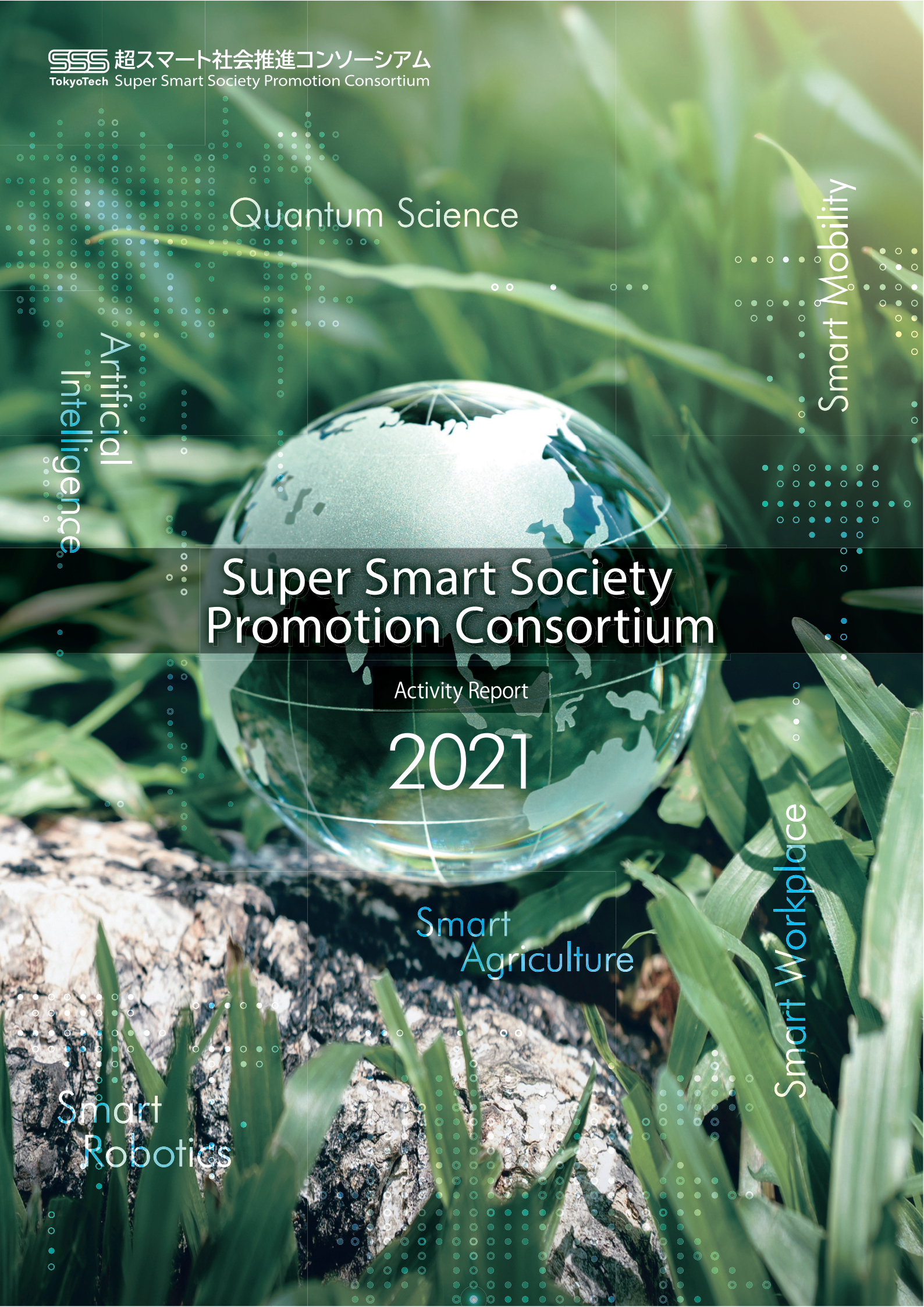

超スマート社会推進コンソーシアム
TokyoTech Super Smart Society Promotion Consortium
Quantum Science
Artificial Intelligence
Smart Mobility
Super Smart Society Promotion Consortium
Activity Report
2021
Smart Agriculture
Smart Workplace
Smart Robotics

Table of Contents

Super Smart Society Promotion Consortium Activity Report (2021 Academic Year)

1. Overview of Activities in the Fourth Year (2021 Academic Year)

1-1 What is the Super Smart Society Promotion Consortium?

The Super Smart Society Promotion Consortium was established in October of 2018 to create a platform for next-generation social collaborative education and research, where everything from human resource development to R&D are integrated through a collaboration with industry, government, and academia in order to foster leaders who can lead the coming Super Smart Society (Society 5.0). As of April 2022, 48 partners (not including individual members) shown in Table 1-1 including research institutes, local governments, and private companies are participating in this consortium to promote open innovation and open education for Super Smart Society.

The Super Smart Society Promotion Consortium has three committees as shown in Figure 1-1. 1) The Super Smart Society Promotion Committee provides networking opportunities for Super Smart Society, plans and holds events such as the Super Smart Society Promotion Forum, and provides social enlightenment through One-Day Schools. 2) The Social Collaborative Education Steering Committee assists with human resource development and career support. It helps with human resource development in collaboration with the WISE-Super Smart Society (SSS) Program (established at the Tokyo Institute of Technology (Tokyo Tech) in April 2020), and supports off-campus projects (internships). 3) The Interdisciplinary Research Promotion Committee helps to coordinate research and development teams, holds matching workshops, and helps to develop SSS research and education fields. The activities during the 2021 academic year are summarized in this report according to each committee.

1-2 Activity highlights of the fourth year (2021 academic year)

Table 1-2 gives an overview of activities and events of the Super Smart Society Promotion Consortium during the fourth year (2021 academic year), along with a list of corresponding committees. The various committees meet together four times a year in order to plan SSS promotion projects and various events. The COVID-19 pandemic continued to have a significant impact in the 2021 academic year. In particular, we were unable to hold almost all of the off-campus projects in summer and spring. Among the scheduled programs, we were able to hold the SSS One-Day School and Ota Ward Entrepreneurship Experience Seminar in a face-to-face format during the very short period of time when the Japanese government eased the quasi state of emergency for preventing COVID-19.

