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NICT REPORT

New ICT technology strategy toward Society 5.0

NICT National Institute of Information and Communications Technology


Imagine a world where the flow of information is no more.
What would it mean if communications just stopped?
Our lives, even their most everyday moments,
have taken shape through a succession of endeavors and innovations.
Our passion is to keep people in comfort and security
and co-create a vibrant society, one full of curiosity.
We will always pursue a freer, more expansive future.
We are transcending boundaries, forging connections,
and liberating people from constraints.
Beyond human intelligence,
co-create new standards for future society.
NICT

Message from the President

Celebrating the start of 2025, we would like to express our heartfelt greetings in this season.

Thank you for your kind understanding of and cooperation with the National Institute of Information and Communications Technology (NICT).

Last year, the Noto Peninsula was hit by a large earthquake in January and again suffered damage caused by heavy rain in September. These repeated disasters made it even more difficult for the afflicted regions to recover, and also made us recognize the importance of enhancing the resilience of information infrastructures. In April of the same year, NICT marked the 20th anniversary of its founding, which was done through a merger between the Communications Research Laboratory and the Telecommunications Advancement Organization. We would like to express our gratitude to all our stakeholders who have given NICT a range of support over the past two decades, including those engaging in the industrial, academic and governmental sectors as well as former NICT officers and staff. Your invaluable contributions have shaped NICT into what it is today.

In April 2025, the final fiscal year of the Fifth Mid-to-Long-Term Plan will start. In this five-year plan, we set five priority R&D areas, which are areas for advanced electromagnetic technology, innovative networks, cybersecurity, universal communication, and frontier science. Moreover, in line with the Japanese government's strategies, we have been proactively conducting research in four strategic fields: "Beyond 5G," "AI," "Quantum ICT," and "Cybersecurity." We believe that advanced technologies for these fields are indispensable to build a next-generation ICT foundation to create Society 5.0 as soon as possible. In particular, in the "AI" field, the use of generative AI has spread throughout society while various social issues are becoming more apparent. Under these circumstances, NICT opened the Global Partnership on AI (GPAI) Tokyo Expert Support Center in July 2024 and then established the AI Research and Development Promotion Unit to speed up R&D on AI in September of the same year. Additionally, following the revision of the Act on NICT, we have been implementing the new NOTICE project while also expanded CYNEX Alliance activities. These efforts aim to transform NICT into more than just a conventional research institute, positioning it as a national hub that fosters collaborative research across universities, private companies, and other institutions throughout Japan.

In the "Beyond 5G" field, in addition to R&D into Non-Terrestrial Networks (NTNs), space-time synchronization technologies and terahertz communication technologies, we are proactively participating in international joint research projects and international standardization activities and have already made achievements. These accomplishments will be presented at the Mobile World Congress 2025 in Barcelona this March.

In the "AI" field, based on the Global Communication Plan 2025, we succeeded in advancing long-used multilingual translation technology with the VoiceTra app, which provides simultaneous interpretation service. This technology will be widely used at Expo 2025 Osaka, Kansai, Japan, to be held starting in this April. Also, with regard to our Large Language Model (LLM) that is set for further development, we are accelerating R&D to develop a Japanese language-oriented generative AI based on a large dataset of Japanese text and by leveraging past R&D results, including those about the WISDOM-X system.

In the "Quantum ICT" field, we launched the Quantum ICT Collaboration Center, which has been leading the development of new collaborative research fields by providing the following four functions as Japan's quantum security technology research center: "Research and development," "Open testbed," "Dissemination activities towards society," and "Human resources development." Notably, the Center has made significant progress with initiatives such as the NICT Quantum Camp and the Young Researchers Lab to foster talent in this field.

In the "Cybersecurity" field, we launched Cybersecurity Nexus based on the cybersecurity skills and know-how that we have accumulated for more than 20 years. We use it to widely share cybersecurity information and as a platform to develop experts in cybersecurity across industrial, academic, and governmental sectors to enhance Japan's cybersecurity-related capabilities. We are also proactively conducting research into AI system security in addition to applying AI technologies to the security field.

Further, for public services—which are part of NICT's important operations—we will steadily provide services for Japan Standard Time, calibration of wireless devices, cyber training programs including CYDER, and space weather forecast. For the space weather forecast service, the sun will reach its solar maximum period of greatest activity in 2025 in the 11-year solar cycle. We have already been cautioning citizens regarding each large-scale solar flare activity since last year and will continue to diligently provide the space weather forecast service.

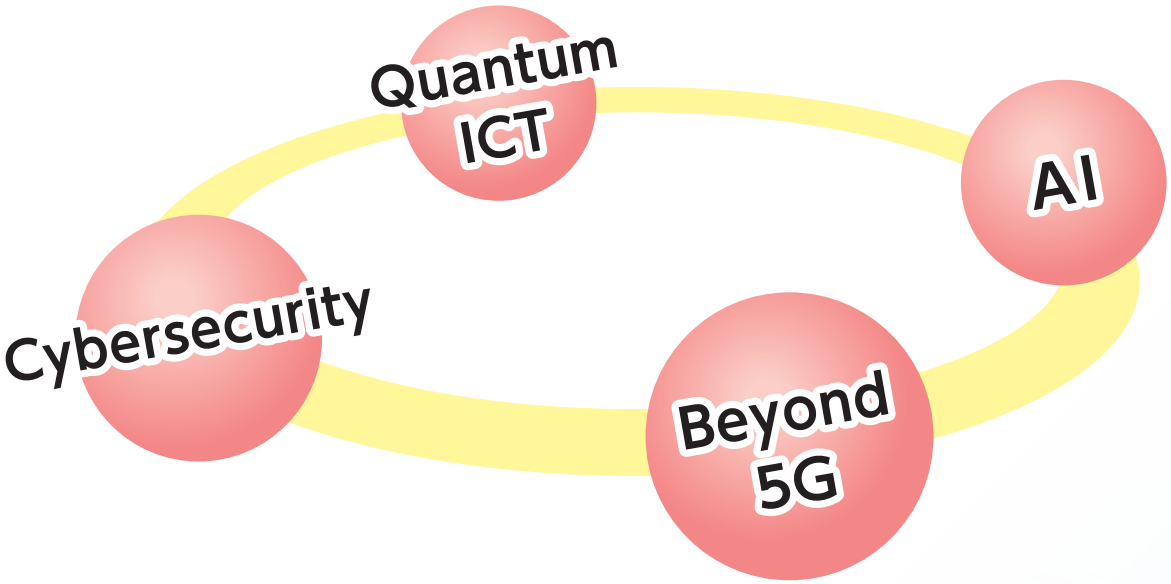
We hope that you will kindly continue to support us in implementing measures to achieve our vision: Beyond human intelligence, co-create new standards for future society.

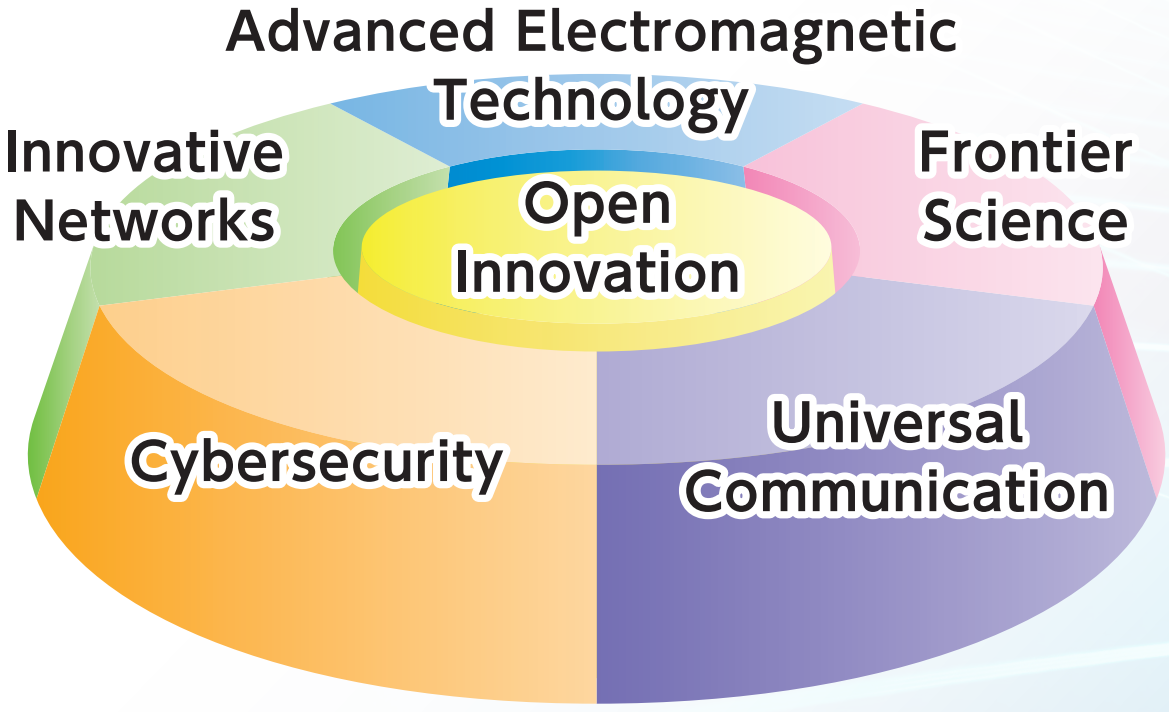
In closing, we extend our heartfelt wishes for a healthy and prosperous New Year to you.

President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki

New ICT technology strategy toward Society 5.0





NICT's **fifth mid-to-long-term plan** (April 2021 to March 2026) inherits the "five priority R&D areas" of the fourth mid-to-long-term plan, and promotes open innovation by widely disseminating our R&D results within society.

The "five priority R&D areas" are the areas of

- **Advanced electromagnetic technology**
- **Innovative networks**
- **Cybersecurity**
- **Universal communication**
- **Frontier science**

In addition, we will promote cross-sectional and strategic R&D in four research fields that should be pursued strategically The strategic fields are:

- **Beyond 5G**
- **AI**
- **Quantum ICT**
- **Cybersecurity**

Collaboration across fields is also important for building a total system that links elemental technologies in addition to advancing them. Through these activities, NICT is promoting **Open Innovation** in order to contribute to solving social and regional issues, digital transformation, and value creation in social systems for the new era, and achieving SDGs.

PR movie for NICT

A Future with N

The AI robot character "N" from the year 203X explains NICT's future R&D vision in an easy-to-understand manner. We hope you enjoy it!

https://youtu.be/YOenAWHhRIA

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Advanced Electromagnetic Technology Area
Radio Research Institute

Director General NAKAGAWA Katsuhiro

The Radio Research Institute drives research and development of various technologies related to electromagnetic waves within the field of ICT, as well as the promotion of these technologies in society. Our institute aims to realize Society 5.0 by utilizing electromagnetic waves.

Radio Propagation Research Center

At the Radio Propagation Research Center, we primarily advance research and development of monitoring and forecasting technologies for the Earth and space using radio waves. We contribute to risk avoidance by sensing events in real spaces using electromagnetic waves, reconstructing these situations in cyberspaces, predicting the future with simulation technologies, and feeding back the results into real spaces.

Remote sensing technology

In response to the Noto Peninsula Earthquake on January 1, 2024, we used Pi-SAR X3 to observe the whole Noto Peninsula in February. We processed the emergency data requested by research institutions on board. We then processed all of the data at NICT and provided it to related organizations later. Fig.1 shows an example of data observed along the coast of Wajima City. The two red circles mark rock areas raised above the sea by the earthquake.

We promoted our originally developed 2-μm seed laser and water vapor differential absorption lidar (DIAL) system to private companies and research institutions through various opportunities such as CEATEC 2023. This led to the development

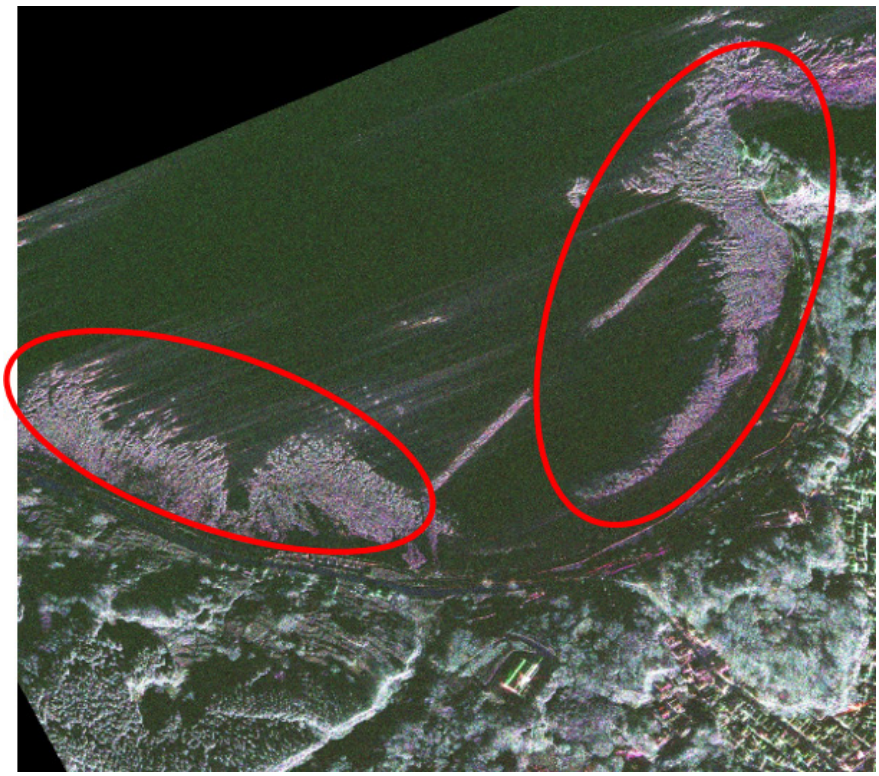


Fig.1 : An example of the data observed along the coast of Wajima City. The two red circles indicate rock areas raised above the sea by the earthquake.

of a more compact and stable seed laser. The module improvements we made to the room-temperature pulsed laser, which amplifies the light from the seed laser, achieved the world's highest performance (by signal detection capability index) as a coherent lidar transmitter, allowing for more distant measurements of wind and water vapor.

We also verified the Global Precipitation Measurement (GPM: current version V07A) dual-frequency precipitation radar (DPR) products. An improvement in the DPR's precipitation detection algorithm was confirmed to increase precipitation frequency. We also mitigated the positive trend of precipitation frequency in the older version (V06A) caused by a side-lobe level change of radar.

Space environment technology

To assess current conditions and input for ionospheric data assimilation, we are developing a system to acquire 100 real-time Global Navigation Satellite System (GNSS) receiver data points distributed globally and convert these to the total electron content of the ionosphere. We have now begun implementing this project. Using data collected from the GNSS receivers, we also succeeded in observing irregular structures in the ionosphere caused by atmospheric waves with concentric pressure waves after the major eruption of the underwater volcano in the South Pacific near Tonga. We then elucidated the mechanism of plasma bubble generation due to lower atmospheric fluctuations caused by the volcanic eruption (Fig.2).

Progress is also being made in developing an engineering model of a space environment sensor capable of being mounted on Himawari-10. We have manufactured all devices (electron beam measurement instrument, proton beam measurement instrument, charge measurement instrument, and shared circuits), performed individual performance evaluation tests for each measuring instrument, and evaluated feasibility before transitioning to the proto-flight model. Through cooperation between the Japan Meteorological Agency (JMA) and NICT, we implemented a joint procurement project, Next Generation Geostationary Meteorological Satellite Manufacture, and commenced the manufacture of Himawari-10.

To support international cooperation in monitoring solar wind disturbances through the upcoming Space Weather Follow-On (SWFO-L1) satellite, we have set up a ground station for the SWFO antenna network at the Kashima Space Technology Center and have already begun trial operations, ahead of other global efforts. The SWFO program is expected to see participation from nearly ten countries.

Electromagnetic Standards Research Center

The Electromagnetic Standards Research Center aims to contribute to establishing measurement standards for electromagnetic waves, fulfilling two external roles: "supporting national and international standards as a standards organization" and "researching and developing cutting-edge measurement technologies as a research organization".

