a research and development group working on atmospheric entry shields that open like an umbrella when in use, comments:

"In 2017, the microsatellite EGG (*1) was released into space from Kibo, the Japanese experiment module of the International Space Station, which attracted fellow specialists in aerodynamics from JAXA and universities. I think we are able to produce unique ideas because we are a group of aerodynamicists and are not sticking to the traditional space technologies"

With EGG, we made a paradigm shift proving that atmospheric entry is possible without a rigid capsule, and now with the launch of its successor, BEAK (*2), in 2022 we plan to further challenge the technology.

"With BEAK, we are planning to demonstrate the technology that can change the value of the aerodynamic drag from "to be avoided (for a satellite not to fall) " to "to be utilized (for controlling the flight orbit without using fuel)" and at the same time put the equally unfavorable unloved aerodynamic heating during atmospheric pass to use for driving power to open umbrella-like aeroshell deployed with the ribs made from the shape memory alloy" (Prof. Suzuki)

In addition to microsatellites' lower cost and shorter development time, microsatelites greatest strength could be its comparative ease in allowing a broad variety of experiments and research to be conducted in space.

[BEAK, which transforms again and again in flight]

By opening its umbrella and then discarding it, thus changing the shape several times, the satellite can change its air drag, and control its flight orbit, that is, how to fall to the ground.

400 km
Depart from the International Space Station

Open the external solar array panels and the film stretched between them
▶Rapid increase in air drag, the satellite begins descent

200 km
Detach the external solar array panels
▶Rapid decrease in air drag, descent stops

160 km
Deploy the aeroshell with the shape-memory-alloy ribs
▶Second rapid increase in air drag, descends again, enters the atmosphere, burns up

SUZUKI Kojiro
Professor
Department of Advanced Energy

*1: Abbreviation of re-Entry satellite with Gossamer aeroshell and Gps/iridium. This represents its objectives with the E for re-Entry satellite into the atmosphere, the G for Gossamer aeroshell for demonstration of functions including the deployment of aeroshells in space, and the G for Gps/iridium for demonstration of the positioning and communication system using GPS and Iridium global network service.

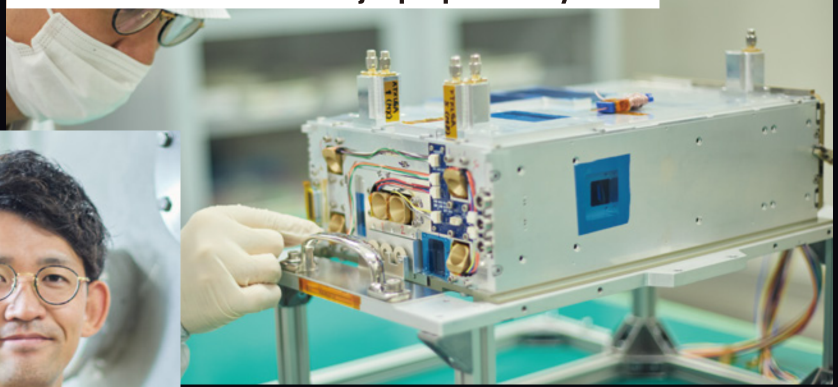
*2: Abbreviation of Breakthrough by Egg-derived Aerocapture Kilt vehicle. The objective is to demonstrate engineering technology for achieving planetary exploration with micro-probes and nano-landers.

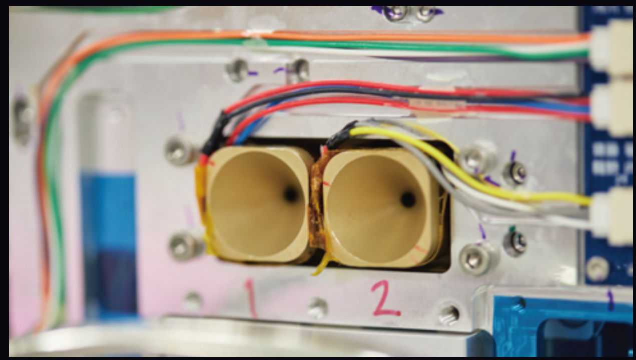
Latest GSFS-led research into "microsatellites"

GSFS's characterstic feature of functioning as a node joining different fields of research is proving relevant in carrying out a variety of research and technical development relating to microsatellites. Recently, in addition to BEAK, we have been developing instruments to be installed on EQUULEUS (*3), a domestically produced microsatellite to be launched in 2022 in the first of NASA's next-generation large rockets in the SLS. Let us present the latest research into microsatellites being led by GSFS.

*3: Abbreviation of EQUilibriUm Lunar-Earth point 6U Spacecraft. A CubeSat Earth–Moon Lagrange point probe-developed by the Intelligent Space Systems Laboratory (ISSL), the University of Tokyo,, and the Japan Aerospace Exploration Agency (JAXA). The main body is a 6U cube sat, and in addition to being provided with AQUARIUS for propulsion, it also has an extreme UV observation device (PHOENIX), ultra-high-speed camera (DELPHINUS), and dust sensor (CLOTH).

Use water for fuel!
AQUARIUS: water resistojet propulsion system





▲Two adjacent jet nozzles in the center.
◀Water vapor is emitted from six nozzles: two in the center and four in the corners.

SEKINE Hokuto
Assistant Professor
Department of Aeronautics and Astronautics, Graduate School of Engineering (Doctoral degree from Department of Advanced Energy)

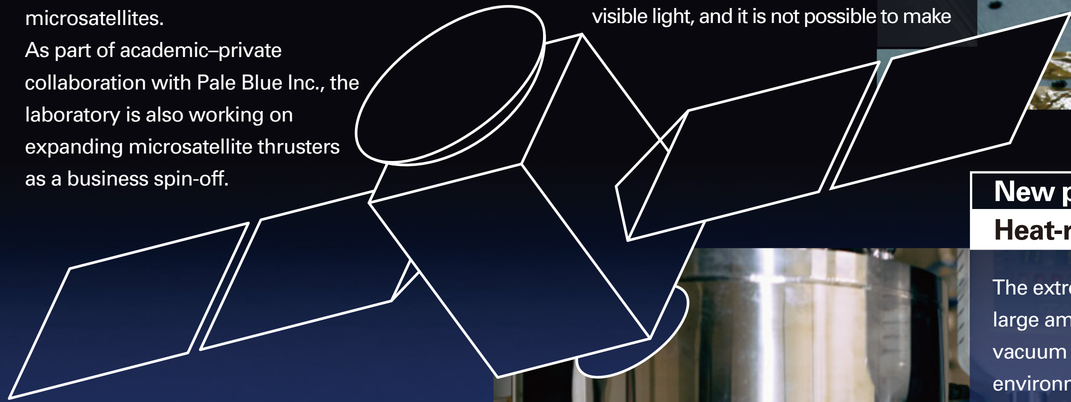
The Komurasaki-Koizumi Laboratory has continued research into engines (thrusters) for microsatellites. In 2014, they developed and successfully demonstrated the operation in the space of an ion thruster, which was the propulsion system for the microsatellite PROCYON.

Now, they have developed the compact water resistojet thruster named AQUARIUS. We asked Assistant Professor SEKINE Hokuto from the laboratory about the significance of this development.

"As water is safe, harmless, and easy to handle, it holds great potential for use in microsatellites, which have stringent mass restrictions. However, water freeze rapidly in space and requires large amounts of heat to vaporize. By locating the communication instruments, which constantly generate a great amount of heat, near the water vaporization chamber, EQUULEUS minimizes the heater power needed for vaporization, allowing the system to work under limited resource restrictions."

Thrusters that use water are a world-leading technology. As both the Moon and Mars may have water (ice), in the future, we may even be able to procure water on-site for use in microsatellites.

As part of academic–private collaboration with Pale Blue Inc., the laboratory is also working on expanding microsatellite thrusters as a business spin-off.