On the other hand, the need for on-demand distribution of educational content has increased due to COVID-19, and results have exceeded the initial plan. Details of each event are summarized in this activity report. The consortium has jointly obtained multiple competitive funds, including a grant from the WISE Program (Doctoral Program for World-leading Innovative & Smart Education) operated by Ministry of Education, Culture, Sports, Science and Technology (MEXT). The purpose of these funds is to make a dramatic leap forward after the COVID-19 pandemic has settled down. Thus far, we

Table1-1 Consortium partners（As of April, 2021）

1. Tokyo Institute of Technology
2. Japan Agency for Marine-Earth Science and Technology
3. Information Technology and Human Factors, National Institute of Advanced Industrial Science and Technology
4. ICT Testbed Research and Development Promotion Center, National Institute of Information and Communications Technology
5. National Agriculture and Food Research Organization
6. RIKEN Center for Advanced Intelligence Project
7. National Institutes for Quantum and Radiological Science and Technology
8. aiwell Inc.
9. Azbil Corporation
10. ANRITSU CORPORATION
11. ITOKI CORPORATION
12. AGC Inc.
13. NTT Urban Solutions, Inc.
14. LG Japan Lab Inc.
15. Kawasaki Heavy Industries, Ltd.
16. Kubota Corporation
17. KDDI CORPORATION
18. Koden Electronics Co., Ltd.
19. Komatsu Ltd.
20. JTEKT CORPORATION
21. SHO-BOND CORPORATION
22. SoftBank Corp.
23. DENSO Corporation
24. Central Japan Railway Company
25. TOSHIBA CORPORATION
26. Tressbio Laboratory Co., Ltd.
27. NSK Ltd.
28. NEC Corporation
29. Panasonic Corporation
30. FUJITSU LIMITED
31. Honda Research Institute Japan Co., Ltd.
32. Makino Seiki Co., Ltd.
33. Mazda Motor Corporation
34. MITSUBISHI ESTATE CO., LTD.
35. Mitsubishi Electric Corporation
36. YASKAWA Electric Corporation
37. Yokogawa Electric Corporation
38. Rakuten Mobile, Inc.
39. Ricoh Company, Ltd.
40. ROCKY-ICHIMARU Co., Ltd.
41. Ministry of Agriculture, Forestry and Fisheries
42. Ota City
43. Kawasaki City
44. City of Yokohama
45. Kanto Head Office, Organization for Small & Medium Enterprises and Regional Innovation, JAPAN
46. The Ocean Policy Research Institute, The Sasakawa Peace Foundation
47. The Ecozzeria Association
48. Marine Open Innovation Institute

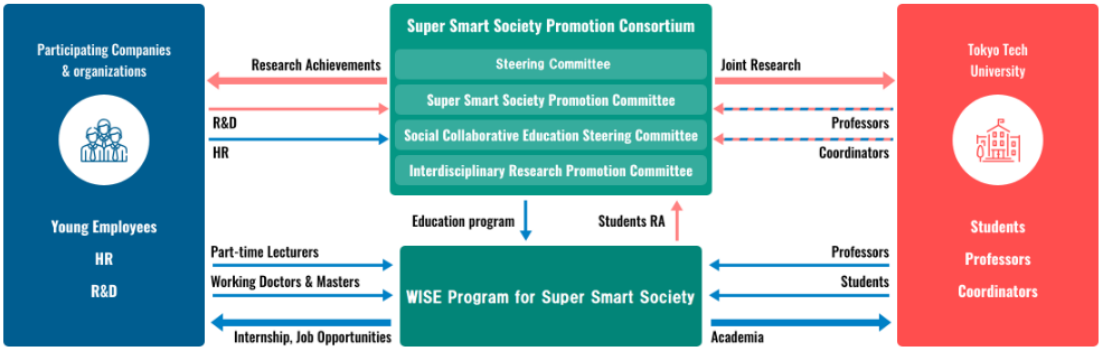


Figure 1-1 Organization of the Consortium

have constructed the six SSS research and education fields shown in Table 1-3. These research and education fields are positioned as microcosms of the ideal Super Smart Society, and are open platforms that can be used for education and research by any Consortium Partner. The themes and structure of the research and education fields were determined by having open recruitment at various joint committees during the previous academic year and having discussions with related Consortium Partners. In the 2021 academic year, the consortium proposed the Suruga Bay Smart Ocean Vision with the aim of making the entirety of Suruga Bay into a research and education field of smart ocean. An all-party Diet group was established as a marine version of the Vision for a Digital Garden City Nation promoted by the Kishida administration, and a budget was passed for the 2022 fiscal year. Afterwards, we began construction of the field in actual society; for example, we held a kick-off symposium in the local city of Shimizu. We would like to ask all Consortium Partners to actively contribute to the construction and utilization of research and education fields. We are also looking forward to hearing ideas such as for solving social issues and verifying social implementation by means of these research and education fields.

2. Activities of the Super Smart Society Promotion Committee

2-1 SSS Promotion Forum

In this academic year, we held two SSS Promotion Forums; one in the first semester and one in the second semester. Details are given below.

(1) 4th SSS Promotion Forum "Quantum Science and Technology towards Super Smart Society"

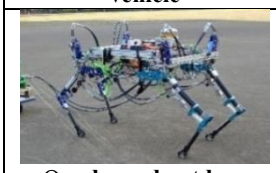
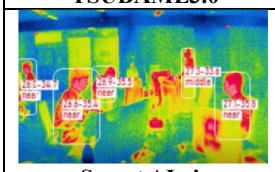
In recent years, there have been many cases of growth and new development of quantum science in academia and industry. One example is the use of quantum computers. Quantum science has traditionally been considered the subject of physics. However, it has now begun to expand into concrete products and actual businesses. In that sense, quantum science is thought to be moving from science to the phase of practical application. Based on these trends, the Super Smart Society Promotion Consortium held a technical forum entitled "Quantum Science and Technology towards Super Smart Society." The forum featured experts from both inside and outside of Tokyo Tech.

Table1-2 Our activities in AY2021

Month	Events	Committee
June, 2021	10th Joint Committee	(1)(2)(3)
June	Matching Workshop (Spring, 2021)	(3)
June, July	Super Smart Society Innovation A3	(2)
July, August	Off-campus Project (Summer, 2021)	(2)
September	11th Joint Committee	(1)(2)(3)
September	Super Smart Society Promotion Forum	(1)
October, November	Super Smart Society Innovation A1	(2)
November	12th Joint Committee	(1)(2)(3)
November, December	Matching Workshop (Autumn, 2021)	(3)
November	SSS One-Day School	(1)
December, January	Super Smart Society Innovation A3	(2)
December, January	Ota Ward Entrepreneurship Seminar	(2)
2022, January, February	Off-campus Project (Spring, 2022)	(2)
March	13th Joint Committee	(1)(2)(3)
March	Super Smart Society Promotion Forum	(1)
March	SSS MOOC webcast Learning Programming with computer Shogi	(2)
March	SSS MOOC webcast Invitation to the Super Smart Society	(2)

(1) The Super Smart Society Promotion Committee
(2) The Social Collaborative Education Steering Committee
(3) The Interdisciplinary Research Promotion Committee

Table1-3 SSS Research and Education fields

 **Automated driving vehicle**	**Smart Mobility** A platform for smart mobility to utilize automated driving and cutting-edge wireless systems such as 5G and millimeter-wave V2X.
 **Quadruped outdoor field robot**	**Smart Robotics** A platform for utilizing robots in the fields of land, sky, aqua, and manufacturing. We are conducting researches about four-legged robots for outdoor fields (land), drones(sky), underwater robots and drones (aqua), and digital manufacturing technology, etc.
 **Cryogenic measurement system**	**Quantum Science** A platform for quantum computing and quantum sensors for the next generation. We are conducting research and application of ultrafast next-generation quantum computers and ultrasensitive quantum sensors.
 **Supercomputer: TSUBAME3.0**	**Artificial Intelligence** A platform for artificial Intelligence (AI). The super computer "TSUBAME" and Wi-Fi6 are used to build a platform for the use of machine learning services.
 **Smart AI air conditioning based on thermal images**	**Smart Workplace** A platform for smart workplaces with the aim of establishing better workplaces. We are building workplaces for the post-COVID-19 era, including air conditioning control using a variety of sensors and AI.
 **Agricultural drone**	**Smart Agriculture** A platform for smart agriculture in response to problems related small-scale agriculture in Japan. We are working on remote agricultural technology that enables automated and stable production of high-quality crops by fully utilizing AI, IoT, and robot technology.