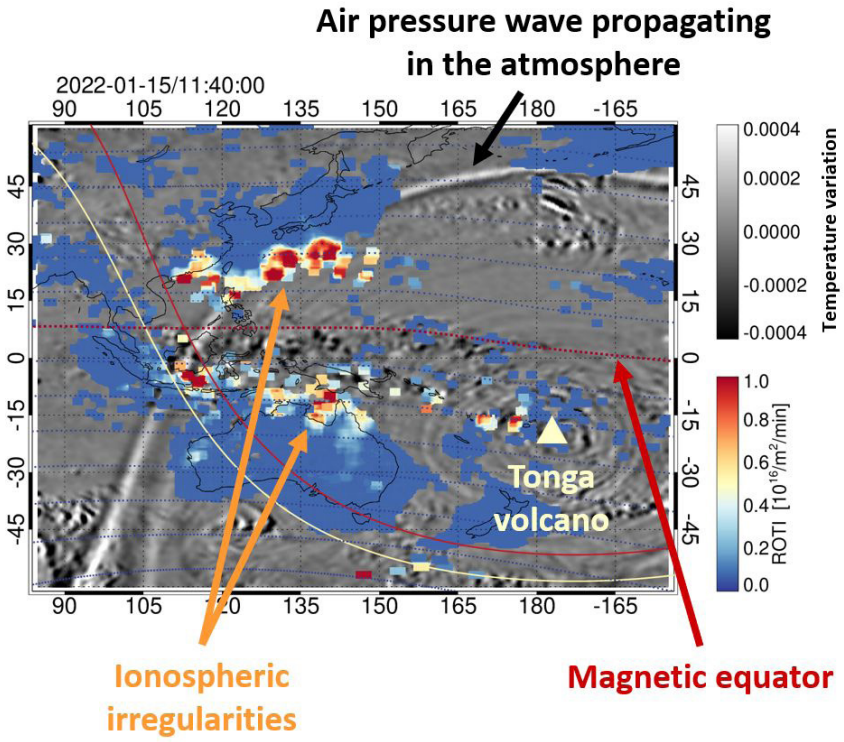


Fig.2 : Irregularities in the ionosphere detected by analyzing GNSS receiver data captured after the Tonga underwater volcanic eruption

Electromagnetic compatibility technology

Assuming a high-density distribution of wideband electromagnetic noise sources, we derived the probability distribution of noise power from the strongest (single) electromagnetic noise source and all electromagnetic noise sources, considering general conditions such as the probability that the major lobe of noise radiation is in the direction of the radio receiver and the occupancy rate of the noise spectrum within the desired frequency band. The validity of the results was demonstrated by comparison with Monte Carlo simulations. Furthermore, based on results of considerations of the strongest electromagnetic noise source, we proposed an electromagnetic disturbance limit setting model to be applied to international emission standards. Applying this model to set electromagnetic disturbance limits for the protection of 5G systems resulted in its adoption as a draft in International Special Committee on Radio Interference (CISPR) technical documents.

We were the first in the world to clarify the quasi-millimeter-wave exposure level from commercially operational 5G base stations. To achieve this, we constructed and evaluated a measurement system that enables the taking of measurements while downloading data to a mobile phone terminal so as to capture the radio waves of the main beam in response to controlling the antenna beam. It was shown that the radio wave exposure level from a 5G base station, including during data transmission, is equal to or less than that of conventional mobile phone systems (Fig.3).

We determined power reference values (300-500 GHz) to realize the exceptional measures of special experimental radio stations. Using these reference values, NICT developed a world-leading power meter comparison system to provide a service for the exceptional measures of special experimental radio stations, evaluated its performance, and incorporated it into operations.

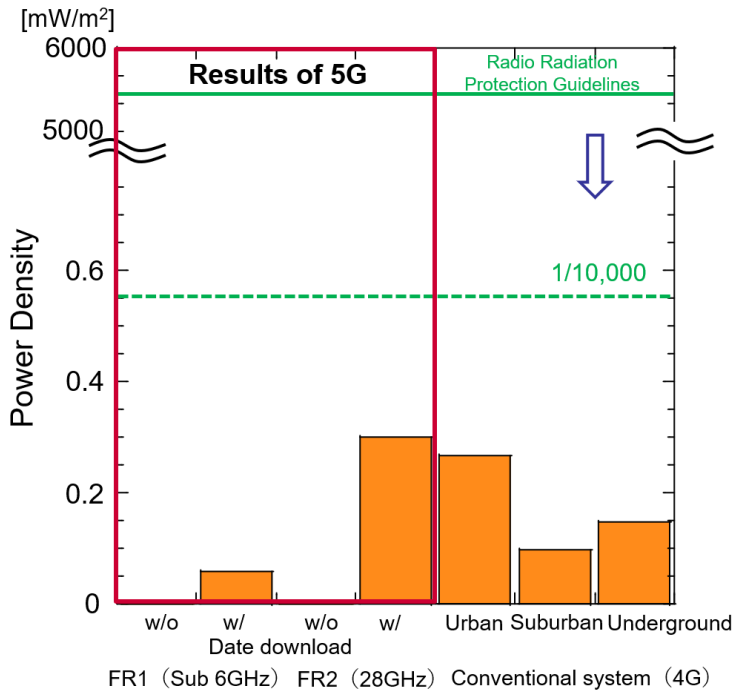


Fig.3 : Radio wave exposure levels from mobile phone base stations

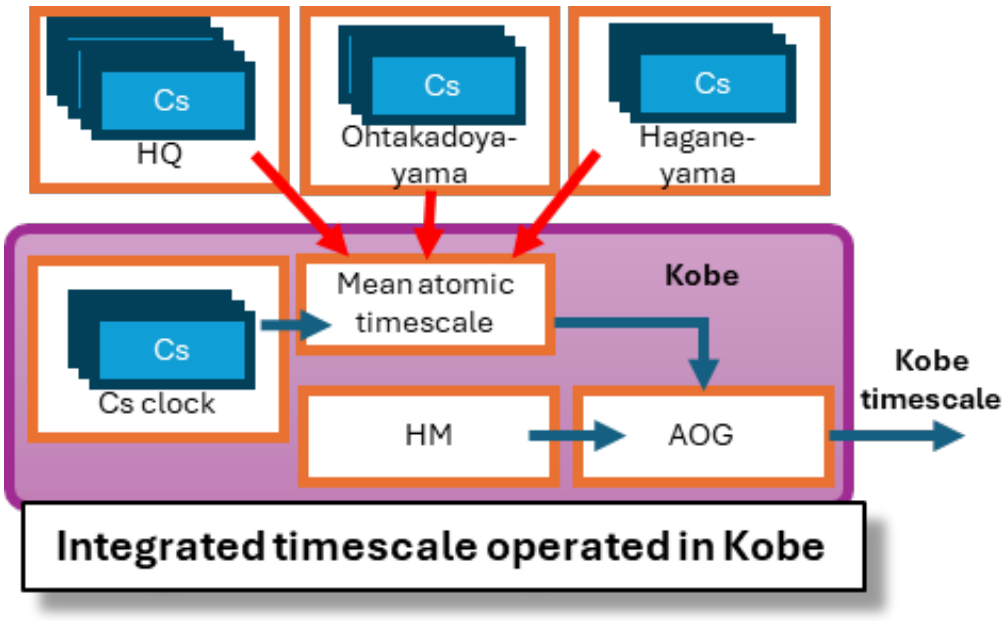


Fig.4 : Utilizing the Kobe backup time scale integrated with the time scale from four stations

Space-time standards technology

We regularly conduct frequency adjustments of Japan Standard Time using an optical lattice clock, which we initiated in 2021. We have achieved improved accuracy in Japan Standard Time by establishing an algorithm to generate a mean time scale from multiple hydrogen masers, maintaining deviations from Coordinated Universal Time (UTC) within approximately ± 2 nanoseconds.

We continually operate an ensemble time scale utilizing clocks at four stations (headquarters, Kobe, and two long wave transmission stations), and we commenced its usage as an actually-used time scale at the Kobe substation. We have thus ensured that time scale generation would continue through clocks other than those at headquarters in the event of a disaster (Fig.4).

We constructed a new algorithm for a cluster clock timescale, implementing the system with ten operational units on a wired communication network, a world first, and verified the implementation of the time scale algorithm in actual equipment. As a result, we confirmed that frequency stability was improved by more than an order of magnitude through weighted averaging compared to operating an atomic clock independently.

In partnership with Meta, we discussed the application of wireless time synchronization in data centers. We developed a wireless time distribution module, verified its accuracy through proof-of-concept (PoC) experiments, and published a joint paper with Meta at an IEEE international conference on time synchronization.

Applied Electromagnetic Research Center

The Applied Electromagnetic Research Center primarily supports research and development activities related to foundational digital optical technologies. The center promotes pioneering and interdisciplinary research using electromagnetic waves and collaborative research and development with users from different fields without being bound by NICT's mid-to-long-term plans.

Digital optics technology

Using HOEs (holographic optical elements) printed in the air, we succeeded in conducting light guiding and retrieval at angles greater than the critical angle to optical waveguides, which will enable the production of optical waveguides through hologram printing and, consequently, contribute to miniaturizing future optical systems. We established a workflow, from HOE design to holographic data output and hologram printing, on widely used industrial optical design software, improving adaptive optics technology to achieve measurement and compensation at 1/10λ (Fig.5). To promote the societal implementation of hologram printing, we accelerated joint research with domestic automotive parts manufacturers through funding partnerships and secured a path for technology transfer aimed at practical application during the fifth mid-to-long-term plan.

We conducted real-time implementation of natural light digital holography using embedded GPUs, achieving real-time reconstruction of digital holography (30 frames per second), a process previously limited to a few frames per second by conventional software-based methods. We also developed a 1,000-fps natural light holography camera, publishing the results in a paper in Applied Physics B (Springer).

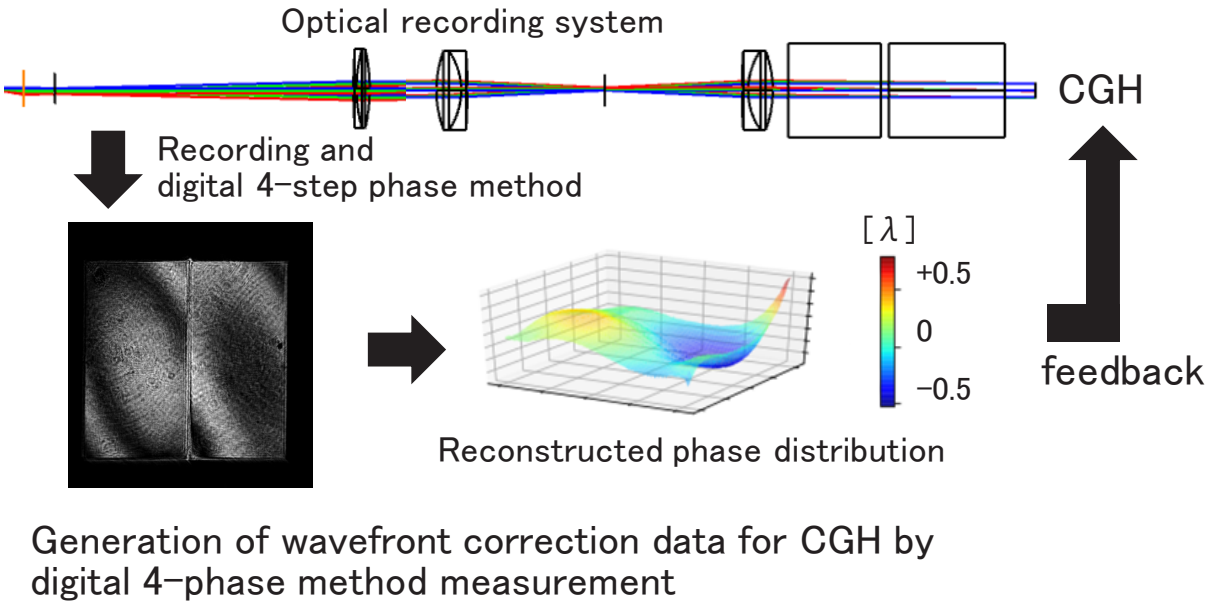


Fig.5 : Enhancing adaptive optics technology to achieve 1/10λ class measurement and compensation

Innovative Network Area

Network Research Institute

Director General HARAI Hiroaki

In the Network Research Institute, we conduct R&D on "Innovative Network" technologies, which can respond to rapid growth in communication traffic, dynamic changes in communication quality, and various network services in order to realize the digital transformation of advanced social systems for Society 5.0 in the Beyond 5G era. We introduce recent R&D activities related to "Computing and AI-enabled Networking Technology", "Photonic Network Technology", "Optical and Radio Convergence Technology", "Next-generation Wireless Technology", "Space Communications Technology", and "Sustainable ICT"(Fig.1).

Network Architecture Laboratory

Our laboratory is advancing research and development of large-scale network control automation technology, a programmable hardware router framework providing deterministic latency, and information-attribute-centric communication utilizing a distributed information management mechanism.

In the area of large-scale network control automation technology, telecommunications operators applied AI cooperative controlled technology that we developed with them through joint research to enhance mobile core network failure detection systems. The commercial application of this technology was featured on a television news program. Additionally, in collaboration with telecommunications and manufacturing companies, we conducted a demonstration experiment using multiple AI technologies to detect signs of network failures and automatically control services. As a result, we demonstrated that AI technologies designed for different applications can interconnect and control services.

For research related to a distributed information management mechanism, we proposed a transport method linked with in-network caching and presented it at the IEEE Global Communications Conference (IEEE GLOBECOM 2023). We also contributed to technology dissemination activities by conducting tutorials on our open-source software package, *Cefore*, at a domestic conference and writing a 46-page feature article on *Cefore* for the computer technology magazine *Interface* (monthly circulation of 30,000 copies).

Photonic ICT Research Center

Our Research Center is engaged in cutting-edge research and development of technologies for ultra-high-capacity optical

Fig.1 : Conceptual diagram of Network Research Institute

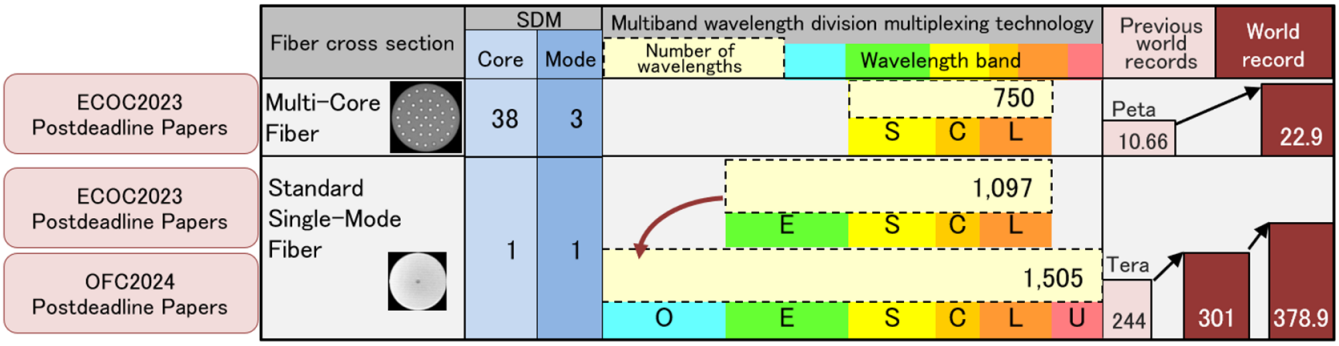


Fig.2 : Overview of optical fiber transmission experiments that set new world records

fiber networks utilizing the spatial and wavelength domains, technologies for using optical network resources more efficiently, and access technologies that integrate optical and wireless communications.

1) Photonic Network Laboratory

Our laboratory is engaged in research on ultra-high-capacity optical fiber networks and has achieved several new world records in this field. Among these is the record for transmission capacity over optical fiber. We were the first globally to introduce multi-band wavelength division multiplexing (WDM) technology using the S-, C-, and L-bands in conjunction with multicore and multimode transmission technologies demonstrating a remarkable per-fiber transmission capacity of 22.9 Pb/s with a 38-core 3-mode optical fiber. This accomplishment was recognized as a postdeadline paper at the 49th European Conference on Optical Communications (ECOC2023). We also set new world records for the wavelength band and transmission capacity of single-core single-mode fiber used in practical applications. Specifically, we expanded the wavelength range to include the O-, E-, S-, C-, L-, and U-bands and successfully achieved a transmission rate of 378.9 Tb/s. This milestone was accepted as a postdeadline paper at the 2024 Optical Fiber Communications Conference and Exhibition (OFC2024) (Fig.2).

In addition, as part of a nationwide effort in Japan to advance research on ultra-high-capacity optical fiber transmission for practical implementation since 2010, a multi-core fiber transmission system developed by Japanese companies has been selected by Google for use in a submarine cable system scheduled to begin operation in 2025.

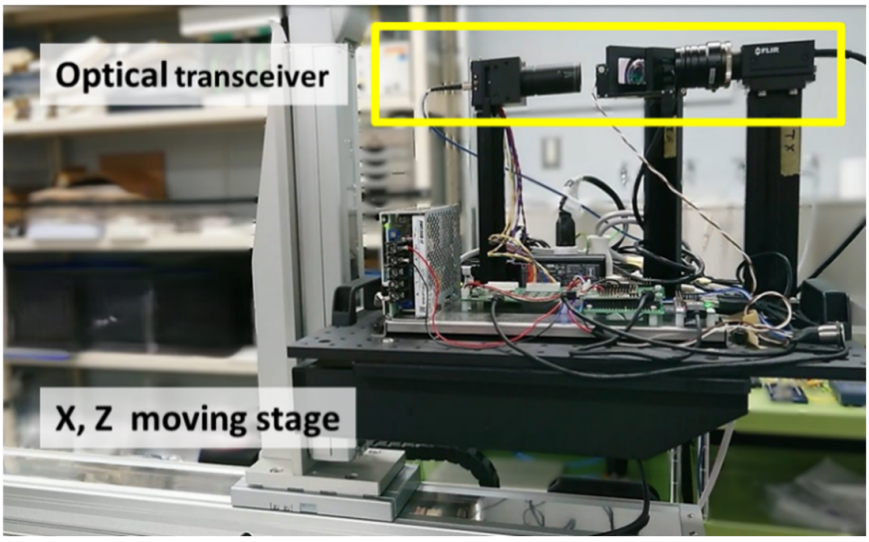


Fig.3 : Experiment on free-space optical communication

2) Optical Access Technology Laboratory

We are conducting research aimed at the realization of access networks that can exchange information without needing to give consideration to which transmission media, such as optical or radio waves, are used.

As part of research to maximize the processing precision of semiconductor lasers, we fabricated quantum dot distributed feedback laser diode (QD-DFB-LD) with a minimum structure of about 100 nm as a light source for silicon photonics integrated circuits, achieving high-temperature operation above 100 °C and line width narrowing below 100 kHz.