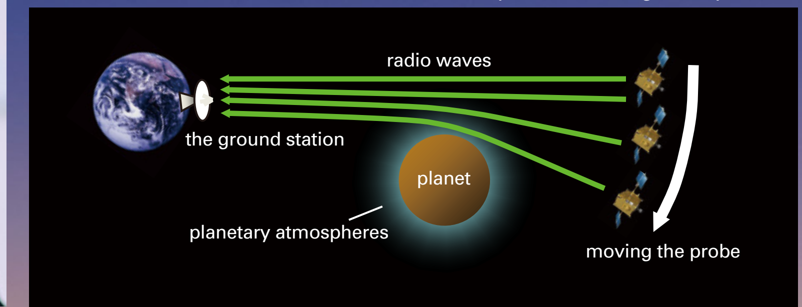
Exploring planetary atmospheres from afar
Radio occultation observation

IMAMURA Takeshi
Professor
Department of Complexity Science and Engineering

Akatsuki, the Venusian probe that gave Japan its first successful planetary exploration, was highly regarded around the world for revealing the atmospheric structure of Venus. The structure was until then unknown due to the thick clouds covering the planet and the technology that enabled this finding was radio occultation observation.

"Radio occultation is an observation method that uses the fact that radio waves connecting a probe and the ground station skim the atmosphere of a planet when the probe hides and reappears from behind the planet from the perspective of the ground station and derives the structure of the planet's atmosphere from the variations in frequency and strength of the radio waves at these times."

This explanation was given by Professor IMAMURA Takeshi, an expert in planetary atmospheric physics and the leading researcher on radio occultation observation in Japan. According to Professor Imamura, radio occultation observation itself is a research method dating to the twentieth century, but it attracted serious attention in Japan when Akatsuki succeeded in obtaining its own data. The simple principle has a wide scope for application, and Akatsuki is also measuring the structure and fluctuations of the high-temperature gases (corona) surrounding the Sun. Professor Imamurais nurturing the idea for future initiatives including installing radio sources for radio occultation observation on microsatellites and observing planets by radio communications between satellites.



▲Useful in cases where optical observation devices can falter, due to thick clouds etc.

Watch the edge of the atmosphere with tiny cameras
PHOENIX extreme UV observation device

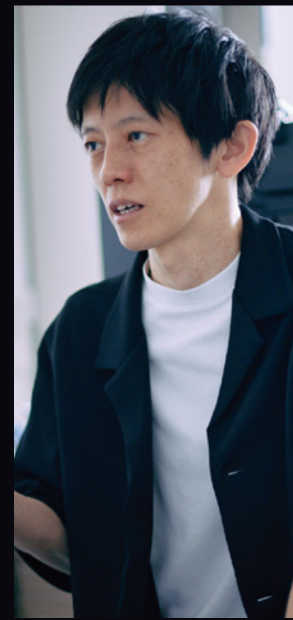
The Yoshikawa-Yoshioka Laboratory has been working on research to visualize the atmosphere and plasma around planets and has developed a microcamera that is about the size of a small can (barrel diameter: 60 mm) to observe invisible extreme ultraviolet light.

This is to be installed on EQUULEUS and will capture images of the helium around the Earth from 2nd Earth–Moon Lagrange point (EML2), which is on the far side on the Moon.

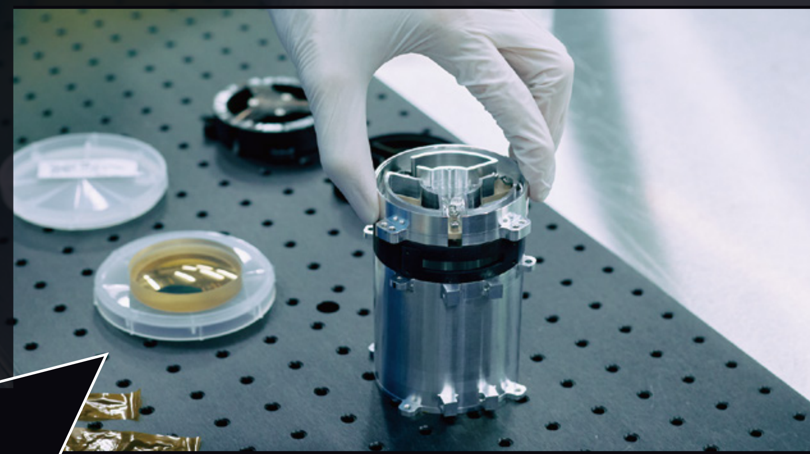
"This is the first time to put a camera like the PHOENIX on a microprobe and send it out into deep space (space further than the Moon). By ongoing observation from a distance of about 380,000 kilometers far from the Earth, we aim to discover the hitherto-unknown broad dynamics of exospheric helium." (Lecturer YOSHIOKA Kazuo)

Nonetheless, the reflectance of extreme UV light is about one-tenth of that of visible light, and it is not possible to make the device larger, as it will be installed on a microsatellite. In these circumstances, Yoshioka and his team developed a mirror that uses an interference effects by cross-deposited thin layers of molybdenum and silicon on the surface of the mirror and efficiently reflecting light at a wavelength of 30.4 nm, which is frequently included in the light scattered by helium ions. They also improved the shape of the light detector that converts extreme UV light into electrical signals using the photoelectric effect. These efforts can truly be considered the result of collaboration between science and engineering.

Additional collaboration is planned to observe the resonant scattered light from hydrogen that is distributed around comets as part of the European Space Agency's (ESA) Comet Interceptor mission scheduled to launch in 2029. We are looking forward to their progress.



YOSHIOKA Kazuo
Lecturer
Department of Complexity Science and Engineering



▲The camera was assembled with the assistance of the laboratory's graduate students.

New possibilities for satellites with new materials
Heat-resistant shape-memory alloys and titanium alloys

MITARAI Yoko
Professor
Department of Advanced Materials Science

The extremely low temperatures and large amounts of radiation make the vacuum of space a supremely harsh environment and the instruments on microsatellites need to be highly durable and stable.

Coming to the forefront of research is materials engineering. The Mitarai-Matsunaga Laboratory has been clarifying the deformation mechanisms of titanium alloys used in airplane jet engines and high-temperature shape-memory alloys and high-entropy alloys, which are expected to be used in a range of high-temperature devices, and designing new materials.

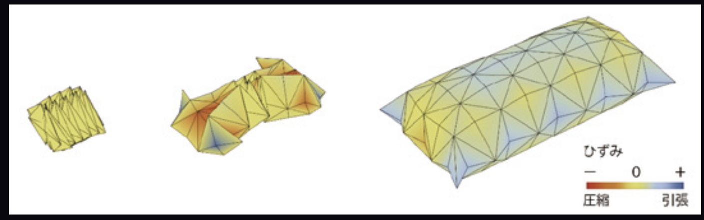
"Metallic materials have different mechanical and thermal properties depending on their compositions, and thermomechanical processing even with the same composition. The new heat-resistant materials microstructure-controlled by alloy composition and thermomechanical processing should play important roles in space, as well as in aeronautics."

Professor Mitarai says that she was in contact with JAXA at her previous position in NIMS (National Institute for Materials Science). Materials used in JAXA satellite attitude control thrusters would deteriorate and fail, and she would provide data on materials characteristics and cooperate in investigations into the cause of failure.

"Expectations are high for heat-resistant shape-memory alloys. Shape-memory alloys, for example, are peculiar alloys that change shape easily but return to their original shape by heating, and we are considering applications for systems like taking them to space, folded up small in low temperatures, and then returning them to the shape of a large antenna that they have in their memory in space by allowing them to be heated by the warmth of the Sun."

Materials engineering is expected to make contributions to space development in the future.

▲A specially made high-temperature testing machine for heating the sample alloy in near-vacuum conditions and investigating its dynamic characteristics.



▲The interior of the pillow-shaped outer skin also contains a raised-floor framework, which extends at the same time.
◀Successful deployment experiment with an aluminum alloy mockup at 1:10 scale.

Launch small, use large
Spatial structure in space

Used to be considered pie in the sky, plans to live on the Moon or Mars have now gained a degree of reality. NASA aims to have a crewed flight land on the Moon in 2024 and is moving ahead with the Artemis plan to begin construction of a moon base by 2028. Elon Musk's SpaceX and X Prize Foundation have announced the concept of successfully sending a crewed flight to Mars by 2026 and ultimately building a permanent base on Mars.