This forum was sponsored by the Super Smart Society Promotion Consortium, co-sponsored by Tokyo Tech and the Tokyo Tech Academy for Super Smart Society, and received cooperation from the Japan Society of Applied Physics, the Information Processing Society of Japan, the Institute of Electronics, Information and Communication Engineers (IEICE), the Japan Society of Civil Engineers, the Architectural Institute of Japan, the Physical Society of Japan, Innovations and Future Creation Inc.

(MIRAI SOUZOU), and the IEEE Japan Council, with endorsements by the Ota Ward, Kawasaki City, and the Tokyo Tech Alumni Association. The program is shown in Figure 2-1.

In the first half of the forum, Prof. Hidetoshi Nishimori, a specially appointed professor of Tokyo Tech, delivered a keynote speech entitled “Overview of the current status of quantum annealing.” Next, as speakers from the industrial world, Dr. Masayuki Shirane of NEC Corporation gave a lecture on superconducting quantum computing, and Dr. Mamiko Kujiraoka of the Computer and Network System Laboratory, Corporate R&D Center, Toshiba Corporation delivered a lecture on quantum cryptography communication. From Tokyo Tech, Prof. Mikio Kozuma, a professor at the Institute of Innovative Research, gave a lecture on technology for improving the accuracy of non-GPS navigation. Prof. Mutsuko Hatano, a professor at the School of Engineering, gave a lecture on quantum sensors using pink diamonds.

The second half of the forum featured a panel discussion. Participants exchanged opinions on the path and issues for the practical application of quantum science, prospects for a future ultra-smart society through concrete application and utilization, human resource development for the future, and expectations for the Super Smart Society Promotion Consortium.

Due to the recent social conditions, we held this forum online. 445 people from inside and outside Tokyo Tech participated to share cutting-edge technology and engage in stimulating discussions.

Figure2-1 4th SSS Promotion Forum Program

(2) 5th SSS Promotion Forum “Towards Super Smart Society in Carbon Neutral Era”

As the world grows increasingly concerned over global warming, we held a technical forum entitled “Towards Super Smart Society in Carbon Neutral Era.” This forum was based on global trends which strongly call for reducing carbon dioxide emissions to zero by 2050. We held this forum online. 280 people from inside and outside Tokyo Tech participated to share cutting-edge technology and engage in stimulating discussions.

This forum was sponsored by the Super Smart Society Promotion Consortium, co-sponsored by Tokyo Tech, the Tokyo Tech Academy for Super Smart Society, and the InfoSyEnergy Research and Education Consortium, and received cooperation from the Society of Instrument and Control Engineers, the Society of Automotive Engineers of Japan, the Information Processing Society of Japan, the Institute of Electrical Engineers of Japan, the Institute of Electronics, Information and Communication Engineers (IEICE), the Japan Society of Civil Engineers, the Japan Society of Mechanical Engineers, Innovations and Future Creation Inc. (MIRAI SOUZOU), the Solution Research Center for Advanced Energy Systems, and the IEEE Japan Council, with endorsements by the Ota Ward, Kawasaki City, Yokohama City Economic Bureau, and the Tokyo Tech Alumni Association. The program is shown in Figure 2-2.

The forum began with opening remarks by Prof. Tetsuya Mizumoto, Executive Vice President at Tokyo Tech. His remarks were followed by a greeting from the distinguished guest Mr. Mitsuhiro Doishita, Director of the Environment and Energy Division, Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology. Afterwards, Prof. Ken Okazaki, Institute Professor at Tokyo Tech, gave a keynote speech entitled “Significant role of hydrogen toward carbon neutrality and contribution to smart society.” Next, speakers from the industrial world delivered lectures from an extremely wide range of perspectives. Mr. Masahiro Aoki of Hitachi Ltd. discussed green transformation (GX) in core industry. Mr. Kazuyuki Iwata of Honda R&D Ltd. spoke on the motorization of mobility. Ms. Yuko Kanamori of the National Institute for Environmental Studies gave a lecture on lifestyles for a sustainable carbon-free society. Mr. Eisaku Shiratani of the National Agriculture and Food Research Organization discussed technology for reducing and absorbing greenhouse gas (GHG) emissions from agriculture. The final speak was Prof. Manabu Ihara, Director of the Tokyo Tech Academy of Energy and Informatics, and Head of the InfoSyEnergy Research and Education Consortium. He delivered a lecture on grid-coordination and distributed energy systems for carbon neutrality, as well as related demonstration experiments.

The second half of the forum featured a panel discussion on the vision for achieving carbon neutrality and related human resource development. Speakers from the corporate world proposed visions on how to utilize the energy usage history of companies and individuals as big data. On the other hand, speakers from academia discussed how the organization of standardized data and the construction of a system for data sharing may be a future role of the university. Participants also noted that the manufacturing industry may require human resources who can monitor carbon emissions in addition to quality and cost. In addition to the agenda listed above, members of the panel discussion also engaged in lively debate on questions received from attendees.

Figure2-2 5th SSS Promotion Forum Program

2-2 One-Day School

This One-Day School was held as a recurrent education in November and provided an opportunity for practical training in the research and education fields in five areas (artificial intelligence, quantum science, smart mobility, robotics (Sky), and workplace). The school was held for Consortium Partners of the Super Smart Society Promotion Consortium. Table 2-1 shows contents of the practical training. As implied by its name, this One-Day School features one day of lectures and practical training for a single research and education field. By giving an overview of the research and education fields to the Consortium Partners, the school assists them in considering future utilization and R&D. In principle, the number of participants is limited to 5 to 10 per field. This ensures close discussions with the faculty

Table 2-1 One-Day School Program

Research & Education fields		Date	Contents of Program (lecture / practice)	Venue
Smart Mobility		11/24	・Lectures on autonomous driving, ITS, and next-generation wireless communication technology ・Exercises using autonomous-driving vehicle	Ookayama Campus
Quantum Science	Computing	11/19	・Cooling down qubit devices and observation of quantum phenomena ・Hands on learning on techniques required for precise measurements	
	Sensors		・Practice concerning fabrication of superconducting thin films that constitute quantum sensors and characterization of their physical properties	
Artificial Intelligence		11/18	・Neural Networks, Stochastic gradient decent and Back propagation, RNN and CNN, The introduction of TSUBAME, Practice using Google Colab, Experiment of building language models.	
Smart Robotics (Robot Zoo Sky)		11/29	・Lectures on Robot Operating System (ROS), feedback control, and coordinated control of multi-robot systems ・Exercise of programming on ROS ・Experimental demos on a multi-drone system	
Smart Workplace		11/25	・Introduction of Smart workplace education and research field ・Technologies and sensors in the smart workplace field ・Visualization of human thermal comfort and droplet nuclei behaviors	Ootemachi 3×3Lab Future

members in charge, and opportunities for all participants to come into direct contact with the research and education fields. 23 people from 7 companies participated in this year's One Day School. Through lively discussions and practical training, the School promoted technical contribution to Consortium Partners.