In research on seamless connectivity between wired and wireless communication, we constructed a multi-channel connection network including optical fiber communication, 28 GHz radio communication, 286 GHz radio communication, and free-space optical communication. We successfully transmitted 16 and 64 quadrature amplitude modulation orthogonal frequency-division multiplexing (QAM OFDM) signals, a world first. Furthermore, as part of efforts to enable free-space optical communication with moving bodies, we developed a large-aperture high-speed photodetector consisting of serially connected large-scale photodetector arrays. We conducted experiments on free-space optical communication using this photodetector, successfully transmitting data at 20 Gb/s without interruption while tracking an object moving at 400 mm/s (Fig.3). This achievement was accepted at ECOC2023.

Advanced ICT Device Laboratory

At the Advanced ICT Device Laboratory, we have set up a research and development environment for device technology that enables the rapidly materializing new ideas of researchers. Using the Lab's resources, researchers in various technological fields, such as optical and electronic semiconductors, superconductivity, and organic materials, create world-leading advanced and innovative devices. We also contribute to creating new information and communication concepts, such as all-band communication technology and optical-radio convergence technology. To advance the device research field further, we strive to offer an open lab environment accessible not only to NICT researchers but also to external researchers and students. Of particular note, more than 100 students use our open lab, which contributes to the nurturing of the young talent that will help develop new fundamental device technologies. Interaction among researchers is crucial for generating innovative device ideas, and our lab hosts annual collaboration meetings. In 2024, the meeting had 79 participants, and the participation of many researchers and students led to active discussions on device technology.

Wireless Network Research Center

By integrating and expanding Non-Terrestrial Networks (NTN) and terrestrial systems, we are advancing research and development of wireless network technology for seamless three-dimensional global communication networks from oceans to space, ensuring connectivity under all circumstances and environments.

1) Next-generation Wireless Technology

Using small aircraft simulating High Altitude Platform Stations (HAPS) with multiple domestic companies, we were the first in the world to successfully conduct a demonstration experiment on cellular-based wide area network formation technology using 5G New Radio (NR) in the 38 GHz band from an altitude of approximately 4 km and demonstrated a backhaul line of multiple links using an aerial relay. These achievements were highlighted in IEEE Spectrum (Fig.4).

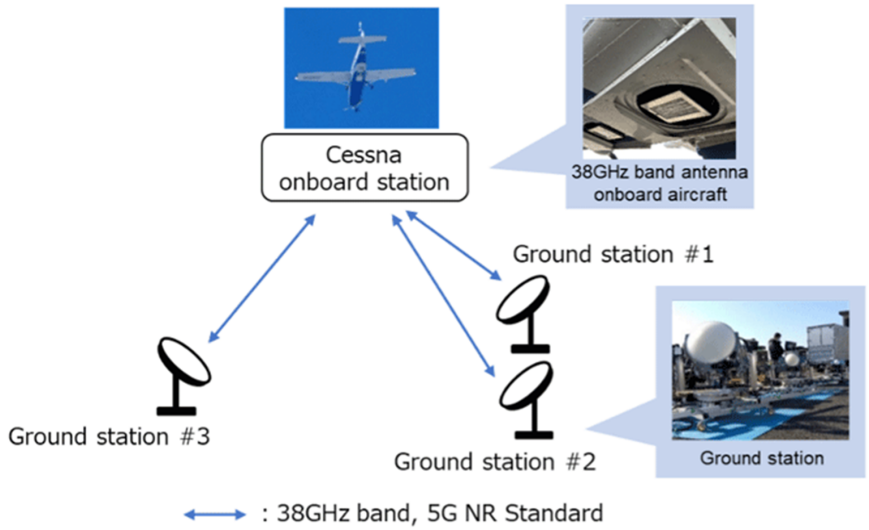


Fig.4. : Verification test of cellular-based wide area network experiments using aircraft

To achieve high-density flight for aerial autonomy level 4, we developed collision avoidance algorithms based on elastic motion theory to ensure flight safety. We proved that four drones moving at 25 km/h can perform group flight and collision avoidance while maintaining appropriate safety distances. Additionally, we successfully maintained communication via a relay drone up to 3 km beyond the line of sight in a mountainous environment with complex river systems and no LTE or other communication infrastructure, and we succeeded in conducting aerial photography of checking an erosion-control dam.

Through research and development of a wireless emulator that enables evaluation and verification of next-generation systems at low cost and in a short time by simulating radio systems in cyberspace, we developed a pseudo-radio device that implements 5G NR physical and upper layers and conducted a remote demonstration evaluation of 5G NR communication performance between Tokyo and Yokosuka using the emulator.

2) Space Communication Technology

In three-dimensional networks containing links with various characteristics, such as geostationary and Low-Earth-Orbit (LEO) satellites and radio, and optical links, we introduced the concept of NTN slicing to meet increasing user demands, for the first time in the world, confirming a reduction in control costs of 20-50%, and presented this work at the International Astronautical Congress (IAC) 2023.

For the Engineering Test Satellite-9 (ETS-9), advanced satellite communication technology will be demonstrated and the satellite is scheduled to launch in FY2025. Furthermore, we completed the manufacturing and testing of the 10 Gbps optical communication equipment and the beacon transmission equipment onboard the satellite. We also developed a pseudo-satellite ground station to verify resource control technology for flexible next-generation High-Throughput Satellites (HTS) before the launch of the satellite by constructing an on-ground performance evaluation environment.

As a result of research into atmospheric propagation models, which are crucial for achieving high-speed optical communication between the ground and satellites, our analysis of the received optical power in a ground-to-geostationary satellite optical link using the atmospheric propagation model was published in the journal Optics Express.

Resilient ICT Research Center

We are committed to researching and developing technologies for information

and communication infrastructure that functions in harsh physical spaces with dynamic changes, such as network disconnection or reintegration caused by large-scale disasters or failures. As an example, regarding low-latency non-regenerative relay technology that has been demonstrated in a test field specified for robot applications (Fig.5), we submitted a contribution document with a private enterprise to 3rd Generation Partnership Project Radio Access Network Working Group 1 (3GPP RAN1) Release 18. It was successfully incorporated into the final technical specifications (such as TS 38.213-3) related to network-controlled repeaters. This could contribute to expanding the communication coverage of future 5G NR standards. Regarding resilient natural environment measurement technology that detects sudden changes in natural phenomena, we have long been operating an observation system located around active volcanoes in the Kyushu area. It features a high-resolution camera with a low-latency transmitter as well as an infrasound sensor to detect infrasound or low-frequency sounds. Its low-power design and power management with self-generated power sources of fuel cells and photovoltaic panels enables long-term self-powered operation. This is a crucial requirement for use in such locations where commercial power supply is not available. Since it succeeded in capturing unprecedented high-definition images of the crater in real time, it is now being used by neighboring municipalities to provide images on a trial basis in response to strong requests from them. The images were also cited in the Japan Meteorological Agency's Coordinating Committee for Prediction of Volcanic Eruption materials.

Regarding the resiliency of optical networks, one issue is the degradation of transmission quality due to inter-core crosstalk from time variance in multi-core fiber optical networks. We designed a machine learning model that predicts the occurrence of logical communication link outage based on the time-series data of optical signals. We successfully demonstrated that it is possible to provide notification of a potential communication link outage just before the occurrence.

We also promoted the social implementation of our research results through collaborations among industry, academia, and government to enhance national resilience. By providing technical support and guidance to municipalities on our resilient network technology called *NerveNet,* we enabled these municipalities to increase the number of installations. Shirahama Town in Wakayama Prefecture increased the number by 5, resulting in a total of 20 stations. Nobeoka City in Miyazaki Prefecture newly established 20 stations, and Sarabetsu Village in Hokkaido continued plans for the establishment of 2 stations, which were then completed by 2024. In a project adopted by the Asia Pacific Telecommunity (APT) and initiated in 2020 with the Nepalese government and local NGOs, our continuous technical support resulted in the completion of a regional network including three base stations in Dullu Municipality and the commencement of operation by Dullu (Fig.6). Dullu is located 400 kilometers west of Kathmandu at an elevation of approximately 1,000 meters. Furthermore, we provided presentations with examples of prior setups to promote disaster risk reduction across the country and provided face-to-face explanation to dozens of municipalities in Japan and officers in APT countries. We also submitted some technical proposals to international standardization institutes.

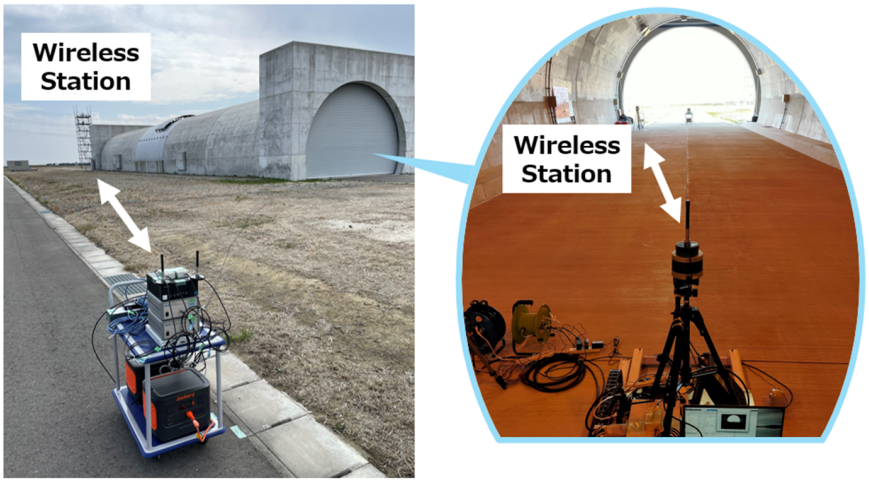


Fig.5 : Low-latency non-regenerative relay demonstration experiment

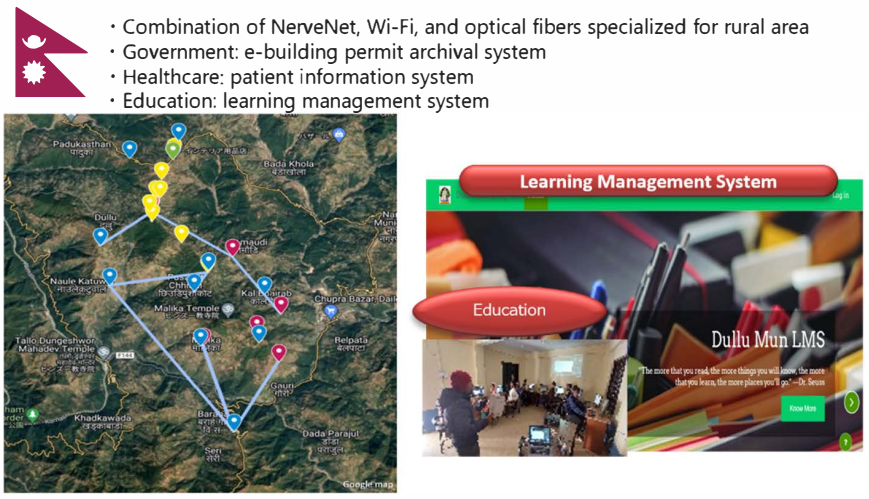


Fig.6 : *NerveNet* implementation at Dullu Municipality, Nepal

Cybersecurity Area

Cybersecurity Research Institute

Director General INOUE Daisuke

Countermeasures against increasingly sophisticated and complex cyberattacks have become an urgent national priority. In the fifth mid-to-long-term plan starting from FY 2021, the Cybersecurity Research Institute is tackling the five items shown in Fig.1.

Cybersecurity Technology

Development of STARDUST NxtGen and commencement of external lending

In the research and development of the next-generation STARDUST (STARDUST NxtGen), we developed a management system that automates constructions and operations, including the design of simulated environments, VM/NW deployment, and operational tests, achieving a speed approximately ten times faster than before. We also developed live forensics, consolidating service groups distributed across multiple servers using Docker components and realized information linkage with the Cybersecurity Universal Repository (CURE). STARDUST NxtGen has been provided to CYNEX and is currently used by 29* organizations. (* As of the end of September 2024)

Enhancement and dissemination of NIRVANA KAI

We developed a transversal analysis for NIRVANA KAI and conducted a dynamic demonstration at Interop Tokyo 2023. This feature enables the collection of attack information from the endpoints of multiple organizations and performs cross-organizational high-perspective analysis per the MITRE ATT&CK attack description framework (Fig.2).

Based on the 5G Security Guidelines (First Edition), we proposed work items for recommendations at ITU-T SG17 and completed the recommendation of Security controls for operation and maintenance of 5G network systems.

Security Fundamental Technology

Demonstration experiment for fraud detection using DeepProtect (Fig.3)

As part of commissioned research on R&D of advanced communication and broadcasting, in collaboration with Kobe University and EAGLYS Inc., we conducted a demonstration experiment using the privacy-preserving federated learning

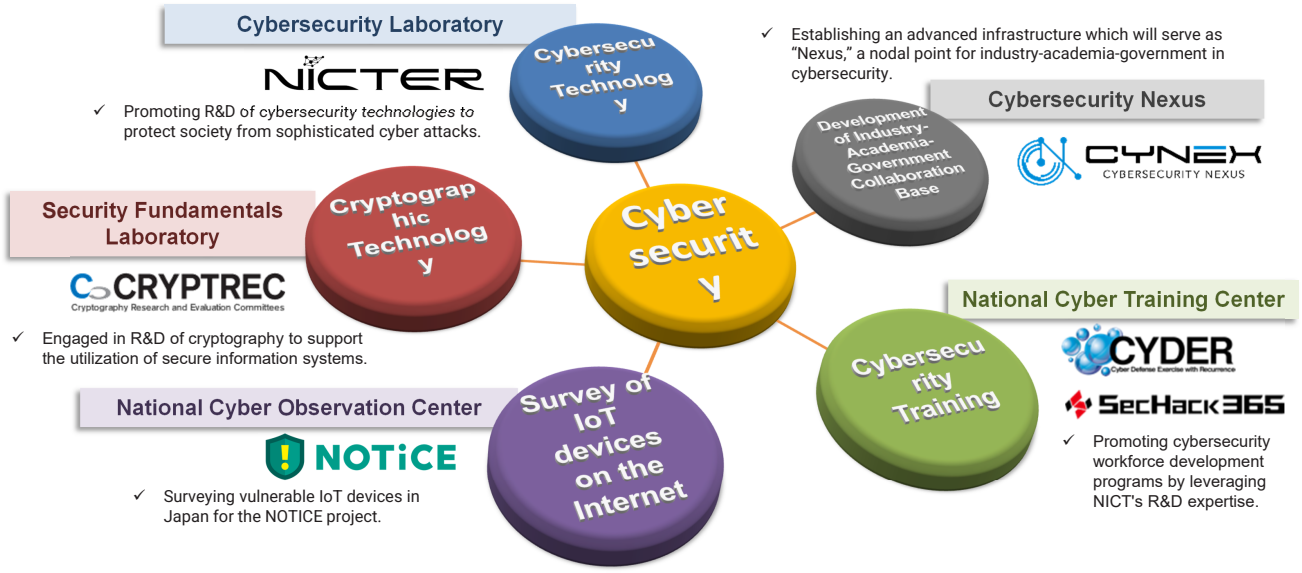


Fig.1 : Mission in cybersecurity area

Fig.2 : NIRVANA KAI transversal analysis function

technology DeepProtect, with cooperation from multiple banks possessing large-scale customer data. We standardized the inspection and formatting of each bank's data to improve the precision of fraud detection.

We conducted a demonstration experiment using transaction data provided through a consignment contract by multiple companies in a different part of the financial sector to banks. We selected and integrated standard features for machine learning and created a federated learning model using the privacy-preserving federated learning technology DeepProtect. As a result, data that could not be identified as fraudulent transactions by individual learning models were successfully detected through federated learning.

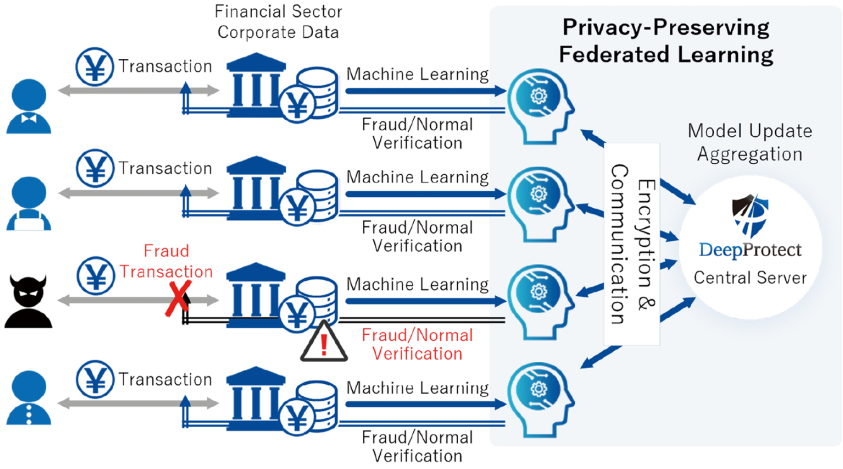


Fig.3 : Example of demonstration experiment using DeepProtect

Security evaluation of modern cryptography using quantum computers

We conducted a security evaluation of modern cryptography using quantum computers in collaboration with Keio University, Mitsubishi UFJ Financial Group, and Mizuho Financial Group. We enhanced the experiment's accuracy by using currently available quantum computers to optimize quantum circuits related to solving the discrete logarithm problem. We demonstrated results guaranteeing the validity of the theoretical definition proposed in FY 2022 on "the ability to solve the discrete logarithm problem using quantum computers." This result was published in the international journal IEEE Transactions on Quantum Engineering.