What is necessary for this is space architecture? In the November 2021 Space Sciences and Technology Conference, Associate Professor Sato Jun, an expert in structural dynamics and structural design who has been working on space architecture research for several years, presented a base camp design with an outer skin and raised-floor framework that can be deployed instantly and simultaneously. "This is collaborative research that was adopted in a public tender by JAXA's Space Exploration Innovation Hub (*4), in which we have proposed how the first base camp could be made on the surface of the Moon before constructing large-scale buildings. In simple terms, it is a pillow-shaped structure with thin panels of aluminum alloy around two to three millimeters thick that are folded up for transport, and when it lands, air pressure of one atmosphere is generated that immediately and automatically deploy the floor and outer skin. The size when inflated is 10 m (width) × 20 m (depth) × 4.8 m (height), and we imagine that about four people could live there with greening on the interior."

The candidate locations for setting up on the Moon's surface include underground spaces (shafts, lava tubes, etc.), and future plans include legs that automatically adjust the height and can touch down on uneven ground.

SATO Jun
Associate Professor
Department of Socio-Cultural Environmental Studies

*4: The Space Exploration Innovation Hub is an organization within JAXA that was established on JAXA's Sagamihara Campus in 2015. It has gathered personnel and knowledge from many different fields and through unprecedented new systems and initiatives, aims to expand and firmly establish research on space exploration throughout JAXA. It conducts requests for proposals (RFP) each year and performs collaborative research with private entities, universities, and other bodies.

Connecting Kashiwa and space with radio waves
Smart GS (Ground Station) for Satellite Operation

The value of microsatellites is realized not by satellite units, but through the operations of the system as a whole. The key to the system is the Satellite Ground Stations, and the processing system for the received data.

Antennas receiving signals from satellites have been already working on by private companies, as well as space institutions in many countries. Now universities can use antennas to communicate with satellites at any time they want, establishing and operating their own ones.

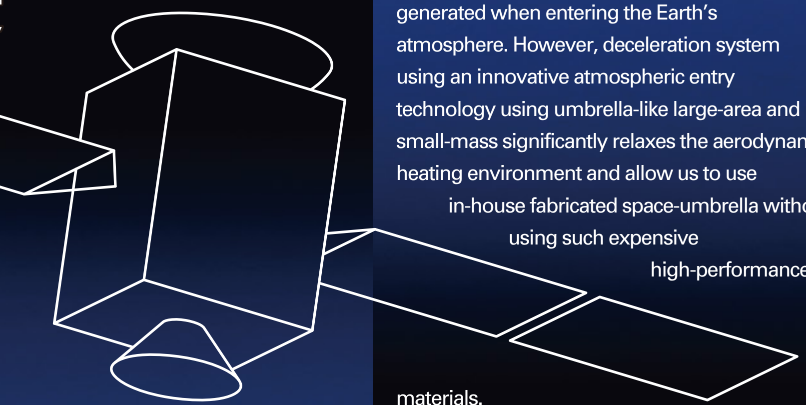
Since 2019, GSFS has also been gradually installing satellite receiving antennas on the roof of the Transdisciplinary Sciences Laboratory on the Kashiwa Campus, and it now operates a three-antenna system with two X-band antennas and one S-band antenna.

Professor Yoshikawa, who is in charge of the installation and operation, describes the background and aim: "As an expert in planetary aeronomy and planetary exploration science our role use to finish once we built an observation device or the like and we were left only with a mockup once it was launched into space. We needed to go through JAXA or the like to get the data. Installing antennas on the Kashiwa Campus and receiving the signals from satellites by our own antennas has greatly expanded the scope and flexibility of our research."

Still, importing foreign-manufactured satellite antennas cost hundreds of millions of yen. We, therefore, decided to buy the parts in Japan and assemble the antennas one by one by ourselves. We can now also receive signals from satellites that JAXA does not handle and have taken steps to gradually master their operating methods. In future, we plan to install another (S-band) antenna and transmit to satellites as well.

"In addition, working jointly with the National Institute of Advanced Industrial Science and Technology (AIST), we are conducting projects to develop algorithms that leverage machine learning and AI to process the enormous volume of data received from satellites for specific purposes. Our aim is to establish a Smart Ground Station (smart GS) that enables efficient, autonomous global measurement."

Now, the satellite receiving antennas are turning into a space development platform on the Kashiwa Campus.



YOSHIKAWA Ichiro
Professor
Department of Complexity Science and Engineering

▲The antennas are operated by the laboratory graduate students.
◀The direction of the antennas must be adjusted several times a day towards the targeted satellites.

COMMITTING TO FOSTERING A BROAD RANGE OF SPACE HUMAN RESOURCES

Until now, space research and utilization has mainly been conducted through national-level projects, but its scope has recently expanded to include efforts in the private sector and at universities, signaling the beginning of a new era. In addition to advances in microsatellites, the collaboration and cooperation between numerous academic fields and areas of study, as well as the cultivation of human resources will be essential to future space development. In this regard as well, GSFS is committed to fostering a broad range of human resources. GSFS will move forward with new initiatives concerning space, including collaborations between different fields.

Kashiwa Campus, the gateway to space

Microsatellites first appeared nearly twenty years ago and since then numerous microsatellites have been launched by companies as well as universities. Now, preparations for the next era have begun.

First, a new stage of incorporating private-sector technology into the bus and mission instruments that make up the microsatellites, and work to reduce their size and improve their capabilities has begun. For example, the sample return capsule of Hayabusa is the product of advanced chemical materials technology that is capable of withstanding the ultra-high temperatures generated when entering the Earth's atmosphere. However, deceleration system using an innovative atmospheric entry technology using umbrella-like large-area and small-mass significantly relaxes the aerodynamic heating environment and allow us to use in-house fabricated space-umbrella without using such expensive high-performance materials.

Second, private sector and universities are now capable of operating microsatellites. Of course in some cases, highly accurate operations systems from national-level space agencies are required but the demand for receiving data from satellites is under pressure around the world, and there is a need for participation by new players. The role of universities is important in space research, in particular.

Third, microsatellites have been injected mostly in Earth orbits to date, but in future they are likely to be deployed beyond the Moon to deep space. For this reason, human resources who have studied the collaboration between science and engineering will be even more essential, and this will also lead to new topics for research. In order to forge a new era for microsatellites, GSFS will play a new role on the Kashiwa Campus as a gateway to space.

Learning at the frontier of space development
JAXA collaborative laboratories

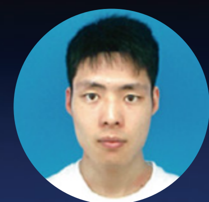
Essential in the role as a gateway to space is fostering human resources.

GSFS holds collaborative laboratories with JAXA, "Space energy systems" and "Deep space exploration I, II," offering students the chance to learn at the frontiers of aerospace engineering at the graduate level.

In the collaborative laboratories, researchers who are active on the forefront at JAXA are commissioned as professors and associate professors at the university, and the JAXA researchers take students into JAXA for a certain period and provide graduate school education (education and research supervision), like university instructors. In addition to lectures, the JAXA's leading researchers act as academic supervisors for master's and doctoral dissertations.

Alternating from top right: FUJITA Kazuhisa, professor / KWAK Dongyoun, professor / AOKI Yuichiro, associate professor / KAWAKATSU Yasuhiro, professor / SAKAI Shinichiro, professor / TANAKA Satoshi, associate professor

Carrying out research tasks during actual missions



I had been conducting research at the Institute of Space and Astronautical Science (ISAS), JAXA since I was an undergraduate student, and I selected GSFS's JAXA collaborative laboratories as an environment where I could continue research at the institute. Currently, I am working on the trajectory design for the CubeSat mission developed by the University of Tokyo and JAXA. Under the supervision of JAXA researchers, I could carry out the researches closely related to the ongoing flight projects. My goal is to become a researcher who can propose and lead space exploration missions.

CHIKAZAWA Takuya Doctoral degree course, 2nd year , Academic supervisor: Prof. KAWAKATSU Yasuhiro

Challenge in education to eliminate borders between science and engineering
DESP (Deep Space Education Program)

The entry-level education program in deep space exploration that GSFS has set up is known as DESP.*5

"Introduction to deep space exploration," a lecture subject begun in 2018, features learning without barriers between science and engineering. Experiment practicums and exercises to create mission proposals have been added to supplement the program.