Figure 2-3 Autonomous driving exercise

2-3 Ota Ward Entrepreneurship Seminar

Tokyo Tech actively supports venture startups by students through programs such as "business contests." Additionally, Ota Ward (a local ward near Tokyo Tech) has newly established Haneda Innovation City as a base for transmitting information on new industries and company startups. In conjunction with the operation of existing facilities for supporting start-ups and establishment of companies, and the operation of factory apartments where SME (Society of Manufacturing Engineers) manufacturing companies are concentrated, Haneda Innovation City is promoting even more startup-support activities than before. Tokyo Tech and Ota Ward signed a "Basic Agreement on Collaboration and Cooperation. Based on the Agreement," the Super Smart Society Promotion Consortium organized and held a two-day entrepreneurship seminar for students in collaboration with Ota Ward.

(1) First day (December 22, 2021)

The first day was held at Haneda Innovation City, that Ota Ward operates in order to support the founding of companies.

In the morning, staff from Ota Ward presented an outline of the ward. Next, Mr. Yuki Yonekura of the SDGs Innovation HUB gave a lecture on basic the knowledge and state of mind needed when starting a business; for example, articles of incorporation and tax precautions. This provided participants with a concrete image of starting a business. In the afternoon, participants visited a block of the Haneda Innovation City. They rode on an autonomous driving bus and toured companies located in offices for company founding support. Afterwards, participants listened to discussions of entrepreneurial experience from Mr. Yu Kudo, CEO of Amanogi, Corp., and Mr. Takayuki Kawaguchi, CEO of Sigma-Energy Co., Ltd. (venture companies from Tokyo Tech). Finally, in preparation for the second day, participants received an explanation for the "Entrepreneurship Plan".

(2) Second day (January 26, 2022)

The second day was held online due to the rapid spread of COVID-19.

In the morning, an explanation of business activities was given by Nifco Inc., which is located in the offices for company founding support, and by General Incorporated Association, Kanetsu Gijutsu Kyokai. In the afternoon, students brought entrepreneurial plans which they created using the "Foundation Plan" downloaded in advance from the Japan Finance Corporation website. After the group session, students were divided into two breakout rooms and discussed their entrepreneurial plans with mentors. Through this group work, students learned the effective appeal points for obtaining the loans necessary for starting a business.

Figure 2-4 Lecture at Ota Ward Entrepreneurship Seminar

3. Activities of the Social Collaborative Education Steering Committee

3-1 Implementation of cyber / physical off-campus projects

As part of the activities of the Social Collaborative Education Steering Committee, this consortium together with the Tokyo Tech Academy for Super Smart Society are planning cyber/physical off-campus projects (interdisciplinary internships for master's degree program and doctoral degree program students). In the 2021 academic year, we asked the Consortium Partners to recruit internships. Recruitment information on each Consortium Partner was posted on the consortium website and made widely known to students. This internship is a key requirement for enrolling in and completing the WISE-SSS Program, and has encouraged highly motivated students to apply. Despite the difficulties during the state of emergency that was issued in response to the COVID-19 pandemic, 7 partners handled recruitment during the spring break period of 2021, and three partners accepted internships for three students. For the internship during the summer vacation period of 2021, two partners accepted internships for four students. The impact of COVID-19 was serious at this time and major issues remained; for example, it was particularly difficult to set up internships in English for international students. In the 2022 academic year, we hope to continue the active discovery of new fields where the needs of participating partners can be matched with the professional abilities of students, and that more internships can be accepted. In particular, from the 2022 academic year, while protecting the privacy of students, we will build a framework for sharing information summarizing the research themes and research achievements of each student with Consortium Partners. This will enable reforms to ensure efficient matching with partners. The assumed period is during summer vacation (August 2022) and during the spring vacation in 2023. Also, because of the spread of globalization, we want to promote internships in English and plan overseas internships.

We look forward to continued cooperation from Consortium Partners.

3-2 Courses related to Super Smart Society Innovation

The goal of the Tokyo Tech Academy for Super Smart Society is to cultivate the needed expertise and see the big picture for realizing Super Smart Society for students enrolled in the WISE-SSS Program or interested students in the master's degree program and doctoral degree program, and to offer omnibus lectures on trending issues in the real world in collaboration with Consortium Partners. This will allow us to create original science and technologies in specialized fields spanning both cyber and physical fields, and resolve various social issues by having an overview of the path from quantum science to Super Smart Society, with the aim of developing students with leadership skills capable of leading each sector of industry, government, and academia. In the 2021 academic year, with the cooperation of Consortium Partners, we started the social cooperation courses Super Smart Society Innovation A1, A2, and A3. We selected part-time lecturers from Consortium Partners to provide omnibus lectures on the frontiers in quantum technology (A1), IoT, robotics, and smart cities (A2), and smart agriculture (A3). These lectures are held using on-demand distribution of lecture videos and discussions via a bulletin board system. Super Smart Society Innovation A1 had a total of 20 students registered for courses, 16 of which earned credits. A2 had a total of 21 students registered for courses, 19 of which earned credits. A3 had a total of 12 students registered for courses, 10 of which earned credits. The on-demand video-style lectures and discussions using a bulletin board system were extremely well-received by students in a variety of different departments and courses at Tokyo Tech. There was an enormous amount of positive feedback on the contents and format of the lectures. From the 2022 academic year, we plan to hold Super Smart Society Innovation A4 on smart workplaces.

3-3 Producing online educational content for Super Smart Society

In the 2021 academic year, as SPOC (Single Private Online Course) held by edX edge (note: a free online education service jointly launched by Harvard University and MIT), we developed a campus-only program “Learning the foundation of programming with Japanese chess” for studying the MATLAB language programming from October 29, 2021 to March 31, 2022. During this period, 147 students (128 students from the undergraduate program to the doctoral program and 19 faculty/staff members from all schools at Tokyo Tech) studied in the program. 64 students took the quiz (1 point or more). 20 students achieved a passing score (60 points), with a high score of 95. The program was extremely well-received by all students. Furthermore, from March 29, 2022, we held two edX Massive Open Online Courses (MOOC) that were open to the public: “Learning the foundation of programming with Japanese chess” and “Introduction to Super Smart Society.” The former course adds a competition between human beings and computers to the campus-only version of the program. It is scheduled to be open until September 27, 2022. The latter course features several research and education fields of SSS. It is scheduled to be open until November 29, 2022. Additionally, as the Online Board of Education of the Tokyo Tech Academy for Super Smart Society, the SSS Online website was released as a portal site for online education on September 1, 2021. Furthermore, we posted the Super Smart Society Innovation A3 “Frontiers in Smart Agriculture” that was delivered by a part-time lecturer.

4. Activities of the Interdisciplinary Research Promotion Committee

4-1 Matching workshops

In the first semester of the 2021 academic year, interdisciplinary matching workshops were held online on June 9 and June 30, 2021. The S-Round on June 9 was the stage where students from Tokyo Tech offered the university’s research seeds, while the N-Round on June 30 was the venue where Consortium Partners of the Super Smart Society Promotion Consortium presented their needs in an opposite way. There were lively discussions among the 30 participating students, researchers from 27 partners, and university faculty members. In the second semester, workshops were held on November 17 and December 8, 2021, in the same format as the first semester. 41 students, researchers from 19 partners, and university faculty members participated. In order to enhance the appeal of these workshops, we planned keynote lectures for both the first and second semesters. (Fig. 4-1) At each event, questionnaires were administered to students and Consortium Partners in order to facilitate joint research and human resource matching. A total of 18 matches were established.