Cybersecurity Nexus

The Cybersecurity Nexus (CYNEX), established in FY 2021, contributes to the continuous improvement of Japan's cybersecurity response capabilities and the development of cybersecurity human resources throughout society as an industry-academia-government nodal point (nexus) for cybersecurity information analysis and human resource development in Japan.

The CYNEX Alliance was launched on October 1, 2023, with the aim of supporting the self-sufficiency of the industry-academia-government collaboration hub. The participating organizations cover part of certain costs as joint beneficiaries. Applications for participation from supporting organizations in industry, academia, and government are accepted as required, and the number of participating organizations has gradually increased since the preparation period and after the Alliance's official launch, reaching 61 organizations as of the end of FY 2023 (Fig.4). The CYNEX Alliance's activities are divided into four subprojects or Co-Nexuses (A/S/E/C) that promote activities concurrently across their respective domains.

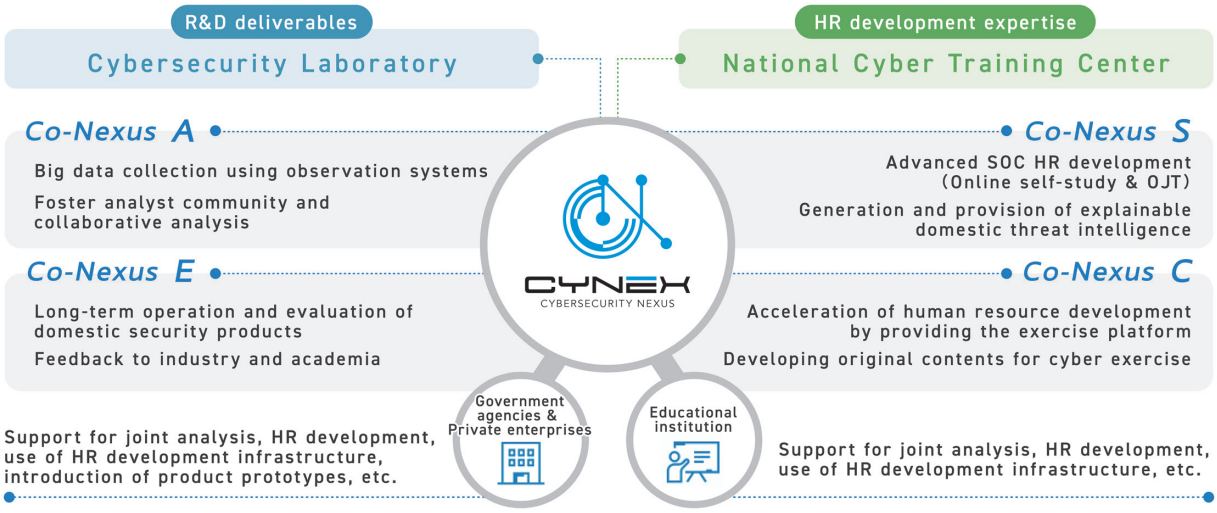


Fig.4 : Missions and activities of Cybersecurity Nexus

National Cyber Training Center

The National Cyber Training Center was established on April 1, 2017, to maximize the utilization of NICT's technical knowledge, research results, and facilities as Japan's sole public research institution specializing in the information and communications field and to plan and promote practical cyber training. While conducting related research and development, the center implements human resource training projects related to cybersecurity and ICT, such as the security operator training project and the Security Innovator (Innovative Researchers/ Developers) training project. Every year, on a national scale, we have performed more than 100 CYDER practical cyber defense exercises, involving over 20,000 people by the end of FY 2023 (Fig.5). Additionally, we conduct the Practical Cybersecurity Exercise Response Practice for Cyber Incidents (RPCI) certified as specialized training for Registered Information Security Specialists (RISS), and the SecHack365 security innovator development program targeting young talent in ICT. Additionally, in FY 2023, in preparation for the World Expo 2025 in Osaka, we have been running the cyber defense course CIDLE, based on CYDER, for information system personnel in organizations affiliated with the Expo. These efforts ensure NICT's research and we return development results to society.

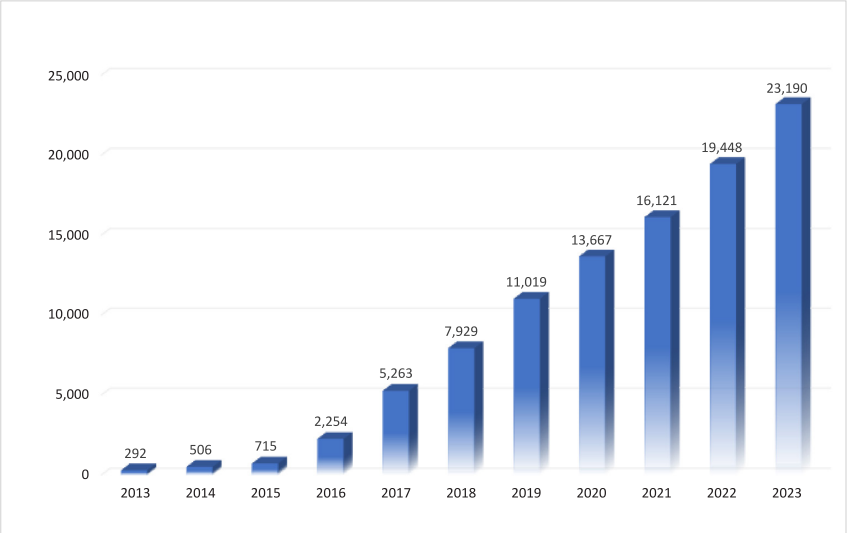


Fig.5 : Changes in cumulative participants for CYDER group training

Practical implementation of CYDERANGE

By FY 2017, our laboratory utilized the knowledge obtained from operating the CYDER program and cybersecurity research technologies owned by NICT to develop the exercise automation system CYDERANGE. This system allows for the automated generation of exercise scenarios and the automated construction of exercise environments. Since FY 2018, we have begun the full-scale operation of CYDERANGE, part of the CYDER program. From FY 2019 onward, we have been developing and operating finely optimized cyber exercise environments tailored to courses for local governments and national administrative agencies, ensuring rapid deployment and significant cost savings.

National Cyber Observation Center

The National Cyber Observation Center, based on Article 14, Paragraph 1, Item 7 of the Act on the National Institute of Information and Communications Technology, National Research and Development Agency, utilizes its technical knowledge to provide necessary advice and information to managers and other stakeholders

of IoT devices that are perceived as being inadequately secure in terms of cybersecurity. This includes surveying IoT devices with inadequate password settings and providing information to telecommunications carriers per Article 18 of the Act in collaboration with the Ministry of Internal Affairs and Communications and related agencies. When implementing these efforts, in addition to investigating vulnerabilities related to password settings (Fig.6), we also survey devices with firmware vulnerabilities and devices already infected by malware and notify owners.

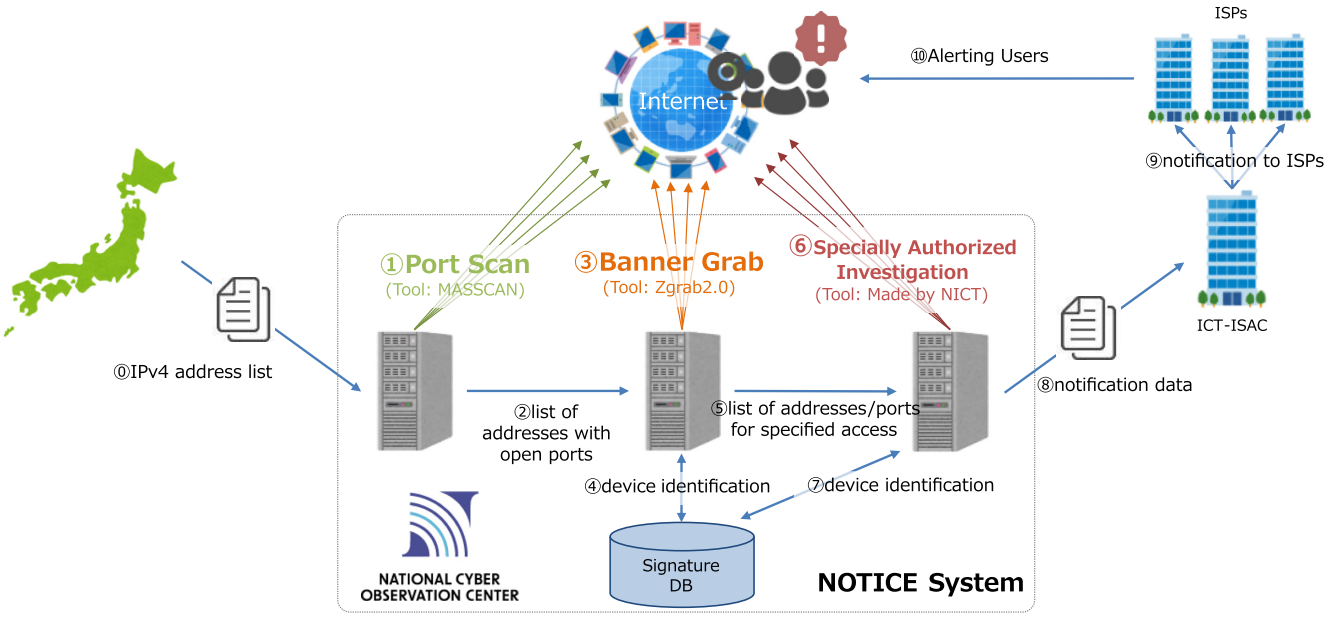


Fig.6 : Workflow for investigating password-setting vulnerabilities

Universal Communication Area

Universal Communication Research Institute

Director General UCHIMOTO Kiyotaka

The Universal Communication Research Institute (UCRI) conducts research and development of multilingual communication technology, data-driven intelligent communication technology, and smart data analytics technology with the aims to achieve universal communication and to establish mutual understanding among people. These initiatives use advanced technologies like deep learning to process vast amounts of data, such as voice, text, and sensor data. We also promote initiatives for the social implementation of systems compatible with diverse user interfaces. We hope these activities will contribute to solving various social issues and creating new value using ICT as we move towards the Beyond 5G era.

R&D of Multilingual Communication Technology

We are advancing the research and development of simultaneous interpretation technology based on the Global Communication Plan 2025 (March 31, 2020, Ministry of Internal Affairs and Communications). For Expo 2025, Osaka, Kansai, chunk translation between any two of the languages of Japanese, English, Chinese, Korean, Vietnamese, and French was needed. We quickly made this possible by integrating chunk segmentation and universal translation models and successfully transferred this technology to end users. We also developed an end-to-end speech recognition model for 22 languages, reducing recognition errors in everyday conversation while achieving entirely CPU-based real-time processing. The trial operation of a legal translation system by a private company utilizing an engine built by NICT commenced at the Ministry of Justice in December 2023. Operation across all ministries commenced in April 2024, expanding the application of NICT's speech translation technology across multiple fields.

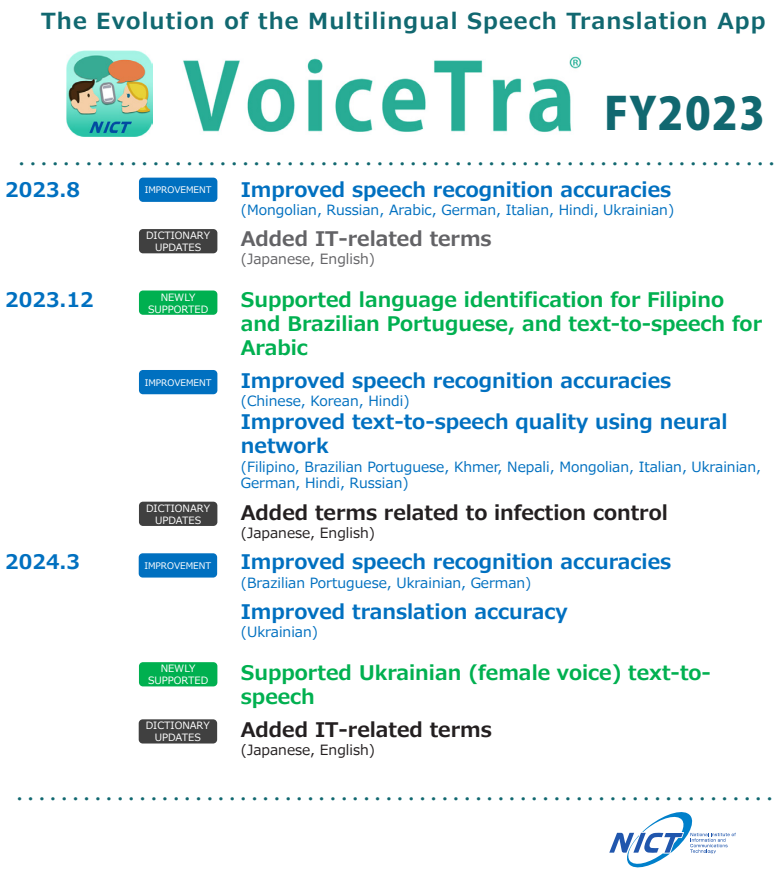


Fig.1 : The evolution of VoiceTra in FY2023

NICT has improved the synthetic speech quality of text-to-speech synthesis for the languages we focus on. Specifically, we developed neural text-to-speech models at a practical level (with minimal reading errors, capable of clearly and naturally reading most texts) for Filipino, Brazilian Portuguese, Nepali, Mongolian, Khmer, German, and Italian, and at a semi-practical level (a few reading errors, but clarity and naturalness remain practically unaffected) for Hindi, Russian, Arabic, and male voiced Ukrainian. These neural text-to-speech models were publicly released on the VoiceTra® multilingual speech translation

experimental verification application and licensed to external partners in December 2023.

A speech corpus was also built for Ukrainian female voice, and a neural text-to-speech model was developed. This was publicly released on VoiceTra® and licensed to external partners in March 2024.

We also proposed a very fast neural text-to-speech model capable of synthesizing speech 14.3 times faster using a single logical CPU by introducing the ConvNeXt network, which is more lightweight and faster than conventional methods while offering rich expressiveness (Fig.2). Computational demand was reduced to 1/8 compared to the four logical CPUs and 6.7x speed of the conventional method developed in fiscal year 2021. The research outcomes were accepted at the international conference IEEE Automatic Speech Recognition and Understanding (ASRU) 2023 (acceptance rate 45%). We developed very fast neural text-to-speech models for all 21 prioritized languages, publicly released them on VoiceTra®, and started offering commercial licenses.

R&D of Large Language Models

Before the emergence of ChatGPT, NICT limited its research and development of generative large language models (LLMs) to basic research due to various practical risks, such as hallucinations. However, with the appearance and rapid acceptance of ChatGPT in 2022, the Data-driven Intelligent System Research Center (DIRECT) intensified R&D of NICT's proprietary LLM (Fig.3). We completed the pre-training of a 40 billion parameter LLM (NICT LLM) using the 350 GB of high-quality training data, which was previously used for pre-training a model called Bidirectional Encoder Representations from Transformers (BERT). This achievement was announced in a press release issued in July 2023. Subsequently, we pre-trained models of 13 billion, 40 billion, and 179 billion parameters, as well as a model specialized for the Japanese language, consisting of 311 billion parameters, the largest of its kind in Japan. All models were trained using the same 350 GB training data previously mentioned (referred to as pre-training data). Additionally, we pre-trained a 234 billion parameter model using 888 GB pre-training data prepared in the same data construction method as the 350 GB training data. To build even higher-quality and larger-scale pre-training data, we prepared learning data to extract learning-suitable sentences from web pages (labeling the appropriateness of over 2.75 million sentences from 15,000 web pages). A BERT trained with this data was then used to extract texts suitable for training generative LLMs from over 60 billion web pages that

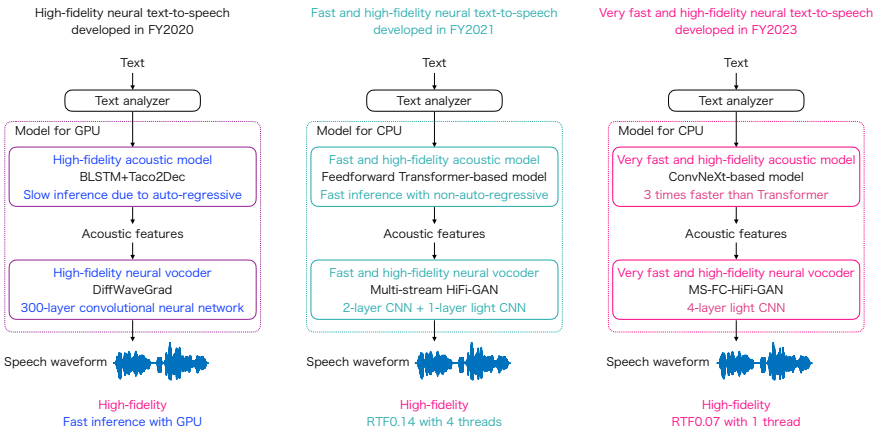
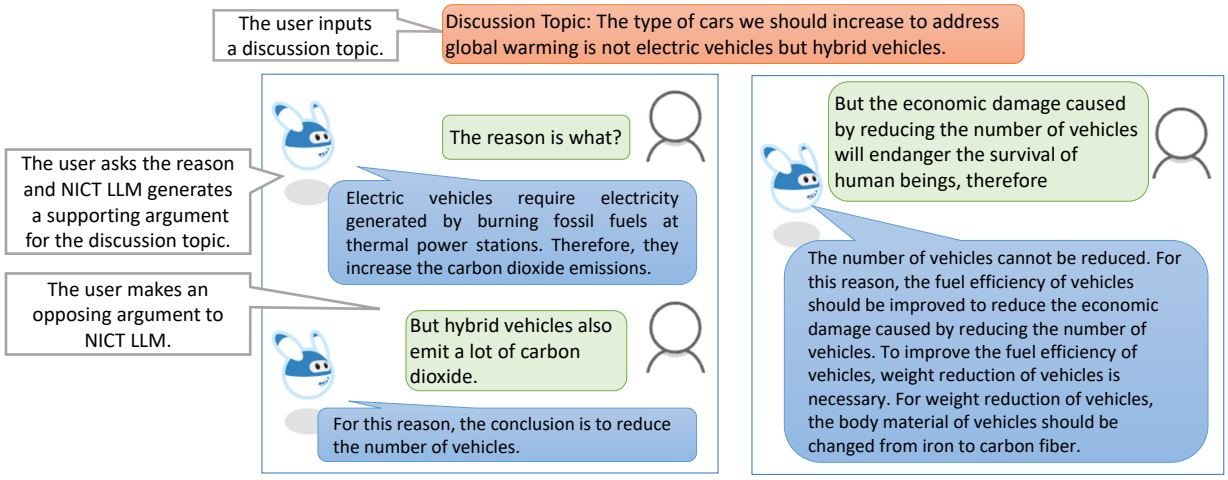


Fig.2 : Progress in acceleration of neural text-to-speech models



Example of discussion between a user and NICT LLM (179B parameters. Originally in Japanese)

*The discussion translated above does not guarantee the correctness of its structure or conclusions.