DESP has a fixed menu of designated subjects, so there are no examinations or pre-applications. You can participate whenever you feel interested.

Besides GSFS master's and doctoral students, we also welcome graduate students from other graduate schools.

https://www.astrobio.k.u-tokyo.ac.jp/DeepSpace/
*5 Abbreviation of DEep Space education Program.

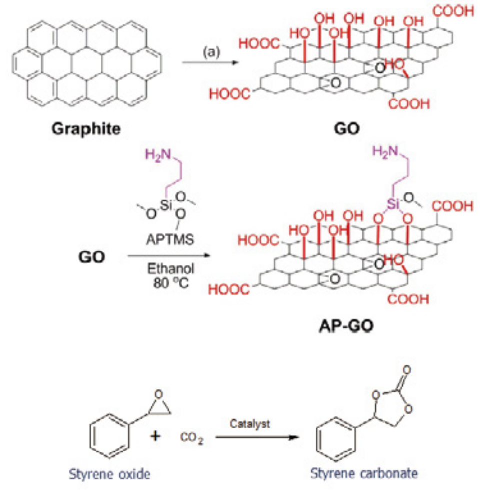
DESP

Catalytic Chemistry to Realize a Sustainable Society

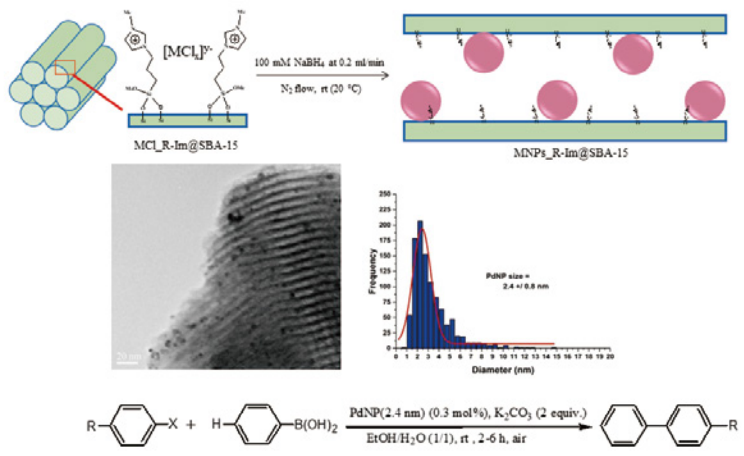
The theme of our laboratory is understanding chemical reactions on catalyst surfaces and creating effective catalysts for controlling reactions. We pursue our research objectives using both experimental and theoretical approaches.

Today, great concern persists about changes to Earth's environment, particularly global warming accompanied by increasing production of greenhouse gases due to human activity, such as the consumption of fossil fuels. Catalyst technologies for the effective use of carbon dioxide and the utilization of biomass resources are being sought as technologies for achieving a sustainable society. We mainly research immobilized catalysts. With an immobilized catalyst, an active site is immobilized on a solid support for easier separation and recovery of the catalyst from products and unreacted reactants, enabling its reuse, and detailed analyses using various solid and surface analytical methods. Our research outcomes are presented below.

Developing technology to convert carbon dioxide into useful compounds could contribute to reducing carbon dioxide emissions. Figure 1 shows a scheme for preparing a catalyst immobilizing aminopropyltrimethoxysilane (APTMS) on graphene oxide (GO). This catalyst has been shown to be a better catalyst that is capable of reacting under milder conditions with lower temperatures and lower partial pressure for carbon dioxide compared to conventional catalysts in reactions that generate stylene carbonate from stylene epoxide and carbon dioxide.[1] GO can have a large surface area because it is formed in single layers by oxidizing and separating graphite. APTMS reacted with functional groups like hydroxyl and carboxyl groups introduced in GO. The increased affinity with carbon dioxide due to the introduction of the amino group is thought to be a factor in improving the catalytic activity.



▲Fig. 1. Preparation process for GO modified with aminopropyl groups and the reaction to generate stylene carbonate.

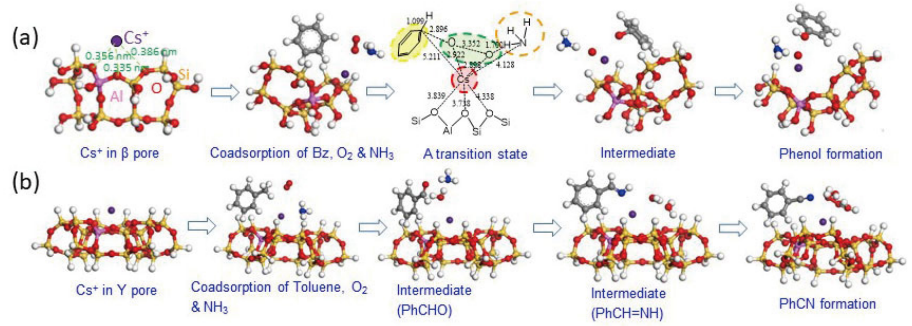


▲Fig. 2. Immobilized ionic liquid catalyst on SBA-15, distribution of Pd nanoparticles (TEM image), and scheme for Suzuki cross-coupling reaction.

Figure 2 shows a transmission electron microscope image and schematic diagram of the measurement of a catalyst in which Pd (palladium) chloride was introduced to a catalyst in which 1-methylimidazolium groups were immobilized on SBA-15 (a type of mesoporous silica), and the divalent Pd cations were reduced using $NaBH_4$ so that Pd nanoparticles were distributed uniformly with a diameter of 2.4 nanometers. Imidazolium is a monovalent cation and chloride anions are distributed as counter ions. After adding $PdCl_2$ $[PdCl_4]^{2-}$ is formed, and the reduction using $NaBH_4$ produces Pd nanoparticles. We found that Pd reduction after introducing imidazolium groups causes the uniform dispersion of the nanoparticles, and that controlling the concentration of the $NaBH_4$ solution and the feed speed enables control of the nanoparticle diameter.[2] This catalyst is used in the Suzuki cross-coupling reaction. Moreover, this method can also be applied in the same way to nanoparticles of Au, Pd, Ru, Cu, Ni, and other metals.

We are also conducting research on catalytic reactions from a theoretical approach using the density functional method and metadynamics method. Figure 3 shows the reaction process, including the transition state for phenol formation from benzene and oxygen in the presence of ammonia with Cs introduced into the zeolite acting as a catalyst, and the reaction process of benzonitrile formation from toluene, oxygen, and ammonia .[3]The activation of C-H bonds without a transition metal using the catalytic effect of Cs^+, an alkaline metal ion, is unprecedented, and we were able to explain this phenomenon in terms of quantum chemistry.

Our laboratory is also working on reduction reactions for carbon dioxide and nitrogen by developing electrocatalysts, which are expected to be effective when inexpensive surplus electricity from renewable energy sources is available, and we want to contribute to the realization of a sustainable society through basic research.



◀Fig. 3. (a) Process for producing phenol from benzene and oxygen molecules in the presence of ammonia with Cs on β-zeolite. (b) Process for producing benzonitrile (PhCN) from toluene, oxygen, and ammonia with Cs on Y-zeolite.

[1] Saptal, V. B.; Sasaki, T.; Harada, K.; Nishio-Hamane, D.; Bhanage, B. M.: *ChemSusChem* 2016, 9, 644-650.
[2] Kusumawati, E. N.; Sasaki, T.: *Chemical Record* 2019, 19, 2058-2068.
[3] Acharyya, S. S.; Ghosh, S.; Yoshida, Y.; Kaneko, T.; Sasaki, T.; Iwasawa, Y.: *ACS Catalysis* 2021, 11, 6698-6708.

Division of Transdisciplinary Sciences

SASAKI Takehiko Associate Professor

Complexity Experiments Program,
Department of Complexity Science and Engineering

http://sas.k.u-tokyo.ac.jp/e-index0.html

Simulations of Vital Processes by Deep Learning and Single-cell Measurement Data

I am conducting research into bioinformatics, which uses computers to analyze biological data. To date, I have researched mathematical modeling of biological phenomena, such as the secondary structure of RNA, genomic evolution, transcription control, and embryogenesis. Because I am a "dry" researcher who analyzes publicly available data and data obtained from experiments conducted by joint researchers, rather than performing "wet" experiments myself, I am now keenly aware of how much biological information I could extract from the data that can be obtained from around the world.