(first half) (second half)

Figure4-1 2021 SSS Matching Workshop flyer

4-2 SSS research and education fields

4-2-1 Smart Mobility

We are building a platform to educate students enrolled in the WISE-SSS Program, and to conduct collaborative research on automated driving and smart mobility services with Consortium Partners of the Super Smart Society Promotion Consortium.

During the 2020 academic year, in the smart mobility field, education provided to enrolled students included intensive exercises in interdisciplinary research, and experience in operating and riding in autonomous vehicles. Road-side units(RSUs) equipped with 60 GHz millimeter-wave (mmWave) antennas, high-definition cameras, and LiDAR (Light Detection and Ranging) sensors were also installed on campus. For example, an RSU can monitor the surrounding environment as three-dimensional information through camera images and LiDAR point cloud. In addition, we have introduced a new automated driving hybrid vehicle (HV) intended for

driving tests on public roads.

In the 2021 academic year, we enhanced functions such as adding more LiDARs to the RSUs that were installed last year and introducing V2I/V2V (Vehicle to infrastructure/Vehicle to vehicle) communication to enhance the functions. We also established a 60GHz mmWave network (including backhaul and access) with ultra-high-speed and low-latency narrow-range communication to support intelligent transport systems (ITS) with coverage of all main roads on the premises. Furthermore, we are proceeding with the establishment of 5G networks for 5G-assited automated driving experiments on campus. We have deployed two private 5G base stations (supporting both FR1 Sub-6GHz and FR2 28GHz bands), and one edge server. (Figure 4-2)

These environments are open to use by Consortium Partners and students enrolled in the Tokyo Tech Academy for Super Smart Society. By utilizing these research infrastructure facilities, Consortium Partners and students registered in the WISE Program are expected to create new services by studying and acquiring fundamental technology that is essential for autonomous driving. (Figure 4-3 and Figure 4-4)

In the next academic year, we will expand coverage of the ITS network by installing more RSUs, and introduce more 5G stations and edge servers. We also plan to introduce new technologies to this private 5G network and expand its capabilities for B5G/6G networks to support safe automated driving.

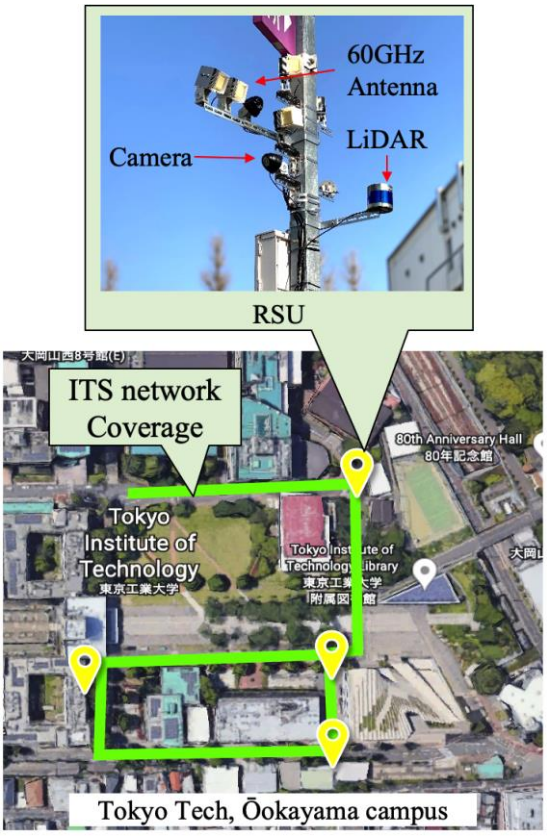


Figure 4-2 RSU and the millimeter-wave network

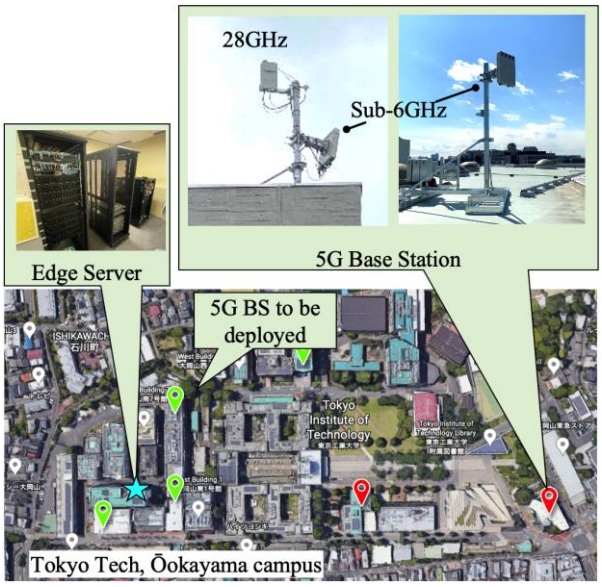


Figure 4-3 Facilities for Concentrated Exercise on Interdisciplinary Research

Figure 4-4 Exercise

4-2-2 Smart Robotics

● Robot Zoo Sky

During the 2019 academic year, we built Robot Zoo Sky as a platform to simultaneously control heterogeneous drones and mobile robots. The main purpose of this research and education fields is to develop efficient and robust environmental monitoring technologies that contribute to supporting damage assessment after a natural disaster, and to contribute to the realization of Super Smart Society in the context of enhancing societal resilience. Also, through exercises in this field, students will be able to gain the skills to safely control and operate multiple systems connected via a network.

In the 2021 academic year, we refined the curriculum for learning how to use the Robot Operating System (ROS) created in the previous academic year so that it integrates experimental demonstrations. Based on this curriculum, we held intensive training for interdisciplinary planning in October, and a One-Day School for Consortium Partners in November. (Figure 4-5) The One-Day School was particularly well-received. For example, we received reports that a member who studied at the School held, as an instructor, internal education for employees in his division of the company several days later. Furthermore,

Figure4-5 Concentrated Exercise on Interdisciplinary Research(left) and One-Day School(right)

we contributed to the enhancement of online education through measures such as creating content for the MOOC "Introduction to Super Smart Society."

Moreover, we started collaboration with the smart agricultural research and education fields in this academic year. In addition to the faculty members in charge of this field, we formed an attempting interdisciplinary research team consisting of engineering, information science and engineering, and agriculture with researchers from CNR-IEIIT in Italy and the University of Turin. This team started joint research on the utilization of multi-drones in the agricultural field. In particular, we devised Angle-aware Coverage Control (Fig. 4-6), which is a new environmental monitoring control method for map reconstruction of a farmland. Research activities are proceeding smoothly, with one publication in an international journal and three international conference papers. Upon completion of the smart agricultural research and education fields, we expect further research growth such as conducting field experiments.

Figure4-6 Angle-aware Coverage Control

● Robot Zoo Aqua

Robot Zoo Aqua aims to greatly expand the active field of robots to water. In the 2020 academic year, we established this research and education field in the experimental room for the Systems and Control Engineering Department, School of Engineering in Room B107 at West Building 8 on the Ookayama Campus, Tokyo Tech. We have also heightened the degree of completeness for the field through infrastructure facilities. For example, in the 2020 academic year, we introduced a large water tank, an optical motion capture system, and an underwater drone. In the 2021 academic year, we introduced an inertial sensor type motion capture system and secured an optical motion capture system to the ceiling of the camera.