Fig.3 : Example discussion with an NICT LLM

DIRECT has collected independently over the past 15 years, building a 9.6 TB pre-training data with duplicates removed and further processing applied. We have not yet identified and removed inappropriate content, but we intend to proceed with refining the data and increasing its volume.

Through exploring uses for the NICT LLM we have developed, trials indicate that its potential lies in enabling discussions among users and multiple LLMs, leading to effective decision-making and possibly addressing the various risks of LLMs. Additionally, its potential for various applications and developments has become clear. New frameworks for security assurance, such as LLMs to counter misinformation from external sources and techniques to verify the credibility of texts generated by LLMs using WISDOM X, are being explored.

R&D of Smart Data Analytics Technology

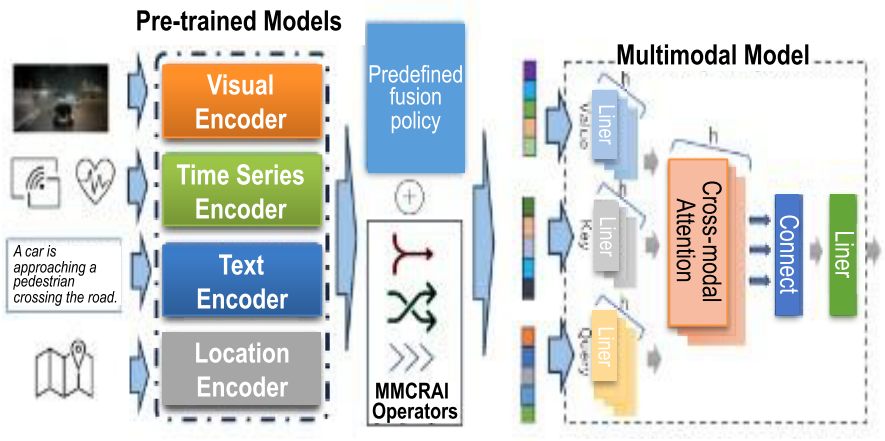
We developed the MMCRAI framework, which is capable of efficiently creating multimodal AI models by combining pre-trained models specific to various datasets (Fig.4). Then, we applied it to MM Sensing to predict eight types of driving risks, and achieved a prediction accuracy that was 20% higher than SOTA methods. In addition, we conducted a social experiment on smart driving support in collaboration with a traffic and environmental monitoring company.

In collaboration with NICT's ICT Testbed Research and Development Promotion Center, we promoted the transfer of functional modules and information assets from the xData platform, a cross-data analysis platform implementing our R&D results, to the Testbed's Data Centric Cloud Service (DCCS). We also developed five new users of DCCS, including research contractors of Ministry of Internal Affairs and Communications commissioned research and NICT advanced communications and broadcasting commissioned research. In addition, we reached a licensing agreement to transfer the photochemical oxidant early warning prediction information assets to environmental monitoring service providers. Furthermore, we designed and implemented the architecture of a Beyond5G orchestrator for digital twin collaboration, submitting contributions on Digital Twin Interoperability to the International Telecommunication Union (ITU) Focus Group on Metaverse (FG-MV), pushing forward considerations towards standardization.

R&D of Advanced Reality Technology

Real-time REXR was developed to speed up the processing of REXR (Realistic and EXpressive 3D avataR) technology, which enables a photo-realistic 3D avatar to be constructed using only one ordinary web camera, and to reproduce detailed facial expressions and gestures in 3D. We were able to conduct a real-time remote live demonstration of this technology at several events. We extended this REXR technology to develop a communication system that enables real-time interaction with avatars of multiple users in remote locations (Fig. 5).

For such real-time REXR systems, we were awarded the 7th Hagura Award (Grand Prize), which is given to the most advanced expression technology. We also participated as a member of the Study Group on Realization of Safe and Secure Metaverse organized by the Ministry of Internal Affairs



- Free combination of **three types of operations (CROSS, FUSE, ALIGN)**
- **Multi-head Self Attention mechanism** for improving the prediction accuracy of the generated multimodal model
- **Automatic labeling of multimodal data** based on **Non-Contrastive Self-Supervised learning**

Fig.4 : MMCRAI framework

and Communications, and contributed to activities to establish principles and guidelines for the metaverse. Additionally, we developed REXR Plus technology for converting arbitrary 3D avatars to REXR format, which enables existing 3D avatars to seamlessly reflect users' individual facial expressions and gestures in real time, and conducted demonstrations at exhibitions for visitors to experience this technology.

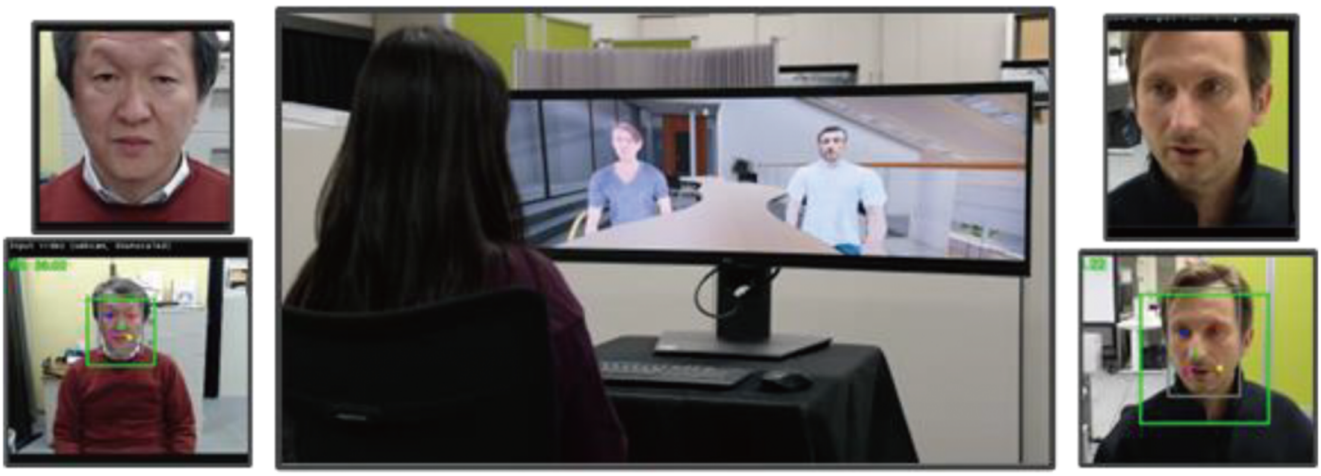


Fig.5 : Communication with multiple avatars using the REXR system

Frontier Science Area

Advanced ICT Research Institute

Director General WADA Naoya

The Advanced ICT Research Institute was established in accordance with NICT's current mid-to-long-term plan as an organization that conducts R&D in the frontier science research field. With the spirit of "cultivating the unexplored fields of the frontier with the plow of science without fear of failure," the institute is conducting cutting-edge and fundamental R&D, grounded in advanced academic knowledge, in order to pioneer the future of ICT.

Kobe Frontier Research Center

Superconductive ICT device technology

The Superconducting Strip Photon Detector (SSPD) has become an indispensable photo detector today because it demonstrates performance that far surpasses that of other photon detectors, including its high detection efficiency, low dark count rate, and low timing jitter over a wide wavelength range from ultraviolet to mid-infrared. Being able to fabricate a large number of high-performance SSPDs with high uniformity and productivity is indispensable for realizing a large-scale multi-pixel SSPD array, but with conventional SSPDs it was necessary to form superconducting nanostrips with a strip width of less than 100 nm in a meandering structure over the entire light-receiving area, causing variations in detector performance and low productivity, which has been a factor hindering the realization of such a detector. We have proposed a new structure that enables highly efficient photon detection even with a wide superconducting strip width and have succeeded in developing the world's first Superconducting Wide Strip Photon Detector (SWSPD) with a strip width more than 200 times that of conventional superconducting nanostrips (Fig. 1).

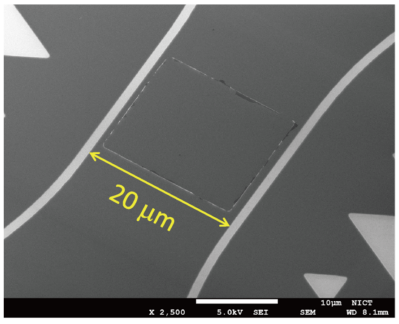


Fig.1 : The newly developed SWSPD

Organic-inorganic hybrid device technology

As a fundamental technology for ultra-wideband electromagnetic wave control devices, we verified the device structure for the streamlining of 300-GHz-band wireless optical modulators for high-speed wireless-optical signal conversion in some wireless sections of optical fiber wireless mobile fronthaul and in remote antennas (Fig. 2). The organic electro-optic (EO) polymer waveguide consists of a lower clad made of cycloolefin polymer (COP) on top of a ground electrode, an organic EO polymer waveguide core, and an upper clad made of UV-curing resin. The antenna array is arranged so that the edges of the antenna gap come to above and below the organic EO polymer waveguide core in the lower clad and the upper clad. When 375-GHz-band electromagnetic waves are irradiated, a vertical electric field acts on the waveguide at the waveguide position, and the optical phase is modulated by the EO effect. Arranging the antennas with the top and bottom swapped around every half cycle (LA/2) enables use of both the "peaks" and "valleys" of the high-frequency electromagnetic wave, improving the optical modulation efficiency. This device was fabricated using an organic EO polymer transfer method, with potential for further development towards mass production of the device.

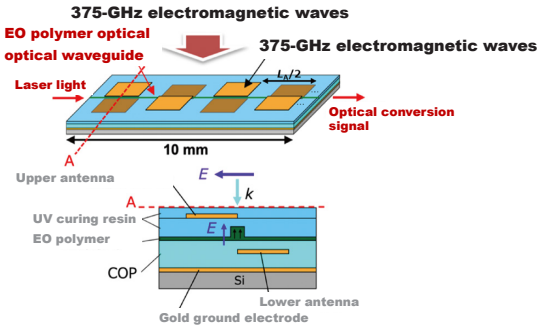


Fig.2 : 375-GHz-band optical modulator using a top-bottom antenna structure

Biomaterial technology

We have been researching and developing artificial biomoleculars capable of unprecedented new functions by skillfully combining natural biomolecular components. This fiscal year, we developed an elastic molecular component (the world's smallest coiled spring) as part of efforts to prototype the elements for building an information processing system made up of biomolecules, and we succeeded in embedding the elements into the cells of the molecule and detecting microscopic mechanical input stimuli (Fig. 3 left). Furthermore, we used a ring fabricated with DNA nanostructures and a modified molecular motor

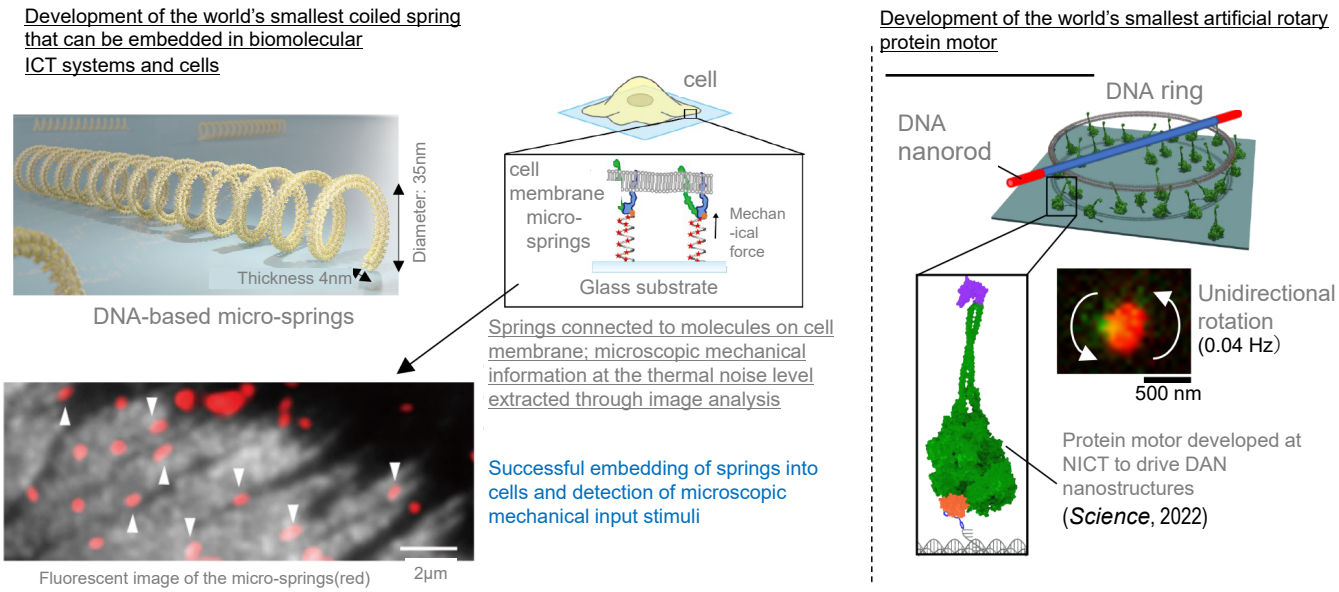


Fig.3 : Prototyping of the constituent elements of an information processing system made up of biomolecules

to develop the world's smallest artificial rotary protein motor and a linear motor that switches the direction of movement (Fig. 3 right). These technologies constitute knowledge that enables the provision of important elements for building an information processing system that uses somatic molecules as agents and are groundbreaking results that contribute to elucidating the operating mechanisms of biomolecules.

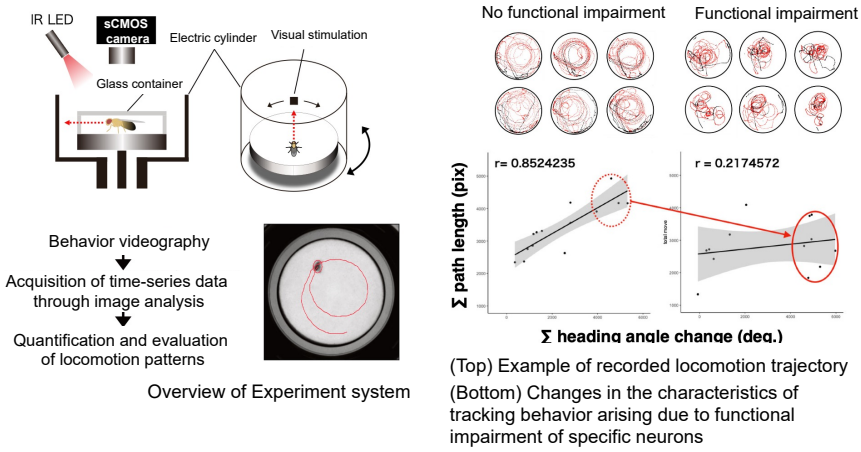


Fig.4 : Analysis of pursuit behavior using individuals under unconfined conditions

New ICT technology learning from an insect's brain

Insects with visual organs that are compound-eye structures have the ability to track other individuals accurately and quickly using visual inputs with an extremely limited spatial resolution. We are working on modeling the process by which the brain of the fruit fly *Drosophila melanogaster* converts visual input into motor output and are gathering the necessary behavioral and neural activity data for that purpose. Currently, we mainly use a "locomotion simulator," in which subjects are confined to the apparatus, to analyze the subjects' locomotion activity. This system is unmatched in its ability to understand the correlations between visual inputs and the locomotion movements that occur as a response to them. However, we cannot completely eliminate the possibility that the partial lack of sensory feedback caused by confining the subjects may cause responses that differ from natural conditions. Therefore, we have developed a new system for measuring tracking behavior using subjects in an unconfined state (Fig. 4). The development of this new measurement system has made it possible to induce and analyze tracking behaviors using individuals under unconfined conditions, and combining this system with the locomotion simulator has made it possible to compare and examine the subjects' behavioral responses to visual stimuli under confined/unconfined conditions. This result provides a solid foundation for the exploration of information processing algorithms for controlling moving objects.