I changed fields from theoretical physics, my first area of expertise in graduate school, and began researching bioinformatics around 2003. This was just around the announcement of the completion of the human genome project, and people were discussing different prospects with a view towards the post-genome era once the genome had been parsed. I recall reading at that time, an article by an expert who predicted that in the case of comparatively simple creatures, like yeasts the complete parsing of the biological mechanisms would occur within the next decade. I thought at the time that if yeasts would be completely parsed in a few more years, we would probably be able to create computer simulations of biological dynamics, in the same way that theoretical physics derives conclusions from basic principles.

Nineteen years have passed since then, and in that time, the accumulated biological data have improved markedly in volume and resolution, but the world is still far from the stage of simulating anything like the division of cells in yeast entirely at the genetic level. The main reason is that too many of the parameters necessary for carrying out these simulations remain unmeasured. At this time, these necessary parameters are not very likely to be completely measured in the near future, and a computer simulation of yeast in the form that I imagined nineteen years ago seems difficult.

Division of Biosciences

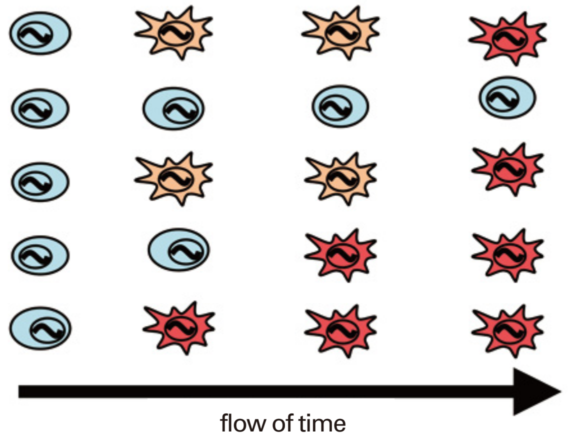
KIRYU Hisanori Associate Professor

Biological Network Analysis, Department of Computational Biology and Medical Sciences

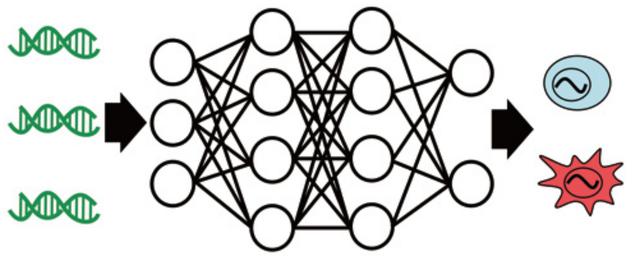
https://sites.google.com/edu.k.u-tokyo.ac.jp/kiryulab-en

On the other hand, there is hope. One is that the progress in deep learning (*1) and other artificial intelligence technologies has markedly advanced technologies to extract the complicated, nonlinear structures hiding in data. Thanks to this, modeling has developed to link quantitative relationships in biological states before and after the biological processes having many parts that existing knowledge has yet to discover, while leaving these processes like a black box. Another is the progress in single-cell measurement technology (*2) to measure the RNA volume and genome activity state for each single cell that makes up a creature. The appearance of this technology has enabled measurement of the biological states that vary in each cell, rather than the quantities averaged over several cells. In addition, because single-cell measurement technology allows the states of tens of thousands of cells to be measured simultaneously in one experiment, it can fully bring out the potential of deep learning, which requires large volumes of data for highly accurate modeling.

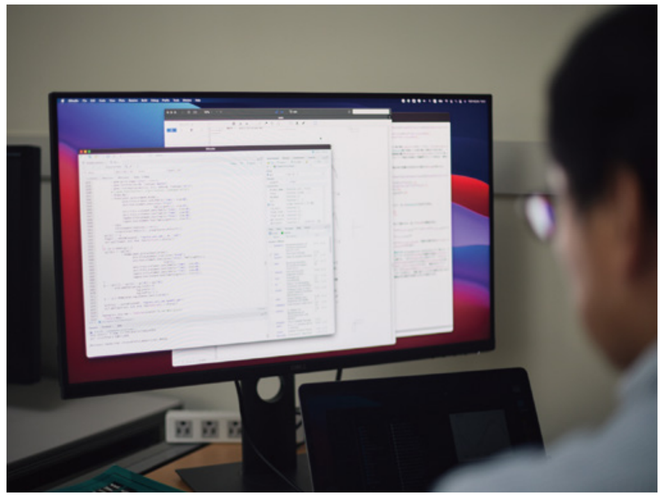
At present, it seems that there is still not quite enough data for meaningful cell simulations at the full genetic level, but because this field progresses rapidly, the era of parsing tissue and drug discovery using simulations like this may not be that far away.



▲Using deep learning to build models for predicting the cell state on the right from the genetic data on the left.



▲Single-cell measurement technology can capture deviations in changes of state between cells.



Key terms ***1 Deep learning:** Artificial intelligence technology that extracts the characteristics hidden in large volumes of data using complex models that imitate the neural networks in the brain. ***2 Single-cell measurement technology:** Technology for measuring the volume of RNA or 3D information on DNA in all genes for each cell that makes up tissue, using microliquid technology.

FRONTIER SCIENCES

Evolution of living organisms as deciphered from bones

Vertebrates appeared on Earth about 500 million years ago. They quickly diversified and expanded into all regions - the seas, on land, and in the sky. Our laboratory conducts research on the bones and teeth of vertebrates with the aim of unveiling relationships between their morphology and ecology, environment, and their evolution.

Investigating the functional significance of the morphology—the shape—of bones is the purpose of functional morphology; comparative morphology, on the other hand, compares morphology of groups living in diverse environments and having different ecologies. From the perspective of functional morphology, I am comparing the shape of bones and teeth of the same vertebrate species from different habitats and investigate their relationship to the species' ecology. My main subject is the sika deer (*Cervus nippon*) (Fig. 1).

The sika deer is distributed widely from Hokkaido in the north to the Kerama Islands in Okinawa. They are also known by several different names such as Yezo (Ezo) deer, Honshu deer, and Kerama deer, but actually these all belong to the same species, not different ones. The Japanese archipelago is long and narrow, stretching from north to south, and its climate and environment differ greatly between regions. I was curious if sika deer evolved different morphologies related to the environments in these regions? I began by collecting the skeletons of sika deer hunted for population control, and have compared many skeletons curated in the collections of museums throughout Japan.

Depending on the region, diet of the sika deer differs. Deer living in the north tend to eat proportionally more bamboo and other graminoids (plants in the *Poaceae* family), and this proportion decreases towards the south. In addition to being fibrous, the graminoid plants contain many small silicate bodies, called phytoliths or plant opal. Our research has revealed that the more graminoid plants sika deer eat, the more their teeth are worn down, and that groups whose teeth wear down more quickly have larger teeth. This suggests the possibility that the sika deer have evolved their morphology in response to their habitats.

In recent years, it has become possible to collect digital morphological data through CT photography and other means, and we are now able to compare shape in greater detail and in a quantitative manner. Our laboratory is also proactively working on digital morphology (Fig. 2). Our greatest focus at present is research on quantitative evaluation of wear traces on teeth and its application to restoring ancient ecologies, using confocal laser microscopy applications from the engineering field (Fig. 3). Worldwide, this research method is only used in six locations, and our laboratory is the only one of its kind in Asia.

When animals eat, tiny marks at the microscopic level (microwear) are left on the surface of their teeth due to contact with the food (Fig. 4). As the microwear reflects the physical characteristics of the diet, investigating it allows us to infer what the animals might have eaten while they were alive. Since 2017, we have been working on research to accumulate microwear data for diverse wild animals with known diets. By using the accumulated data as a comparison, we can reconstruct the ecologies of extinct species (Fig. 5). We began our efforts with mammals and are now expanding to dinosaurs.

As I am researching dinosaurs, people often say, "That's the stuff dreams are made of." It may seem like the subject of childhood dreams, but personally, I see little difference between studying mammals and dinosaurs. I am driven by the interest to reconstruct their ecologies and understand their evolution in interaction with their environments and recreate an image of the living creature from fossils. I hope to share that fascination of evolutionary biology and paleontology with many people by conducting and publishing exciting research.