In this academic year, as shown in Figure 4-7, we cooperated in creating content for the MOOC in order to enhance the educational environment. The created content has already been published. Moving forward, further development of online education utilizing this research and education fields is expected.

When looking at the progress of system construction, our first step was to complete the water drone Iwatobi Kai by cooperating with the Aqua Lab from the Society for the Study of Robotics to repair the underwater robot Iwatobi. Iwatobi Kai can be automatically controlled from a computer (Figure 4-8). We also completed a system that incorporates information from the motion capture system installed in the previous academic year into the robot operating system (ROS). In the future, connecting the drone and the system is expected to enable the creation of a unique curriculum on feedback control and the carrying out of joint research on autonomous navigation of water drones.

Figure4-7 Filming for MOOC contents

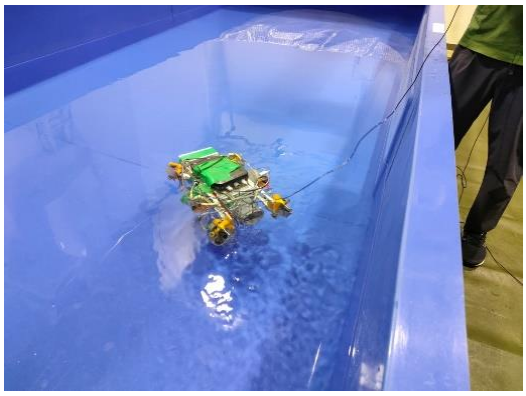


Figure4-8 Marine Drone "Iwatobi remodel"

●Robot Zoo Land

Robot Zoo Land consists of a group of robot platforms for education and research including collaborative robots, quadruped outdoor field robots developed by Tokyo Tech, and multifunctional robot actuator modules, as well as a group of robot evaluation and control equipment including digital signal processors and controller devices, high-speed motion capture systems for control, and high precision GNSS + INS (Global Navigation Satellite System + Inertial Navigation System) hybrid equipment. Through these efforts, we aim to provide an education and research environment and educational program for smart robotics that utilizes 5G, IoT, and AI. We also seek to promote practical education and research that addresses social issues such as disaster response, infrastructure inspection, and aging.

In the 2021 academic year, we created and released educational content on the MOOC Land as shown in Figure 4-

9. As a research activity, we used a high-speed motion capture system for control to perform coordinated motion control and motion analysis of multiple robots. We also constructed a long articulated arm that can be used for infrastructure inspection using robot actuator modules. Furthermore, we proceeded with the construction of a robot remote control system based on ROS by combining it with virtual reality technology (Figure 4-10). Additionally, we improved the reliability of the quadruped robot for outdoor fields. Specifically, we achieved 50 minutes of untethered continuous walking including climbing slopes has been realized in the Ishikawadai area (Figure 4-11).

Figure4-9　MOOC contents (Robots and the Super Smart Society)

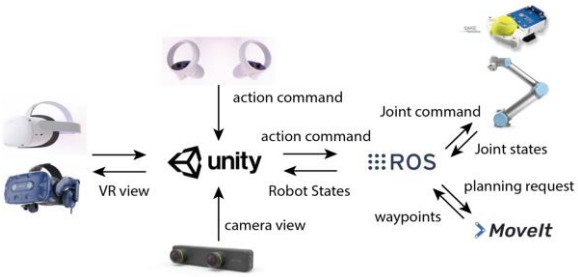


Figure4-10　VR robot remote control system

Figure4-11　Walking experiment on Quadruped outdoor field robot

●Smart Manufacturing

We are promoting education and research using a practical machining system that smoothly connects CAD → CAM → machine, a process for effectively utilizing multi-axis synchronization, which is the original function of 5-axis milling machines that were already in actual operation.

In terms of education, we conducted intensive exercises in interdisciplinary research planning in the curriculum of the WISE Program (Doctoral Program for World-leading Innovative & Smart Education) (Figure 4-12). Since the exercises are mainly taken by students from outside field, the students start by acquiring basic knowledge by studying an outline of the flow of parts production in the precision machining field. Next, by using the above machining system, the students were able to actually experience a series of processes for machining complicated one-piece parts without error. This enabled the students not only to acquire knowledge through classroom lectures, but also to conduct exercises useful for the planning of new research themes by integrating the backbone that each student has.

In terms of research, we have continued initiatives from the previous academic year toward the realization of high value-added manufacturing by coordinating multiple machining processes. In particular, in recent years, maintaining accuracy when the target parts move between processes is a high-priority issue that must be addressed, with the increasing importance of mass customization. We plan to continue our efforts from the next academic year gazing at cooperating with participating corporations.

Figure4-12　Concentrated exercise on Interdisciplinary Research

4-2-3 Quantum Science

● Quantum Computing

Quantum computers are expected to be put into practical use as ultra high-speed next-generation computers that are based on the principles of quantum mechanics. While a normal computer uses a state (bit) of either “0” or “1” for information processing, a quantum computer performs calculations by using a qubit that is a superposed state of 0 and 1. It is known that it can execute massively multiple computational paths in parallel by operating qubits that are integrated on a large scale, and research into how to apply it is progressing. Such technology is also expected to contribute to solving the information processing problems required in　Super Smart Society. Research aimed at realizing qubits is being actively conducted in various physical systems. Although qubits based on superconductors are advancing, the

spin in silicon quantum dots is also viewed as a promising system. This method will enable the integration of devices in the future via semiconductor processing technology. It also has the advantage of a long coherence time corresponding to the information retention time. In this research and education field, while conducting research mainly on the spin system, we are cultivating human resources and conducting education and research for high-level quantum technology. In the 2021 academic year, we constructed a measurement system for realizing and evaluating qubits as shown in the schematic diagram of Fig. 4-13 in combination with existing cryogenic refrigerators (cryogen/cryogen-free type), and expanded to a high-precision, low-noise measurement system for observing quantum phenomena at cryogenic temperatures. We introduced new facilities to our measurement system for quantum computing devices, consisting of e.g. a vector signal generator, a high-speed oscilloscope, and a lock-in amplifier. We thus established an experimental system that can demonstrate the coherent operation of silicon quantum bits (Figure 4-14).

Furthermore, we utilized this field in activities such as One-Day School for Consortium Partners and exercises for students registered in the WISE Program. We also held exercises, demonstrations, etc., for high-frequency technology, precision measurement technology, ultra-low temperature technology, vacuum technology, and other technologies used in cutting-edge quantum science research (Figure 4-15). We plan to continue expanding this research and education field and enhancing its functions from the 2022 academic year. We hope that related companies and National Research and Development Agencies will utilize this to promote collaborative research.