DUV device technology

In order to develop an optics-free deep-ultraviolet (DUV) light-emitting diode (LED) that can control the beam angle, we proposed and demonstrated a new DUV-LED device structure that combines a nano-scale phase-type Fresnel zone plate (FZP) structure with an AlGaN-based micro-LED structure (Fig. 5). The phase-type FZP structure comprises multiple concentric rings (zones) to converge and collimate the light emitted from the active layers by controlling the phase at each zone.

The AlGaN-based LED layer structure (peak emission wavelength: 273 nm) was grown using the metalorganic chemical vapor deposition (MOCVD) method on an AlN substrate and was then fabricated into a micro-LED structure with a 100 μm diameter

circular mesa structure. Additionally, a center alignment was conducted to form the phase-type FZP structure with a diameter of 2,500 μm (outermost zone width: <150 nm) on the AlN light extraction surface. These approaches allow for the control of the beam angle of the DUV light emitted from the DUV LED active layer.

Koganei Frontier Research Center

Quantum ICT technology

In order to expand the possibilities of the quantum channels that constitute quantum secure networks, and to realize a highly secure communication channel between satellites and the ground, we have confirmed the normal operation of physical layer encryption equipment (10 GHz clock optical transmission equipment) that enables information-theoretically secure key sharing between the International Space Station (ISS) and transportable optical ground stations using an instrument installed on the ISS, and have successfully received beacon light from a transportable ground station and a signal light at the transportable optical ground station. (For the details, refer to the section on the Quantum ICT Collaboration Center.)

Regarding quantum node technologies, we have succeeded in implementing a calcium ion quantum bit phase rotation gate that is approximately 20 times faster than conventional methods in an ion trap system that realizes quantum bits.

Ultra-high frequency device technology

As part of the development of elemental technologies for terahertz-band transceivers for establishing high-speed and large-capacity wireless communication technologies, a beam-steerable 300-GHz-band wireless receiver was developed. The quasi-two-dimensional beam-steering operation is achieved by a mechanically steerable antenna and a one-dimensional phased-array system (Fig. 6 (a)). The phased-array system consists of a one-dimensional array antenna with horn, the waveguide transitions and the passive components on a printed circuit board (PCB), and the 300GHz-band down-converter chips designed in a 40-nm silicon complementary metal-oxide semiconductor (CMOS) process. Down-converted signals from each chip mounted in a staggered arrangement due to dimensional constraints are synthesized by the passive components on the PCB (Fig. 6 (b)). The wireless link performance of the developed beam-steering CMOS receiver module was evaluated with the IEEE Std802.15.3d channels using off-the-shelf instruments (Fig. 6 (c)) and achieved a data rate of 25.9 Gb/s with a steering angle of 28° (Fig. 6 (d)).

Ga_2O_3 device technology (Green device technology)

We have combined our device process technologies that have been developed in recent years with halide vapor phase epitaxy technology for high-quality Ga_2O_3 thin films on Ga_2O_3 (010) substrates developed by our joint research partner, the Kumagai Laboratory at Tokyo University of Agriculture and Technology, to fabricate vertical Ga_2O_3 fin transistors and evaluate their device characteristics. Based on physical properties such as electron mobility and thermal conductivity, the device characteristics of vertical fin transistors on Ga_2O_3 (010) substrates can be even better than those on Ga_2O_3 (001) substrates that have been commonly used to date due to the existence of commercially available epitaxial substrates. Vertical fin transistors on Ga_2O_3 (010) substrates have never been reported to date, and our result marks the world's first demonstration of their operation (Fig. 7).

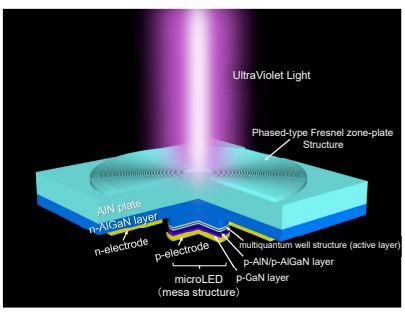
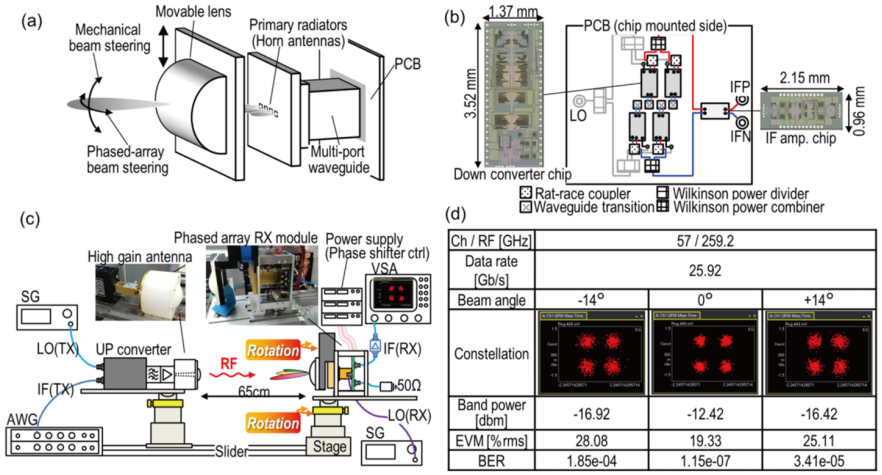


Fig.5 : Schematic of a DUV LED whose beam angle can be controlled



Ch / RF [GHz]	57 / 259.2		
Data rate [Gb/s]	25.92		
Beam angle	-14°	0°	+14°
Constellation			
Band power [dbm]	-16.92	-12.42	-16.42
EVM [%rms]	28.08	19.33	25.11
BER	1.85e-04	1.15e-07	3.41e-05

Fig.6 : 300-GHz-band beam steering CMOS wireless receiver

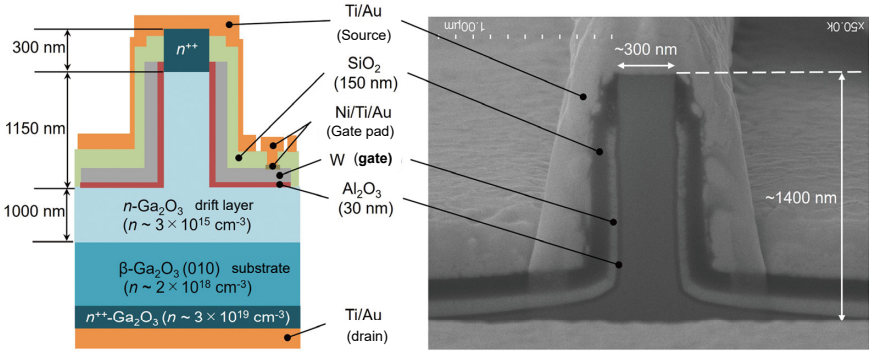


Fig.7 : (a) Cross-sectional schematic diagram and (b) electron microscope image of vertical Ga_2O_3 (010) fin transistor structure

Center for Information and Neural Networks

People can mentally imagine bodily movements without actually performing them. This is generally known as motor imagery, but since this is a mental process without the expression of behavior, it is difficult to objectively evaluate whether people have properly imagined the movements. By using the Controllability of Motor Imagery (CMI) test, in which people mentally construct an image based on verbal instructions regarding the movements of body parts and then actually reproduce the finally created body posture, it is possible to objectively evaluate whether people have been able to manipulate the motor imagery (Fig. 8. Left). When we used this test, with functional MRI (fMRI), to investigate the characteristics of the brains of people with higher controllability, we found that the motor simulation network in the premotor cortex and superior parietal lobe is functionally linked to the higher-order visual body areas and sensory-motor areas, and that people who predict the sensations associated with movement are able to manipulate the motor imagery more skillfully (Fig. 8. Right).

Previous research has suggested that well-being is associated with various desirable outcomes. For example, people with higher well-being tend to be healthier, live longer, and be more productive at work. Establishing a methodology for effectively increasing well-being will enable us to investigate the brain mechanisms that support such a state in much more detail. Toward that goal, we examined the relationship between individual psychological characteristics and different well-being scales among Japanese people. To date, most studies have originated from research groups in Europe and the United States, and their applicability to individuals with different cultural backgrounds has been called into question. In this study, 71 participants were requested to evaluate their trait gratitude, self-esteem, and trait optimism using psychological scales. In addition, they answered questions measuring two different types of well-being: subjective well-being, which focuses on life satisfaction, happiness, and positive emotions, and psychological well-being, which focuses on aspects such as purpose in life and relationships with other people. The results of this analysis are shown in Fig. 9. Primarily, results indicated that trait gratitude was more strongly associated with dimensions underlying psychological well-being, suggesting that for Japanese individuals, gratitude interventions are more likely to enhance psychological well-being than subjective well-being. This study was published in the journal BMC Psychology.

We used Stable Diffusion, an advanced image generative AI, to attempt to reconstruct visual experiences from fMRI signals and verify how that process is similar to human brain functions. The study revealed that the images reconstructed by Stable Diffusion had high imaginal and semantic similarity to the images the subjects of the experiment actually visualized (Fig. 10). The study also showed that the image representation of Stable Diffusion predicted activity in the human early visual cortex, while semantic representation predicted activity in the higher visual cortex. This pioneering research linking generative AI and neuroscience was widely reported on by major media outlets in Japan and overseas and also attracted attention in the academic community, with more than 90 citations recorded in just nine months after its publication.

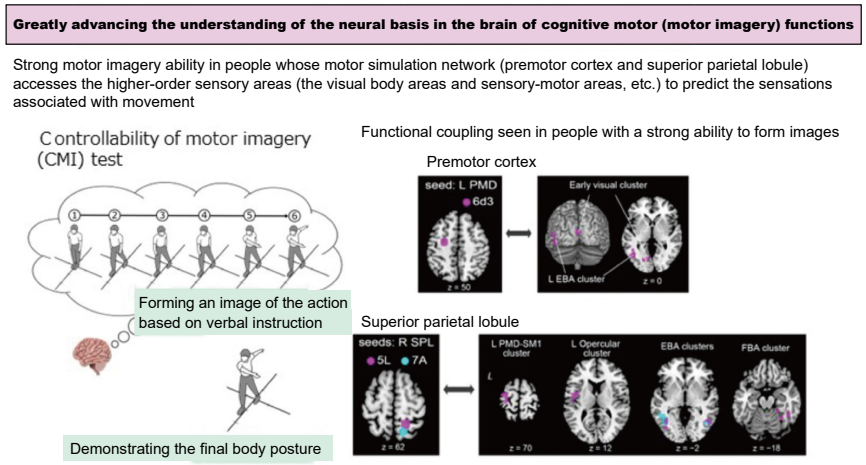


Fig.8 : Elucidation of the neural basis in the brain of human motor imagery

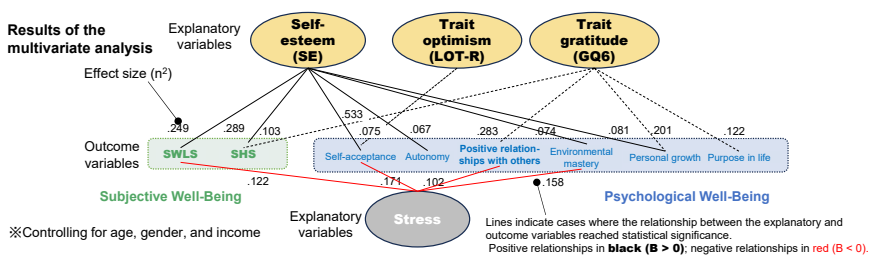


Fig.9 : Relationship between trait gratitude, self-esteem, trait optimism, and scales associated with subjective and psychological well-being.

Fig.10 : Results of image reconstruction using the Stable Diffusion Model

B5G Field

Beyond 5G Research and Development Promotion Unit

Director General HOSAKO Iwao

The Beyond 5G Research and Development (R&D) Promotion Unit strongly promotes the R&D of cutting-edge elemental technologies within NICT as a command tower for R&D toward the realization of Beyond 5G at NICT, while ensuring that previously physically and socially divided communities from different fields can collaborate and co-create through Beyond 5G. It's ultimate goal is to enable everyone to freely create new value, establishing Beyond 5G as a foundation of society that contributes to achieving the SDGs and Society 5.0.

The Beyond 5G Design Initiative advances cutting-edge elemental technology R&D within NICT to realize Beyond 5G / 6G, through strengthening the cooperative frameworks and awareness sharing within NICT, formulating strategies on collaboration policies outside NICT, and promoting effective information dissemination through branding and system demonstration. The initiative also conducts R&D on concepts and architectures of Beyond 5G / 6G that bridge different industries to create new value.

In FY2023, the initiative worked to deepen cross-laboratory discussions on the Beyond 5G architecture, leading to the development of a proof of concept (PoC) system to visualize the system's core concepts. It also established a collaborative research scheme with Germany, including a fund for collaboration, advancing the formation of a partnership a year ahead of schedule to achieve early concrete results in international collaborative R&D.

Discussions on Beyond 5G Architecture

By deepening cross-laboratory discussions on the Beyond 5G architecture, we realized specific orchestrator functions and interfaces necessary for integrated control of terrestrial and non-terrestrial networks (TN/NTN), and coordinated between inter-industry digital twins. We also constructed a framework and share strategies that enable integrated R&D within NICT.

These activities attracted global attention, leading to paper authorship and 46 invitational seminars, including at national-level workshops, in seven countries. They were also reflected in the content of the Beyond 5G Promotion Consortium's white paper supplementary volume on architecture, leading global discussions on 5G architecture.

We developed the PoC system to visualize the core concept of a Beyond 5G system that facilitates inter-industry collaboration, accelerating engagement activities that included demonstrations to stakeholders. These achievements were then input into international standardization activities (ITU-T, IOWN, etc.) (Fig. 1).

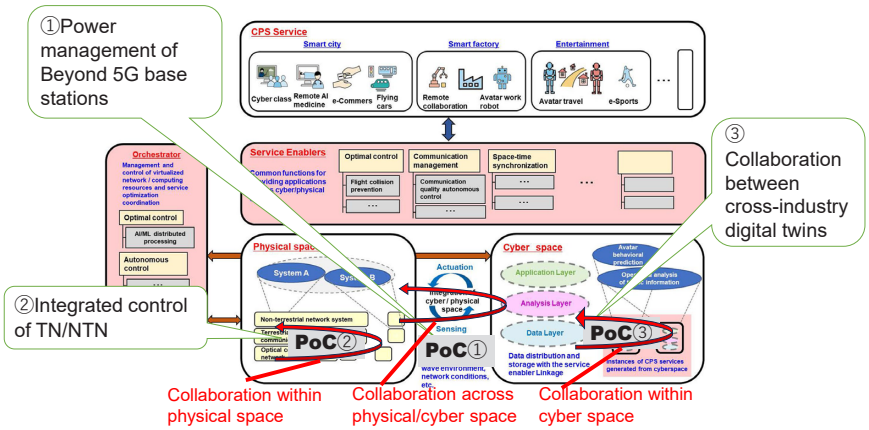


Fig.1 : Conceptual demonstration system of Beyond 5G architecture

Deepening Strategic Partnership with Germany

To further deepen the strategic partnership with Germany, which is advancing initiatives on Beyond 5G, Germany-Japan Beyond 5G/6G research workshops were organized. The workshops, held in April and June 2023, facilitated discussions on the potential and direction of Germany-Japan collaboration, leading to the formation of numerous connections with German 6G researchers and the discovery and in-depth exploration of research themes for matching purposes. A joint research scheme with budget measures from an internal fund was also created, leading to the acceptance of six projects. At a third workshop held in Tokyo in February 2024, a plan to promote new Germany-Japan projects was implemented, conducting processes from

project formation and budgeting to public application and selection within one year, thereby advancing the establishment of a collaboration system with the world's top groups a year ahead of schedule (Fig. 2).

Terahertz Wireless Testbed Base Technology

R&D was conducted to enhance radio-on-terahertz-over-fiber systems by applying optical fiber wireless technology. Two laser beams at different wavelengths that generate terahertz waves were generated by extracting two laser beams separated by 355 GHz from a previously developed wideband flattened optical frequency comb. Data was encoded onto one of these laser wavelengths, then combined again to create an optical signal with data modulation on a 355 GHz carrier wave. After 20 km transmission through optical fiber, data-modulated terahertz waves were generated by inputting this signal into a UTC-PD. The terahertz waves emitted from the transmission unit were received at the reception unit after 4 m of propagation. Down-conversion with a local signal is necessary to convert the received terahertz waves back to optical signals, so a new method for generating local signals using optical signals was developed to demonstrate reduced signal degradation compared to electrical signals multiplied as local signals. As a result, the modulation frequency of 16 QAM OFDM signals was successfully increased, demonstrating the possibility of 60 Gbps data transmission with 16 QAM OFDM signals (Fig. 3).

Terahertz Spectrum Measurement Platform Technology

Aiming to achieve high-accuracy terahertz band spectrum measurement, we proposed a strategy that utilizes mutual wavelength conversion with the optical waveband (near-infrared light), for which advanced generation, control, and measurement base technologies have already been established, to achieve high-accuracy terahertz light generation, control, and measurement methods traceable to national standards. Fig. 4(a) provides a schematic diagram of the reference terahertz light generation. The brightened optical reference signal, traceable to national standards, was used as the optical frequency reference and excitation light during wavelength conversion. A narrow linewidth tunable optical source was prepared as the control light to determine the terahertz optical frequency. A spectral drill cavity capable of measuring changes in transmitted light intensity as the optical frequency changes at any frequency was introduced, serving as high-accuracy frequency control light. Fig. 4(b) shows the time variation of optical frequency. Frequency stabilization to about a few MHz was achieved. By using the absorption lines of gas molecules or optical comb signals as reference signals, it is possible to effectively generate, control, and measure highly-accurate terahertz light frequencies that correspond to the differences in frequency from the reference light, which are traceable to national standards based on the accuracy of light.