Division of Environmental Studies

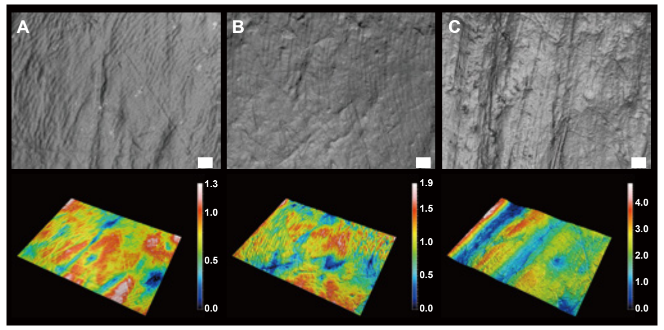
KUBO Mugino Lecturer

Biosphere Functions, Department of Natural Environmental Studies

https://sites.google.com/edu.k.u-tokyo.ac.jp/mugino-kubo-lab/home

▶Fig. 1. A sika deer skull from Iwate decorates the laboratory wall.
▼Fig. 2. Digital data analysis makes it possible to quantitatively evaluate the complicated antler shape of sika deer.

▲Fig. 3. Scanning the wear on tooth surfaces with a confocal laser microscope.



▲Fig. 4. 3D surface models of teeth generated with a confocal laser microscope. The field size is 140 × 105 μm. The height (color scale) is measured in μm. Among sika deer, individuals that eat more graminoids (C) have deeper wear marks.
A: Yakushima Island, B: Shizuoka, C: Kinkazan Island.

▲Fig. 5. Fossils of deer mandibles excavated from the Pleistocene cave in Okinawa Island. The larger is called "Ryukyu deer", and the smaller is "Ryukyu old muntjac". Both died out about 30,000 years ago. We are working to reveal their ecologies from microwear on the teeth.

"Designing a Sustainable Society with Life Cycle Thinking"

Creating a next-generation society through dialog with life cycle thinking

At the moment, I am working as the representative of the Wholeness Lab with the mission of "quantifying environmental impact "LCA" (life-cycle assessment) and creating next-generation lifestyles." In addition to my sustainable business consulting work for companies, I am conducting surveys, writing, giving lectures, and facilitating while being a member of several research organizations.

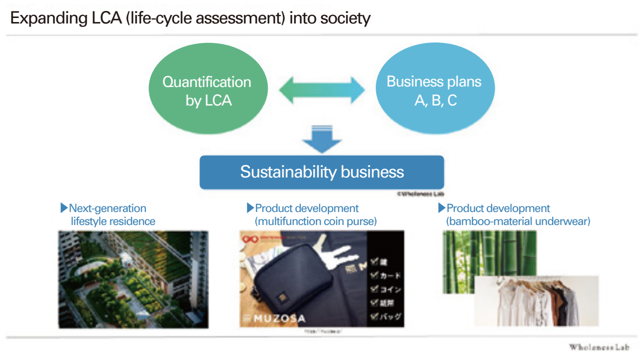
The starting point for my activities is the "life-cycle thinking" that I studied at graduate school. Social awareness of environmental and other issues, such as the SDGs, has grown. However, few organizations have found answers to questions like, "So how can we reduce the environmental impact?" and "What business design should we use?"

In these circumstances, I am creating next-generation social designs that have concrete details and that give ownership to the respective stakeholders by quantifying the environmental impact using LCA and making a space for companies, users, and others to hold a "dialog."

To my juniors

Since completing graduate school, I have performed a variety of activities as a local government employee, NGO member, NPO worker, and researcher at an institute. On looking back, I feel that at each of these locations, the intentionality of "science to create new frontiers" and of "transdisciplinary approaches" is increasing in importance. This is because, in regards to environmental and other social issues, dialog and agreement formation between diverse people is highly important.

I have attempted many things with the motto of "Think Globally Act Locally," and I hope that I might provide a hint of some kind as one example of how to work and make use of research. Starting in 2022, I also plan to begin a doctoral degree course as an adult student. I would love to talk to you about reading this article.



Consulting on Sustainable business for companies

I am also working hard everyday as a mother of one child.

AOKI Shihoko Representative, Wholeness Lab (freelance researcher)

PROFILE

2008: Completed master's program in Department of Environment Systems, Graduate School of Frontier Sciences
2008: Joined the city hall at Fussa, Tokyo
2012: Active in domestic NGOs/NPOs (participating in Ministry of Environment and Ministry of Economy, Trade and Industry projects)
2015: Joined the Center for Global Communications of the International University of Japan (senior researcher)
2021: Became independent as a freelance researcher, while also active in several organizations (concurrently senior researcher at GLOCOM, commissioned employee at Riken Innovation Design Office, part-time researcher at Miratuku, etc.)
2022: (Planned) Commenced doctoral program in Department of Environment Systems, Graduate School of Frontier Sciences

Voices from International Students

Stone, wood, earth: Kovachevitsa, a village of traditional architecture

STOYCHEVA Mariya
3rd year of doctoral program, Department of Socio-Cultural Environmental Studies

The main feature of pre-industrial traditional architecture is its materiality. A small mountain village in southwestern Bulgaria that has been designated as an architectural reserve. The narrow streets are paved with stones, winding between houses with masonry walls, overhung by deep eaves of rough wooden beams that support the roofs covered with heavy stone slabs.

I was born in Stara Zagora(Стара Загора) in central Bulgaria. In 2014, I visited Kovachevitsa(Ковачевица) to study traditional Bulgarian architecture. This village, located in the western part of the Rhodope(Родопи) Mountains and nestled in steep slopes at a height of 1050 meters, began as a builders' hamlet. The carpenters and masons traveled far for work during the warmer months and spent winters in the village with their families. Near the village at a lower altitude there are hot springs, and I recommend bathing in them to relax after touring the traditional architecture.

For many years, Kovachevitsa protected its forgotten building techniques. Most of the surviving residences were built towards the end of the eighteenth century and display a unique architectural style. The first floor is built of stonework to level out the steep terrain, and it has an irregular shape to match the narrow, winding streets. The second floor is rectangular with corners overhanging the masonry walls of the first floor, creating a shelter over the outside pathway from wind, rain, and snow. The roof is carried on a timber framework of posts and beams with walls of wattle and daube. A distinguishing feature is the height of the dry masonry walls, rising up to four floors.

The roofs of Kovachevitsa's houses are in harmony with the surrounding forest-covered mountains. The slate roofs grow moss, and they blend in with the color of the mountain slopes. In the center of the village is the church belfry, which rises above the houses as its sole vertical element. The historical architecture make the visitor rather than fearing the harshness of the elements, to feel nature's power. The power contained in the stone walls and wooden beams that become protection.

Hot springs near Kovachevitsa.

ON CAMPUS × OFF CAMPUS

The column by current students to introduce and support student activities

Labo-Connect https://about.labo-connect.com/

A new academic-focused SNS to connect students and society

We started development of Labo-Connect in October 2020 as an SNS focused on academics (learning and research) that would connect undergraduate and graduate students throughout Japan and society. Considering the loss of venues for publishing research and opportunities for communication due to the COVID-19 pandemic, we devised Labo-Connect from a desire to offer a place that would be useful for undergraduate students choosing laboratories, graduate students publishing research, and promoting communication between students. It began with a few members at first, but it gathered cooperation through business contests and crowdfunding, and we were able to start running an SNS platform.

We held an online discussion forum for graduate students who are unsure about their future path on December 12, 2021, where students in doctoral degree courses and people already in the workforce talked about their own "learning paths." (The archived version is available for viewing on our website.) In future, we aim to conduct research outreach activities by energizing communication between students, and also to develop new services, such as offering venues for relearning, like online lectures by students for working people.

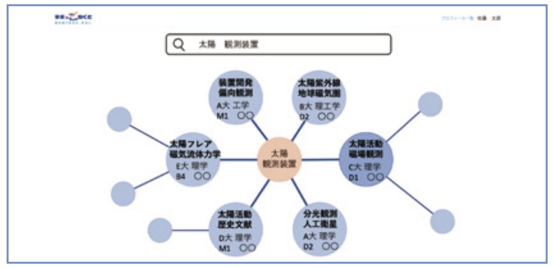
What can we do with Labo-Connect

◆Look for information on laboratories throughout Japan!