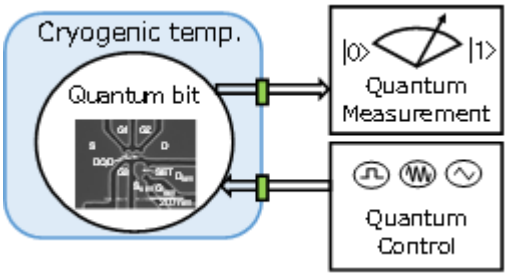


Figure4-13 Schematic image of quantum bit measurement system

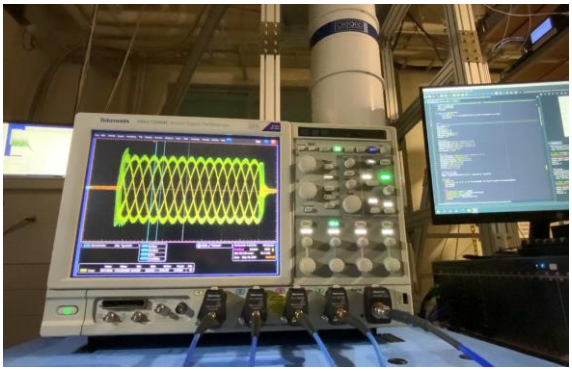


Figure4-14 Quantum bit operation exercise system

Figure4-15 Exercise on cryogenic technology and precision measurement

● Quantum Sensors

A sensor is a device that converts a physical phenomenon or the state of an object into an electrical signal. In particular, a sensor that uses the quantum effect (a phenomenon that appears in quantum mechanics) is called a quantum sensor. These quantum sensors are expected to detect with greater sensitivity than conventional sensors and to contribute to the construction of an ultra-smart society by detecting phenomena that were previously undetectable.

There are many different types of quantum sensors. We are placing particular focus on the Superconducting Quantum Interference Device (SQUID), which is capable of detecting minute magnetic fields (shown in Figure 4-16). The heart and brain also generate weak magnetic fields. If highly sensitive detection were possible, the technology could be applied to medical procedures such as magnetoencephalography and magnetocardiography. It would also be possible to conduct immune tests using magnetic markers. Thus, SQUID sensors are an important element of super smart medicine. However, an issue existing at the current time is the low spatial resolution and the need to operate at very low temperatures. Therefore, in order to develop SQUID sensors that are smaller and can operate at higher temperatures, in this research and education fields, we are developing high-temperature superconductors with a thickness of several atomic layers. In 2021 academic year, we continued to research high-temperature superconductivity of single-layer FeSe thin films on $SrTiO_3$ substrates. We discovered a difference in the temperature at which superconductivity is observed in transport characteristics (40 K) and the temperature at which a gap occurs in the electronic state (60 K). We also obtained important knowledge for clarifying the origin of superconductivity in this system. In collaboration with cooperating organizations, we began searching for optimal surface oxidation conditions aimed at the development of new quantum sensors. These quantum sensors utilize oxygen defects on the surface of silicon carbide crystals, which are wide-gap semiconductors. Moreover, we used the constructed equipment to hold intensive training for interdisciplinary planning for students enrolled in the WISE Program and One-Day School for young employees of cooperating organizations. (Figure 4-17) As shown here, in the quantum sensor research and education fields, we are cultivating human resources and conducting education in quantum science at the same time as performing research. We hope that corporations and National Research Institutes will also utilize this field.

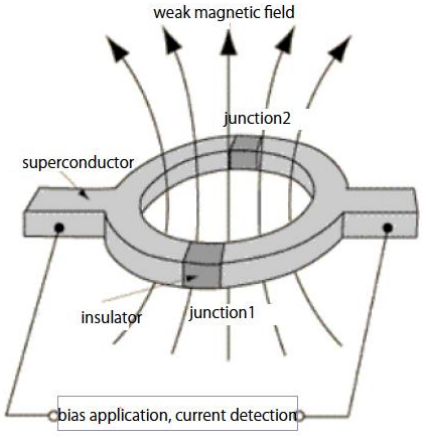


Figure4-16 Schematic drawing of a Superconducting Quantum Interference Device (SQUID)

Figure4-17 One-Day School

4-2-4 Artificial Intelligence

In Super Smart Society, we expect every device that we use in our daily lives to become smart and connected to computers, resulting in a safer and more convenient life. An essential item for control by computers is a system that can operate by recognizing and understanding surrounding conditions via sensors and cameras. Much of the information in the physical world is noisy and unclear. Therefore, in order to properly process these in the cyber world, it must be converted into symbolic information that is easy for computers to process. At this Academy, we consider artificial intelligence technology to be a basic technology that can connect the cyber and physical worlds in Super Smart Society. Therefore, we are providing education with the aim of enabling enrolled students to master artificial intelligence technologies. Starting in the 2020 academic year, university-wide data science and AI (DSAI: Data Science and Artificial Intelligence) education for graduate students started at Tokyo Tech. Unlike existing classroom-only lessons, this allows students to practice while actually operating machine learning tools in a practical environment. For this purpose, at the Academy we started the operation of an education system using Wi-Fi 6 from the 2020 academic year.

To ensure the efficient use of the technology called “deep neural network,” which is one seed of artificial intelligence, there is the need for the advanced computational environment called GPUs (Graphics Processing Units). Currently, GPUs are still too expensive for all students to buy. However, if cloud services could be used, it would be possible to provide all students with the same computational resources at low cost. In this education system, students can easily access the learning environment in the cloud using WiFi from their own computers. On the cloud, it is possible to actually try handling the materials and themes presented by the teacher as a “moving textbook” using a service called Google Colaboratory, thus making it possible for students to learn comfortably. (Figure 4-18) This also allows the GPU of the university's supercomputer TSUBAME (Fig. 4-19) to be used.

This Academy requires students to acquire a certain level of expertise in artificial intelligence in order to complete the program. Also, from 2020 onward, we held intensive exercises in interdisciplinary research planning that utilize artificial intelligence. These exercises are intended for students who are enrolled at the Academy and have an even higher level of learning motivation. Here, each student can learn about the latest research results directly from Tokyo Tech faculty members through demonstrations. By doing so, we aim to further improve the skills of the students. In October 2021, we conducted activities for themes targeting speech recognition and speech synthesis, and held a learning results presentation.

We also started online support from the 2020 academic year. This online support can also be described as a “consultation desk” for technical problems that occur when students actually use artificial intelligence for their research projects.
Students ask questions on a dedicated online bulletin board and meet directly with faculty members when necessary. This system makes it possible to solve problems.
Furthermore, in the 2021 academic year, we held a One-Day School for Consortium Partners. A total of 10 people from 4 organizations participated. At the One-Day School, we explained the principle of neural networks and basic usage of Google Colaboratory(Note 1). We also conducted simple exercises using PyTorch(Note 2).

(Note 1) Google Colaboratory: A development environment for machine learning education and research provided by Google.
(Note 2) PyTorch: Python’s open source machine learning library used in computer vision and natural language processing.