Fig.2 : Workshop held alongside a 1,000-participant 6G event in Germany (2nd Workshop, June 2023)

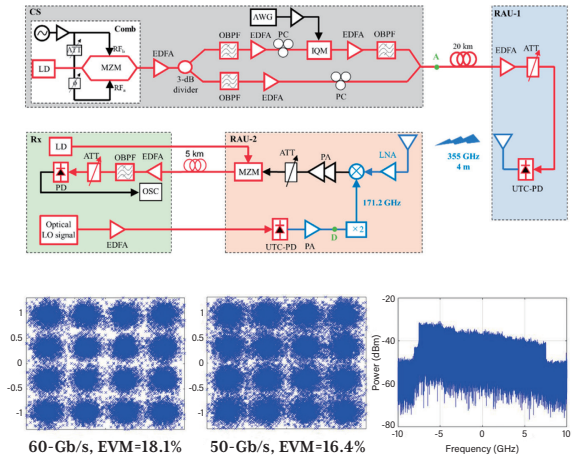
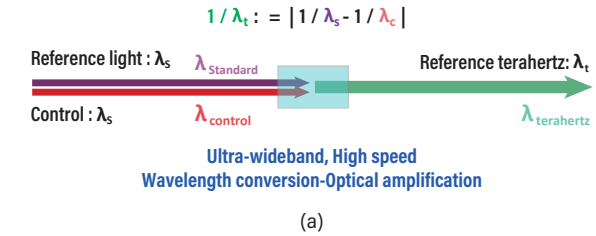
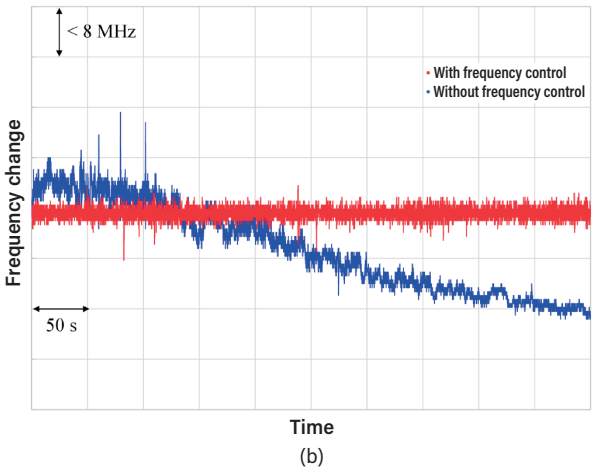


Fig.3 : Radio-on-terahertz-over-fiber experimental system



(a)



(b)

Fig.4 : (a) Schematic diagram of reference terahertz light generation, (b) Time variation of control light frequency

Quantum ICT Field
Quantum ICT Collaboration Center

Director General FUJIWARA Mikio

The Quantum ICT Collaboration Center was established in 2021 as a core organization for managing the Quantum Security Innovation Hub, one of the national quantum technology innovation hubs.

Its missions are: (1) to pioneer a new academic field of quantum security by integrating quantum cryptography and quantum communication with modern cryptography, information theory, and network technology, and to work on the demonstration and a system implementation of its fundamental concepts; and (2) to define a new infrastructure, quantum internet (Fig.1), by merging the new field of quantum security with the quantum computing, quantum measurement and quantum sensing, providing the advanced measurement, sensing, communication, and encryption functions unique to quantum technology.

To accomplish these missions, we strive for seamless integration of research and development, implementation and testing on open testbeds, deployment in society, and human resource development, while building an industry-academia-government collaboration environment through coordination inside and outside NICT.

Satellite Quantum Cryptography Technology

In the field of satellite quantum cryptography technology that is facilitating the globalization of quantum technology, we successfully operated an instrument developed in fiscal year 2022 on the International Space Station (ISS). Following this, we confirmed the operation of physical layer encryption equipment (10 GHz clock optical transmission equipment), enabling information-theoretically secure key sharing between ISS and transportable optical ground stations, and succeeded in receiving a beacon light from a transportable ground station and a signal light at the transportable optical ground station. This confirmed the success of the optical communication channel between the ISS and the ground, thereby verifying the feasibility of an information-theoretically secure key supply infrastructure using satellites (Fig.2). We are also advancing research to enable quantum key distribution (QKD) technology on higher orbits, facilitating a future QKD satellite network. For example, we prototyped a key distillation substrate for QKD using instruments expected to operate under geostationary satellite conditions with high-energy particle exposure, successfully confirming its radiation resistance and normal operation of the key distillation process through radiation tests. During this experiment, it became clear that off-the-shelf storage devices cannot operate under radiation tests, leading to the development of a new radiation-resistant device using NAND memory, and its proper operation in key distillation was confirmed. We also clarified the boundary of responsibility between satellite and ground-based QKD systems, implemented interworking functionality for key relay between different QKD networks onto ultra-compact hardware suitable for satellite mounting, and completed verification of mutual interconnectivity with ground-based QKD networks. Through this

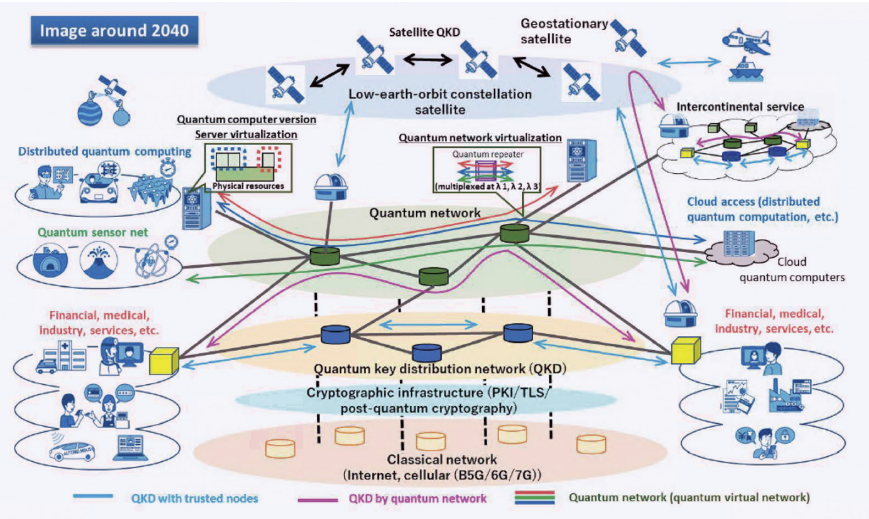


Fig.1 : Conceptual diagram of quantum internet

process, we successfully established the foundational technology for realizing an integrated ground-satellite QKD network.

International Standardization Activities

Among international standardization activities, we are actively participating in the study groups of the Telecommunications Standardization Sector of the International Telecommunication Union (ITU-T), the European Telecommunications Standards Institute (ETSI), and the Innovative Optical and Wireless Network (IOWN) and proposed various contributions, including submitting 54 contributions to ITU-T (Fig.3). We also led the writing of the IOWN Global Forum (GF) Multi-Factor Security (MFS) Proof of Concept (PoC) Reference, which was published in October 2023. For evaluation and certification methods for quantum cryptographic modules, we developed Japan's unique protection profile (PP) and Evaluation Methodology Document (EMD). We also established a framework for making timely updates.

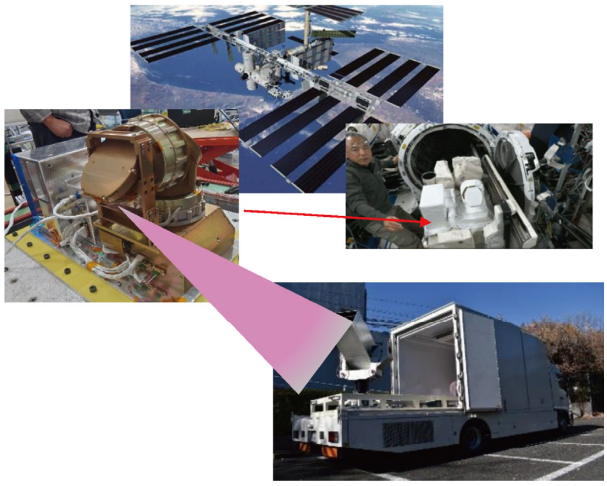
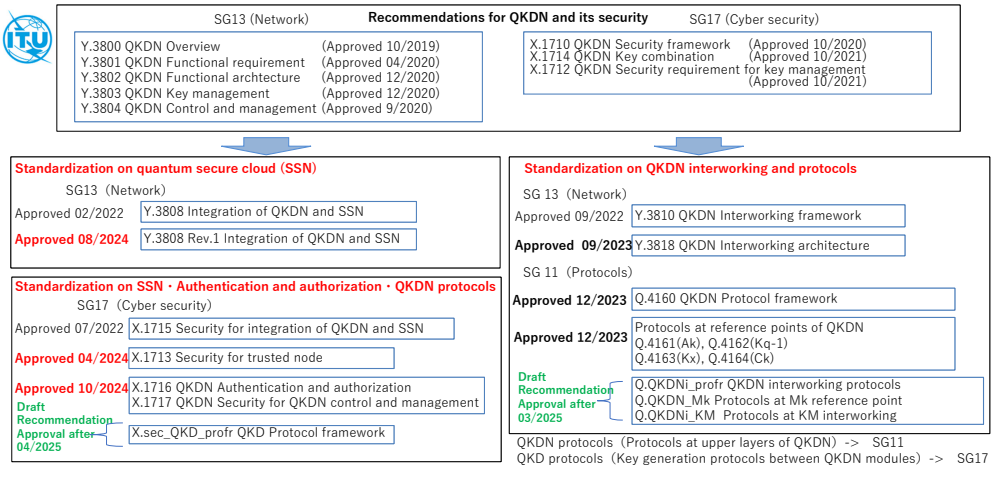


Fig.2 : Overview of secret key sharing experiment with International Space Station and transportable optical ground station

Strategic Quantum-native Human Resources Development

To cultivate quantum-native human resources, we host the NICT Quantum Camp (NQC), which consists of three programs: public seminars for the general public, experience programs offering lectures and exercises by experts for select members, and exploration programs involving research under the supervision of advisors. Additionally, we operate the Young Researchers Lab, where students and other young researchers conduct challenging advanced research as NICT research assistants, helping develop five individuals in fiscal year 2024.



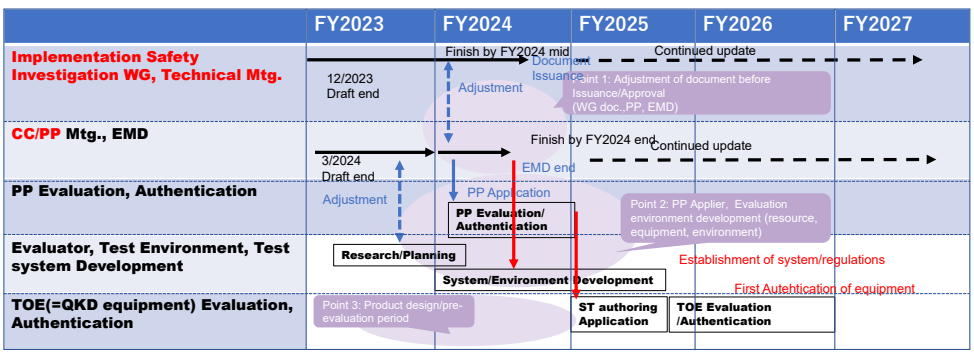


Fig.3 : Overview of ITU-T standardization activities and roadmap for QKD protection profile (draft)

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General NAGANO Hidehisa

The ICT Testbed Research and Development Promotion Center, taking into account the anticipated advancements in new technologies towards the realization of Society 5.0, such as Beyond 5G, has established the Beyond 5G/IoT Testbed with High-reliability and High-flexibility (Fig. 1).

- The Center will construct, a real-time emulation environment, and a verification environment for data utilization contributing to realizing a data-driven society, which are capable of verifying the social and technical needs of the Beyond 5G era on existing testbeds. It also supports verification environments for the world's most advanced technologies, such as optical and quantum communication technologies, thereby contributing to research and development, technology demonstration, social implementation, and international collaboration in Japan's ICT field.

- The Center also aims to contribute to creating new value and solving social issues by bringing together the research and development capabilities of testbed users including NICT, domestic and international research institutions, telecommunications operators, vendors, and ventures onto the testbed through activities at related forums and opportunities for research and development implemented by the government. In addition, the Center practices initiatives to form an internationally attractive research and development hub by cyclically evolving its verification environment by using, operating, and improving the testbed.

Promoting the Development and Utilization of the Beyond 5G/ IoT Testbed with High-reliability and High-elasticity and Cyclical Evolution

The Center has promoted further improvements to the testbed's functions in line with external needs and strengthened promotion of its utilization in response to the "further expansion of use to private companies, universities, etc." that was added to NICT's mid- to long-term goals in February 2023. As a result, it was used in 122 projects (62 projects internally, 60 externally, including 6 NICT-commissioned researches on R&D of innovative information and communications technology), including by 114 external organizations. Additionally, projects utilizing new functions related to Beyond 5G ("Beyond 5G Reliable Virtualization Infrastructure," "Beyond 5G Mobile Environment," "Data Centric Cloud Service (DCCS)," "CyReal Evaluation Environment") accounted for 33% of total usage, indicating steady promotion of the utilization of new functions related to Beyond 5G.

Platform Layer Testbed DCCS, Network Layer Testbed

In the platform layer testbed DCCS, we added/improved and generalized functions in response to high user demand resulting in double the usage compared to the previous year, including by NICT-commissioned research on R&D of innovative information and communication technology. Specifically, we started to provide the new function including live speech translation on an edge server and the data from "Himawari satellite" in response to the requests from Non-Terrestrial Network (NTN)-related R&D. We also opened a DCCS sample application site to introduce usage examples.

In the network layer testbed, we work on various activities to enable the coordinated use of multiple functions that were identified through the analysis of usage patterns. Specifically, we abstract environments such as the Beyond 5G mobile environment, Japan Gigabit Network (JGN), and DCCS as network components, and connect them using virtual network technology to combine the resources, functions, and data

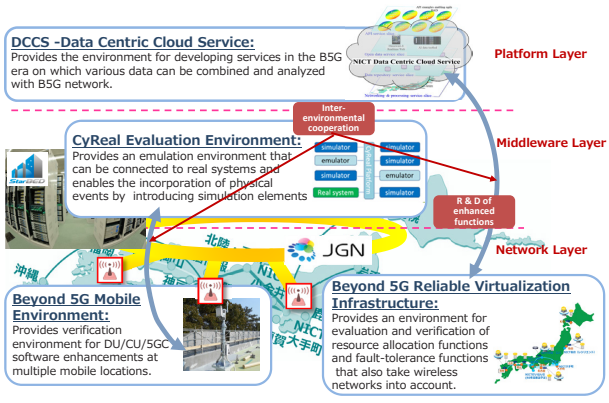


Fig.1 : Overview of functional collaboration in the Beyond 5G/IoT Testbed with High-reliability and High-elasticity

provided by each environment. Through this activity, the basic design of a flexible integration configuration was implemented, a verification environment was built, and a pilot version was provided to some users. It resulted in increased usage of the Beyond 5G Reliable Virtualization Infrastructure by 1.3 times and the Beyond 5G Mobile Environment by 1.4 times compared to the previous year (Fig. 2).

CyReal Evaluation Environment

In the middleware layer testbed, we commenced the general provision of the CyReal Evaluation Environment from April 2023 (Fig. 3). Usage began for 14 cases in StarBED and 3 cases in the CyReal Evaluation Environment, providing wireless emulation in dedicated environments built on the CyReal Evaluation Environment to 5 partners. We migrated existing operational functions to the CyReal Evaluation Environment provision system TENTOU and integrated the CyReal Evaluation Environment and StarBED management functions. As a promotional activity, we exhibited a demo of the CyReal Evaluation Environment at Interop Tokyo 2023 and received the Best of Show Award Special Prize in the innovative challenge (university research, etc.) category.

Demonstration and Research and Development of Testbed Environment, Leading to Acceleration of Terahertz R&D

We demonstrated a use case taking advantage of the ultra-spot characteristics of the terahertz band using 60 GHz band devices and issued a press release on this achievement. Additionally, we conducted dynamic exhibitions collaborating with companies developing ultra-high frequency devices, and the Beyond 5G Research and Development Promotion Unit Terahertz Technology Research Center's Collaborative Research Laboratory of Terahertz Technology. The exhibitions took place at the Combined Exhibition of Advanced Technologies (CEATEC) 2023 (Oct. 2023, Chiba) and the Japan booth of Mobile World Congress (MWC) 2024 (Feb. 2024, Barcelona), etc., demonstrating a system where a small robot car equipped with an IEEE802.15.3e-compliant device uploaded large-capacity data while passing through ultra-spots as a use case for mobile communication services utilizing this technology.

Towards our ultimate goal of building an IEEE 802.15.3d evaluation environment that enables use case validation and performance assessment of terahertz systems in compliance with this international communication standard, we developed a preliminary version of such an environment. This development was worked through joint research with a wireless system-on-a-chip (SoC) development company, the environment utilizes IEEE 802.15.3e-compliant devices that offer high compatibility with the standard, excluding certain physical layer specifications (such as frequency bands and optional modulation schemes). In addition, we developed an IEEE 802.15.3e-compliant communication evaluation device that assesses various communication quality parameters by enabling arbitrary adjustment and fixation of multiple parameters at the physical and medium access control (MAC) layers. Furthermore, in conjunction with a high-precision spatio temporal synchronization stamp mechanism, we also developed an IEEE 802.15.3e-compliant sniffer device capable of high-resolution evaluation of inter-device communication states, including transient phenomena before and after communication link establishment and completed the construction of an evaluation system and preliminary operational verification (Fig. 4).