■Research activity profile

■Ask questions directly to researchers around Japan

◆Connect with researchers!



Students can search for graduate students around Japan by the research topics they are interested in and exchange brief messages. We are aiming for a platform where students can use the information registered on the SNS as an online business card to communicate with others, and in future to communicate with people in society and corporate associates.

"More student energy in society!"

KOBAYASHI Yuzu Labo-Connect SNS chief
2nd year of doctoral program, Graduate School of Frontier Sciences, The University of Tokyo

The activities of graduate students are amazing. This was one of my findings through my experience in a company. Labo-Connect aims to connect students and society, and share students' vitality with the world. We want to develop our services with all of you. I would love you to register as a user!

"Labo-Connect's logo represents our motivation!"

YAMASAKI Daiki Labo-Connect inventor
2nd year of doctoral program, Astronomical Observatory, Graduate School of Science, Kyoto University

We aim to make our society much more familiar with academic researches by developing Labo-Connect. Labo-Connect enhances three types of connections: between undergraduate and graduate students, among graduate students in different fields, and between students and our society. The orange arrow at the center part of the logo represents a creation of "something new" by such connections through Labo-Connect.

The Student-led Creation Project promoted by GSFS provides funding support for activities.

(Interviews, text: ARARAGI Mayuko)

EVENTS & TOPICS

Kashiwa Campus Open Days 2021

【Online event】

The Kashiwa Campus held its open days for the public from October 22 to 29. To prevent the spread of COVID-19 infection, the event was held entirely online in the 2021 academic year. GSFS conducted many projects, including live broadcasts of lectures, video transmissions, virtual tours, and online exhibitions. The open days gave people a sense of the leading-edge research and transdisciplinary efforts occurring every day in GSFS.

Special lecture Saturday, October 23

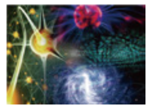
Searching from genomes!
The survival techniques of fish who have left the mother ocean
ISHIKAWA Asano (associate professor, Department of Integrated Biosciences)

The leading edge of high-strength polymer gel development directed at biological and medical materials
MAYUMI Koichi (associate professor, Institute for Solid State Physics)

Activities of the Airplane Body Manufacturing Technology Development Project (CMI)
USUKI Hiroshi (professor, Institute of Industrial Science)

Listen and learn

The complexity of the real world, as revealed by the fusion of science and engineering



Introduction of the latest information on research conducted in the Department of Complexity Science and Engineering (machine learning, deep space exploration, nuclear fusion plasma, brain-bio, virtual reality).

A learning computer: The front line of machine learning research
Introducing mechanisms and the latest trends in machine learning, the technology at the heart of artificial intelligence (AI)

Ask me anything about radiation and medaka
Associate Professor Oda will answer anything about radiation and medaka.

Let's look at the front line of nuclear fusion research
Lectures by nuclear fusion researchers and virtual tours of the experimental laboratory

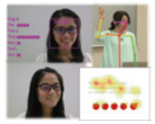
The front line of international studies, as related by instructors
Research introduction by Department of International Studies instructors

16th Environmental Studies Introductory Lecture
Lecture by environmental studies instructors.

Darwin ga kita?!, Kashiwa Campus style
The leading edge of interesting evolutionary research
Four researchers working on the front lines of evolutionary research talk about living creatures' evolutionary mechanisms that have been revealed by the latest technology.

Naturally genomes! The latest in relationships between genomic research and people
Three researchers present leading-edge genomic research, which seems difficult but is actually familiar

Sponsored symposium on creativity studies about revolutionary learning



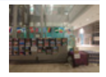
1st session: Latest technology supporting learning
Lecture focusing on the latest technology for a new era of learning

Visiting laboratories, Department of Computational Biology and Medical Sciences
Graduate students and others from Computational Biology laboratories talk about their research and discuss a range of topics with visitors, such as consultation about future studies

Kashiwa-style ☆ deep space exploration 2
A slide and discussion show on Zoom, brought to you by Deep Space Education Program members

Look and learn

Field photography contest



Contest for photographs recorded by current students and instructors during fieldwork, etc.

International studies: Exhibition of student research activities
Introduction of research activities by current students in the Department of International Studies

See, examine, observe with Operand
We introduce the latest Operand measuring technology and its applications, using practical examples of laser treatment state and biomolecule dynamic measurement. (Joint project with the Institute for Solid State Physics)

What are environment systems studies?
Virtual space introducing work in the Department of Environment Systems

"Creature research, assemble!"
What living creatures would you study?
Introduction of the diversity and attraction of research into living creatures, based on research introduction videos by graduate students

Material functions determined in nanospace (Recording of 2020 public lecture)
YouTube broadcast with commentary ranging from quantum mechanics, statistical mechanics, and solid-state physics to quasicrystal physics and thermoelectric generation

Thermoelectric materials:
Key technology for energy and environmental issues
Demonstration of thermoelectric generation and thermoelectric cooling and heating (YouTube broadcast)

Experience

Let's think about decarbonization from the perspective of maritime logistics
An event for considering strategies to reduce CO_2 emissions with a marine transport simulation game

Mozilla Hubs Exhibition of research activities in virtual space
Exhibition of posters in a virtual space to introduce research into sensing, robotics, nanodevices, and sensory augmentation technologies to support human health, safety, and security

Science Course Selection Supporting Event for Junior and Senior High School Girls: "Look into the future!"

[Online event]

On Sunday, October 24, GSFS, the Institute for Solid State Physics, and the Atmosphere and Ocean Research Institute held an event to support junior and senior high school girls in selecting science courses. The joint panel lecture in the morning was attended by Kubo Mugino, a GSFS lecturer. In the afternoon split sessions, GSFS hosted a question-and-answer session with current graduate students and instructors. The participating high school students and their guardians left messages like, "many of the people were friendly and easy to ask questions to" and "it formed a trigger allowing me to encourage my daughter more to select a science course."

Graduate students answer questions from participants on the other side of the screen.

EVENTS & TOPICS

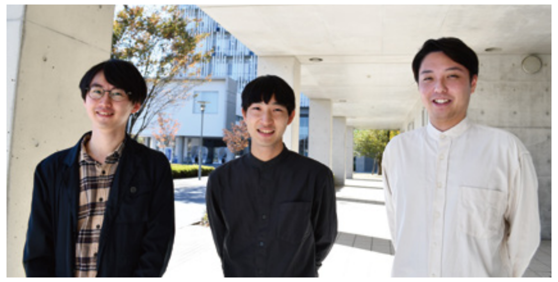
Creating a new space for face-to-face communication
Project to install IoT furniture outdoors on the Kashiwa Campus

We are making use of IoT furniture, which combines mobile chairs and tables with digital devices, to create outdoor spaces for using them comfortably face-to-face.

The effects of the spread of COVID-19 infections have forced classes and research activities online and greatly reduced opportunities for students to communicate face-to-face among themselves and with instructors. The student team from the Spatial Planning & Design Laboratory (Deguchi Atsushi Laboratory) in the Department of Socio-Cultural Environmental Studies thought about making use of outdoor spaces, which alleviate the risk of infection, as a solution.

In autumn 2020, mobile chairs and tables were installed outdoors on the Hongo Campus. These were used more by groups of two to four people than by individuals, and changes were observed in user stay time. Moreover, meals, PC work, conversation, and other uses increased, and the activity in the plaza became more diverse.

In the future, we are considering making and installing furniture with tablet terminals and making it possible to relax in a variety of ways. We are also examining using sensors or the like to monitor usage.



Project members: 5 people, 2nd year master's students in DEGUCHI Atsushi Laboratory, Dept. of Socio-Cultural Environmental Studies
From left to right: SAGARA Ko, FUJII Tatsuro, NOGAMI Masataka and ISOBE Yuta, KODAMA Shun.

SAGARA Ko from the student team comments, "Next, I want to use the 'zelkova' tree avenue on the Kashiwa Campus to expand places for students. We will think about the materials, structure, and design of the chairs and tables to make a space where they can relax in peace."