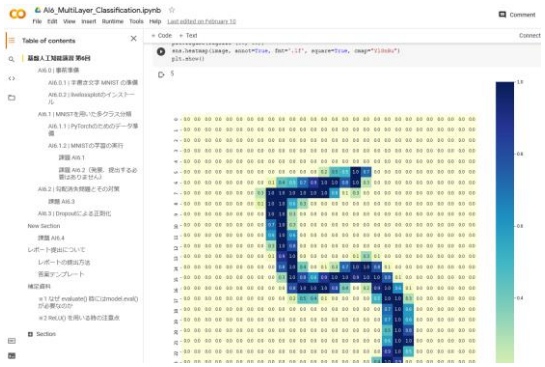


Figure 4-18 Google Colaboratory

Figure 4-19 Tsubame

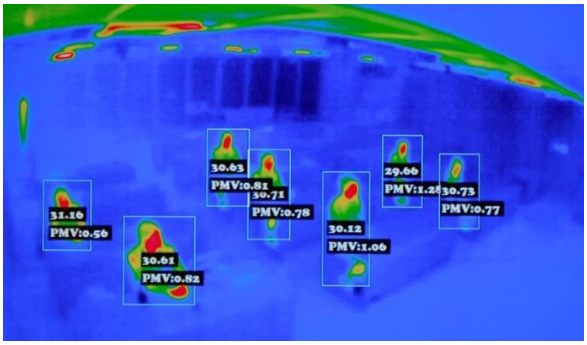


Figure4-20 Thermal comfort judgment system based on thermal images and AI

Figure4-21 Airborne droplet nuclei projection system based on simulation and MR

Figure4-22 Smart Work Home (Suzukakedai Campus)

4-2-5 Smart Workplaces

In this research and the education fields, we are constructing a platform on the theme of "smart workplaces", to realize places where each person can work in a healthy and energetic manner. In this field, we are cooperating with Azbil Corporation, Itoki Corporation, Ecozzeria Association, Mitsubishi Estate Co., Ltd., Mitsubishi Electric Corporation, and Rakuten Mobile, Inc.

In the 2021 academic year, we started verification using a sensor network for the indoor environment and vital signs of workers. The sensor network was built in a third place (neither home nor office) in Otemachi at the beginning of the year. We have mainly developed two systems: (1) a thermal comfort judgment system (Fig. 4-20) using thermal images and AI (Artificial Intelligence), and (2) an airborne droplet nuclei projection system (Fig. 4-21) using simulation and MR (Mixed Reality).

In (1), the cameras and thermal imaging sensors are used for calculating the predicted mean vote (PMV) through AI image analysis. Using those calculating results, the final goal is to control air conditioning units to be closer to workers' actual feelings than the current room temperature control. In (2), CFD simulations and MR technology are used to project in the room the trajectories of airborne droplet nuclei, which could cause airborne infection by COVID-19. It remains for us to realize workplaces where people can work with more safety and peace of mind.

In addition to utilizing these systems for education for students and working adults, we also created a promotional video to facilitate understanding by the general public.

Furthermore, in the 2021 academic year, we constructed a field called "Smart Work Home", which replicates a working-from-home environment on the Suzukakedai Campus of Tokyo Tech. Smart Work Home consists of two rooms, one with a wooden interior and the other with a normal interior. Both rooms are equipped with a variety of controllable housing equipment (air conditioning, ventilation, floor heating, and lighting) (Fig. 4-22). We will measure sleep efficiency from the viewpoint of "rest", which is the basic role of housing. Similarly, we will measure work efficiency from the viewpoint of "work", which has been attracted attention due to the pandemic. We then plan to examine the ideal housing that maximizes both sleep and work efficiencies based on experiments on subjects in the future.

4-2-6 Smart Agriculture

The theme of smart agriculture is attracting attention from the viewpoint of improving the productivity of the entire food chain including breeding, production, processing, distribution, and consumption. It is also a focus from perspectives such as environmental change and environmental conservation. Smart agriculture is also particularly important for the development of rural areas in Japan. This is due to the agricultural situation in Japan; specifically, it is difficult to improve efficiency due to the large number of small-scale agricultural lands in the mountains and the declining farming population. In this research and

education fields, by utilizing robot technology, Information and Communication (ICT) technology, and AI technology, which are Tokyo Tech's strengths, we will build edge AI and cloud AI that can acquire a large amount of data from various sensors and make decisions based on this. In the future, our goal is to achieve remote agriculture that can be operated autonomously.

In the 2021 academic year, the topsoil of the smart agricultural field developed on Tokyo Tech's Suzukakedai Campus was replaced with red soil suitable for cultivation, and farming land of about 200 m^2 was developed. We also installed iron pillars for moored drone flight and sensor network installation (Figure 4-23). In the first half of the 2022 academic year, we will complete a smart agricultural field which can be used to fly mooring drones that is equipped with power, communication, water, and a fixed-point observation sensor network (Fig. 4-24). Next, we will cultivate crops such as soybeans. We will use the data obtained from mooring drones and sensor networks to develop the technological foundation for realizing highly productive agriculture. Furthermore, we will use this as a site for collaborative research with Consortium Partners.

The Academy also aims to develop leaders who promote smart agriculture. In the 2021 academic year, a group of instructors composed of members of the Super Smart Society Promotion Consortium held a lecture entitled "Frontiers in Smart Agriculture." Through these lectures and practical training in the field of smart agriculture, students can study the future of Japanese-style smart agriculture and cutting-edge practical examples for its realization.

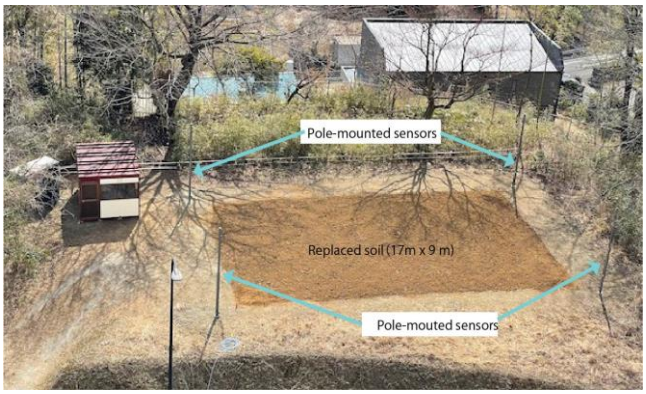


Figure4-23 View of the Smart Agriculture field site (Soil replaced, Iron pillar installed)

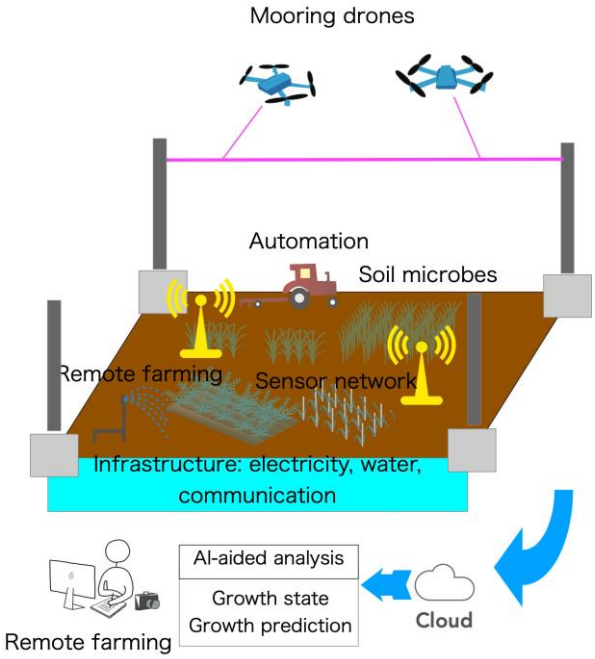


Figure4-24 Mooring drone measurement

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