(Interviews, text: TAKADA Yoko)

Mobile chairs and tables installed on the Hongo Campus.
http://udcx.k.u-tokyo.ac.jp/project_list/chair/

Mockups (prototypes) of the mobile chairs and tables. The team is continually improving them with the aim of operation from March 2022.

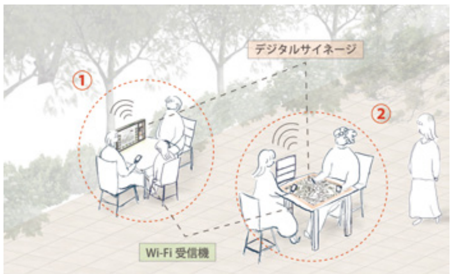


Image of IoT furniture.

GSFS Volleyball Club, deepening international exchange

This volleyball club has a long ongoing history within GSFS.
It currently has about 40 members. Experienced players and beginners account for about half each, allowing beginners to join with peace of mind. We have a very large number of international students, and players can enjoy their time here as a place for international communication. Our activities are practicing for about two hours on Friday nights at the Kashiwanoha Community Gymnasium in Kashiwanoha Park. We also have a camp in summer and a competition vying for the Dean's Cup in autumn. We had difficulty in carrying out activities at times due to COVID-19, but everyone has been working on their skills. We invite everyone to join in our activities.
(Representative: FUJII Tatsuro, 2nd year of master's program, Department of Socio-Cultural Environmental Studies)

The alumni competition on Saturday, December 18.

○ If you are interested in this club, please Email to: tokyo.gsfs.volleyball@gmail.com
The club makes use of the financial support program for joint activities between graduates and current students from Souiki-kai, the GSFS alumni association.

https://souiki-kai.net/support/

INFORMATION

AY2021 Autumn Commencement Ceremony

The ceremony was held on Friday, September 24, 2021, at the Large Auditorium (Yasuda Auditorium). Ms. TOKUMOTO Shoko from the doctoral program represented GSFS. A total of 120 candidates completed GSFS programs, consisting of 81 for the master's program and 39 for the doctoral program.

AY2021 Autumn Entrance Ceremony

The ceremony was held on Friday, October 1, 2021, at the Large Auditorium (Yasuda Auditorium). A total of 146 students were enrolled, consisting of 81 for the master's program and 65 for the doctoral program.
(Photos: OZEKI Yuji)

GRADUATE SCHOOL OF FRONTIER SCIENCES

https://www.k.u-tokyo.ac.jp/en/

Information on Entrance Examination
https://www.k.u-tokyo.ac.jp/en/exam/info/

Souiki-kai

Graduate school of Frontier science Alumni Association, "Souiki-kai", supports exchanges between graduates and current students.
https://souiki-kai.net/

UTokyo FOCUS

UTokyo FOCUS is the official news site of the University of Tokyo, which summarizes the research and education activities of the University of Tokyo in one place

https://www.u-tokyo.ac.jp/focus/en/index.html

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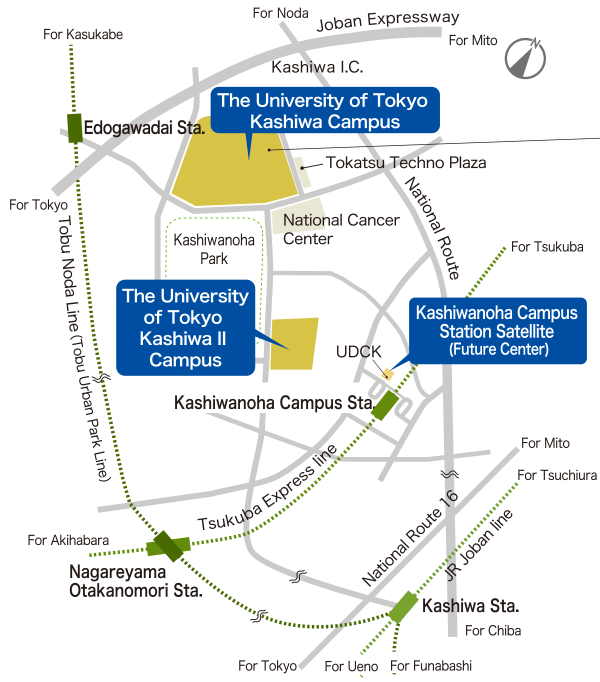
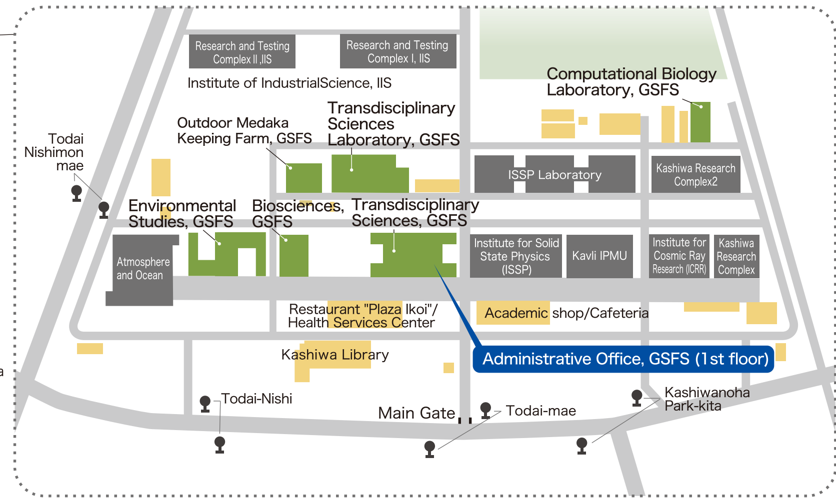


CAMPUS MAP



Editor's Notes

MATSUNAGA Sachihiro Chairperson of the Public Relations Committee

SOSEI volume 39 presented our teachers' research on space engineering in GSFS under the title "Reaching space from Kashiwa." I became aware again of the fact that the use of space has become possible with the support of a range of research and technical development, and that space is becoming a more familiar location. In particular, microsatellites, whose development is being led by GSFS, will contribute to a growing degree to future experiments and research in space. I hope that after reading this article, you will look up at the stars in the night sky and turn your thoughts to the mysteries and magnificence of space.

Date of issue / March 31, 2022

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Relay Essay

A pandemic in the plant kingdom, too?

I apologize for the personal note, but I am nearing retirement and thinking about organizing my possessions, so I have been going back and forth many times on the weekends in an attempt to prepare to take them to the vacant house where my parents used to live.

One day as I was doing that, all of the leaves on a mizunara (Japanese oak) tree over ten meters tall in the corner of the garden had turned brown and withered all of a sudden, even though it was August. When I went just the previous weekend, it was lush and green and nothing seemed wrong with it, so I was shocked at this sudden transformation (see photo). Looking on the Internet, it seems that this is called "nara-gare" (Japanese oak wilt), and it is a contagious disease seen in deciduous and evergreen oaks and Japanese chinquapins that has spread rapidly in Japan in the past few years.

Caused by a filamentous fungus carried by the oak ambrosia beetle (Platypus quercivorus), it previously had not expanded its range, but now, perhaps due to global warming, it seems to be expanding throughout the country. I immediately engaged a landscape contractor to exterminate them and cut down the tree, fumigated it, and burned the wood, but the tree that had grown over many decades disappeared without a trace in a few moments.

The number of people infected through the COVID-19 pandemic around the world continues to increase, and even now (January 2022), when it has passed 300 million people, the pandemic shows no sign of ending. People's ability to travel anywhere around the world is one factor that allowed infections to spread so rapidly, but it appears that in the world of plants, too, diseases can spread both inside and outside Japan, carried by insects and the like, and there is no way of stopping them.

While we may have a real, strong sense of the progress of science when we look at the way that excellent vaccines and drugs are quickly developed and the number of infected cases is steadily declining, it is truly troubling how the means created by this progress have unintentionally assisted the infection and spread of viruses and bacteria. Now seems to be an era of great concern not only to humans but to plants as well.

At the end of July 2021, nothing unusual was found (photo above), but when I came back the following week, I found that the leaves of the Japanese oak had turned brown and died (photo below).

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