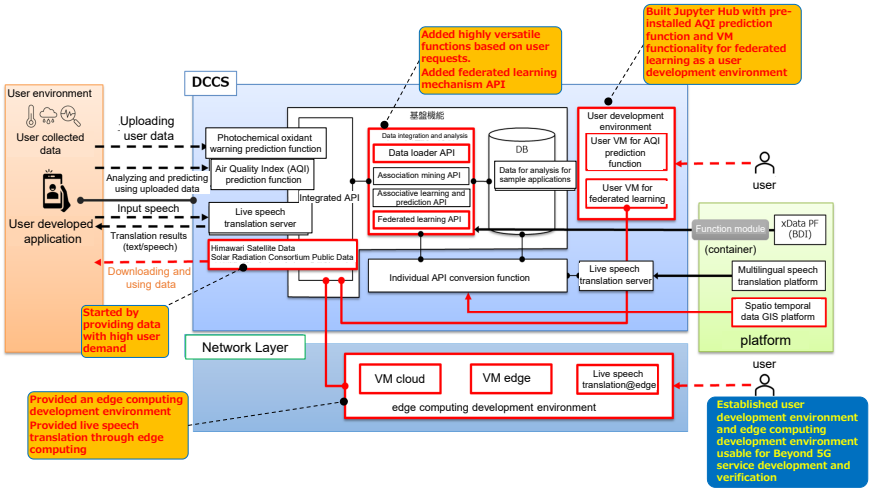


Fig.2 : Overview of DCCS functions provided starting FY2023

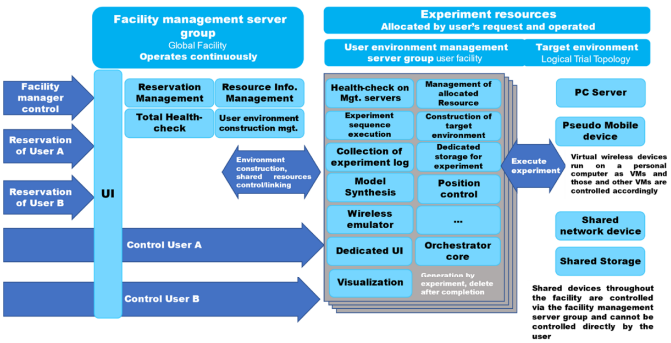


Fig.3 : CyReal: Architecture of cyber and real testbed

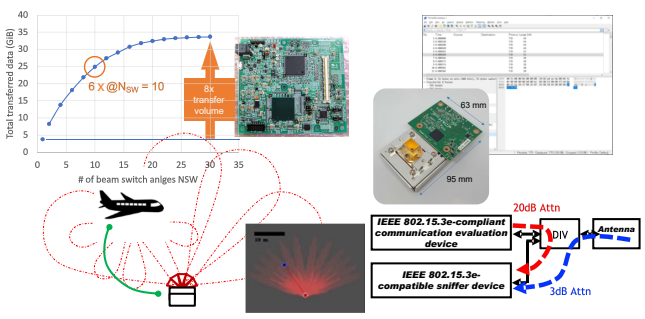


Fig.4 : Development of multi-sensor-compatible spatio-temporal synchronization stamp mechanism and IEEE802.15.3d evaluation environment

Open Innovation

Innovation Promotion Department

Executive Director NAKAZATO Gaku

The Innovation Promotion Department works on the following missions in collaboration with teams within and outside NICT towards the maximization of research and development results in NICT:

- *To promote research and development efficiently and effectively by effectively using external research resources through the respective measures of joint research and sponsored research, and to contribute to further strengthening industry-academia-government collaboration, and*
- *To contribute to the creation of open innovation through the social implementation of R&D results by appropriately securing and effectively utilizing intellectual property and effective standardization activities of industry-academia-government collaboration.*

Promotion of Joint Research and Researcher Exchange

In FY2023, the number of joint research contracts reached 570 (including ongoing projects from the previous fiscal year), of which 113 contracts were new projects initiated in FY2023 (Fig. 1).

Promotion of Sponsored Research

(1) Promotion of sponsored research of advanced communications and broadcasting R&D

In FY2023, in addition to twelve (12) research themes that have been continuing since FY2022, studies of three (3) new themes for research and development were started. NICT researchers in charge of each theme supervise each sponsored research project as project officers who conduct R&D integrated with NICT's initiatives with the intention to maximize their effectiveness. Research outcomes resulted in 102 published papers, 215 general oral presentations, 177 standardization proposals, and 68 industrial property applications (25 domestic and 43 foreign).

(2) Promotion of sponsored research on R&D of innovative information and communication technology

In FY2023, in addition to 69 ongoing themes since the last year, NICT initiated R&D on two (2) core tasks related to function-realization-programs and one (1) task of the Radio Wave Effective Utilization Research and Development Program. The fruits of this research resulted in 537 published papers, 1239 general oral presentations, 355 standardization proposals, 43 standardizations adopted, and 505 industrial property applications (263 domestic and 242 foreign).

Promotion of Acquisition and Appropriate Implementation of External Funding

External funding acquisition efforts

The department investigated the contents and rules of various research funding programs, provided NICT researchers with that information, checked more than 100 application documents, gave advices on those application documents, and supported administrative tasks for expansion of the acquisition of external funding. The department also aimed to provide incentives for the acquisition of external funding by holding briefings on application guidelines, seminars on acquiring scientific research funds, and by implementing a promotion program for acquiring external funding. An overview of the results of external funding acquisition for FY2023 is shown in Fig. 2.

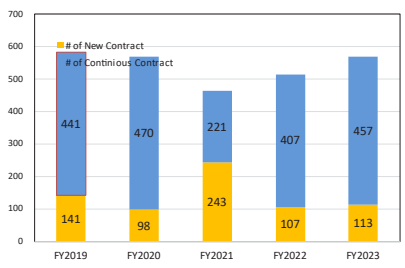


Fig.1 : Trends in the number of joint research contracts

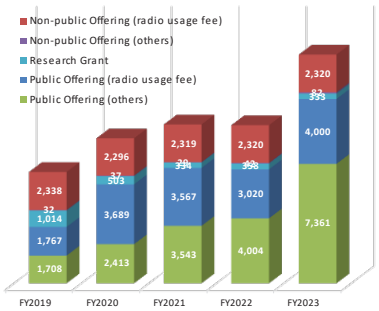


Fig.2 : Annual progress in external funds acquisition

Development of an Environment for Proper Use of External Research Funds

For entrusted research and research grants, the department supported administrative procedures such as contract conclusion, receipt and payment of shared expenses, performance reporting, and inspection work based on contracted agreements. The department also carried out institutional representative duties for scientific research funds (compiling applications, electronic application procedures, etc.) and acted as a contact point for funding allocation institutions, working to streamline procedures and reduce researchers' burdens.

Proactive Acquisition and Use of Intellectual Property

In FY2023, the department handled 149 patent applications (67 domestic and 82 foreign), and the number of registered patents held at the end of the fiscal year was 948 (566 domestic and 382 foreign) (Fig. 3). Compared to last year, domestic applications slightly decreased, while foreign applications increased.

The number of contracts for new technology transfer is 19 in FY2023, totaling 130 technology transfer contracts at the end of the fiscal year. Technology transfer income amounted to 124 million yen, showing an increasing trend compared to the last year (Fig. 4).

Promotion of Standardization Activities

The total number of people, in cooperation with each research institute and center of NICT, who attended meetings held by international standardization organizations, was 530. 205 contributing documents (including 129 related to Beyond 5G/6G) were submitted. This contributed to establishing 17 international standards, etc., based on NICT's R&D results (including 11 related to Beyond 5G).

In November 2023, the first standard on Beyond 5G/6G, ITU-R Recommendation M.2160 (recommendation for the IMT-2030 framework), was approved in Radiocommunication Assembly(RA)-23 of the International Telecommunication Union Radiocommunication Sector (ITU-R) (IMT-2030: the term for Beyond 5G/6G in ITU. 5G is referred to as IMT-2020). NICT contributed to develop section texts on technology trends and capability based on research technologies related to terahertz technology, time-space synchronization, and non-terrestrial networks (NTN), and proposed, in the recommendation, a target value for positioning, which is reflected as one of the research targets for IMT-2030. Additionally, based on NICT's research on terahertz technologies, NICT contributed to develop the report on "Technical feasibility of IMT in bands above 100 GHz" (ITU-R Report M.2541).

In the 3rd Generation Partnership Project (3GPP), NICT proposed, as a research topic for Release 19 dealing with the advancement of 5G, that technology for cooperation among multiple different mobile networks and time synchronization technology through device-to-device communication are required for standardization. Although study of those proposals was regarded as premature for Release 19's consideration topics, NICT continues to propose those technologies to be considered as study topics for Release 20, which deals with Beyond 5G / 6G topics in FY2024 (Fig. 5).

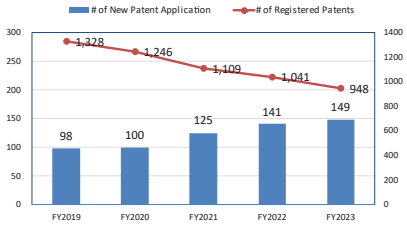


Fig.3 : Trend in patent applications and registered patents

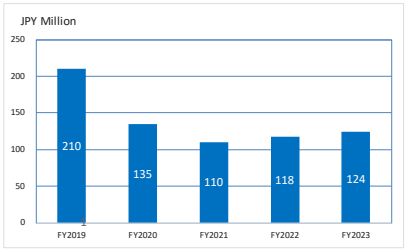


Fig.4 : Trends in revenue from intellectual property

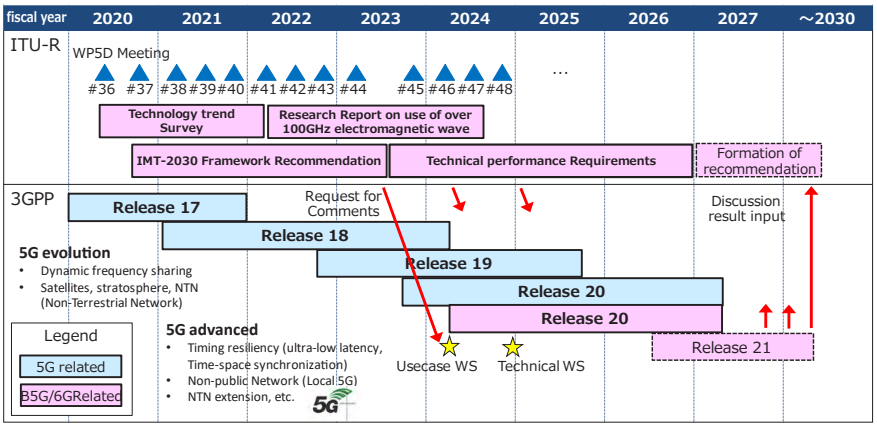


Fig.5 : Schedule for IMT-2030

Open Innovation
Global Alliance Department

Executive Director NAGATA Kazuyuki

Collaboration with leading overseas research institutions and universities is crucial for achieving better outcomes in the R&D of information and communication technology and deploying the results. The Global Alliance Department aims to maximize research and development results and promote their global dissemination, advancing international collaboration and the global deployment of research and development outcomes in NICT's R&D activities.

International Research Collaboration

To facilitate international collaboration, we have exchanged memoranda of understanding with leading overseas research institutions and universities to promote joint research and personnel exchange. In FY2023, we exchanged 11 memoranda with overseas universities and research institutions (7 new and 4 renewals), promoting international research collaboration and actively engaging in the international deployment of NICT's research results (results as of the end of FY2023: 74 memoranda with 72 institutions across 24 countries/regions)(Fig.1).

Collaboration with Southeast Asia and Joint Research Projects

The ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO), a research collaboration organization jointly operated by NICT and research institutions and universities within the ASEAN region, has gained significant recognition in the ASEAN area and has grown into a large, joint research alliance with 98 participating institutions (Fig. 2). Since its inception, a total of 47 projects have been implemented, involving 576 researchers from 110 institutions.

In FY2023, ASEAN IVO supported 17 joint R&D projects (initiated between FY2020 and FY2022) targeting common social issues in the ASEAN region, such as food, environmental protection/disaster risk reduction, safe and smart communities, and health/welfare. For example, in the field of safe and smart communities, it advanced multinational joint research aimed at solving issues through ICT, such as detecting voice spoofing (a biometric indicator), constructing a cybersecurity platform for healthcare, developing biosensors for early detection of cholangiocarcinoma, and building diagnostic support systems for non-communicable ocular diseases.

Additionally, the ASEAN IVO Forum 2023 was held in Vientiane, the Lao PDR to form projects starting in FY2024. 20 project ideas were introduced at the forum, and active discussions took place. This exchange of opinions and the formation of groups led to 47 new project proposals, of which 5 were selected by the steering committee to start in the next fiscal year.

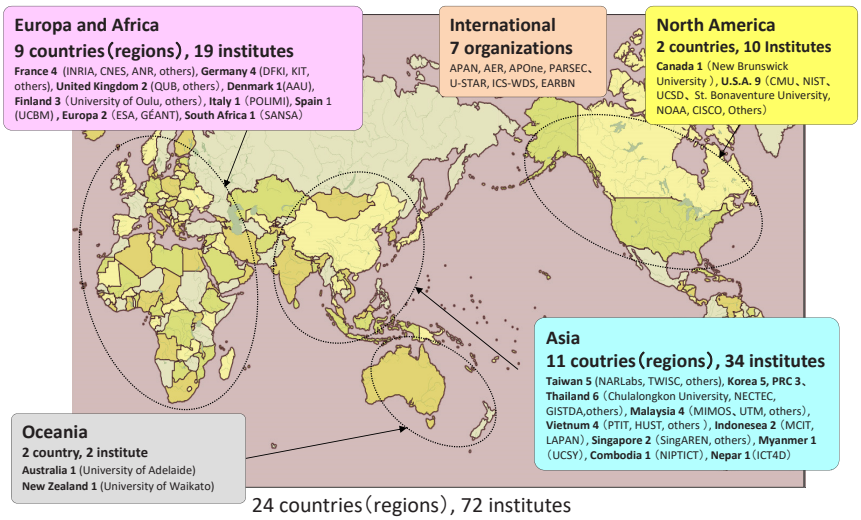


Fig.1 : Overseas institutions with which memoranda of understanding have been exchanged (End of March 2024)

International Joint Research Program with the United States of America and Europe

In the Japan-US Network Opportunity 3 (JUNO3) international joint research program, jointly operated with the National Science Foundation (NSF), 5 joint research projects related to the R&D of programmable networks for next-generation core and Beyond 5G / 6G networks were further progressed. In the

Collaborative Research in Computational Neuroscience (CRCNS) international joint research program, 4 projects were renewed (including 1 proposed by NICT), and 1 new project was initiated.

To promote Japan-Germany joint research and development in the Beyond 5G field, we established a new NICT internal fund, the Beyond 5G Collaboration Fund, in FY2023, and solicited projects from within NICT, of which 6 were selected with joint research commencing in January FY2024.

Promotion of International Collaboration in the Strategic Field of Beyond 5G

At the Internet Governance Forum Kyoto 2023 (IGF 2023) hosted by the United Nations in Kyoto, NICT organized and managed a Beyond 5G panel discussion (Fig. 3). Through discussions with information and communication experts from North America, Europe, Asia, and Africa, we were able to broadcast NICT's Beyond 5G R&D policy as an open service platform architecture to the world, reaffirm that challenges vary by region, and foster a shared understanding of global information and communication policies and R&D direction.

At the Mobile World Congress Barcelona 2024 (MWC Barcelona 2024) held in Barcelona, Spain, we exhibited and operated part of NICT's research outcomes in the Beyond 5G field within the Japan Pavilion (Fig. 4). The NICT booth, which aimed to present a new form of "society transcending industry boundaries realized through 5G & Beyond," attracted over 1,000 visitors and received coverage from domestic and international press, contributing to increasing awareness of NICT within the ICT sector.

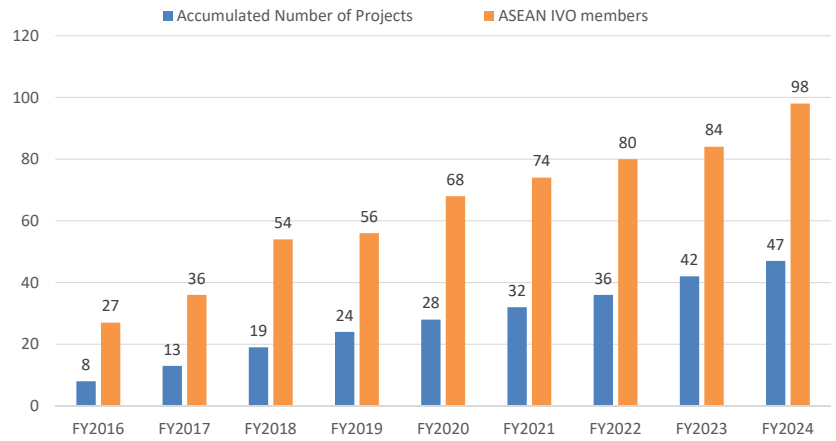


Fig.2 : Number of projects and member institutions in ASEAN IVO

Fig.3 : Beyond 5G panel discussion at IGF 2023 Kyoto (Oct. 2023, Kyoto, Japan)

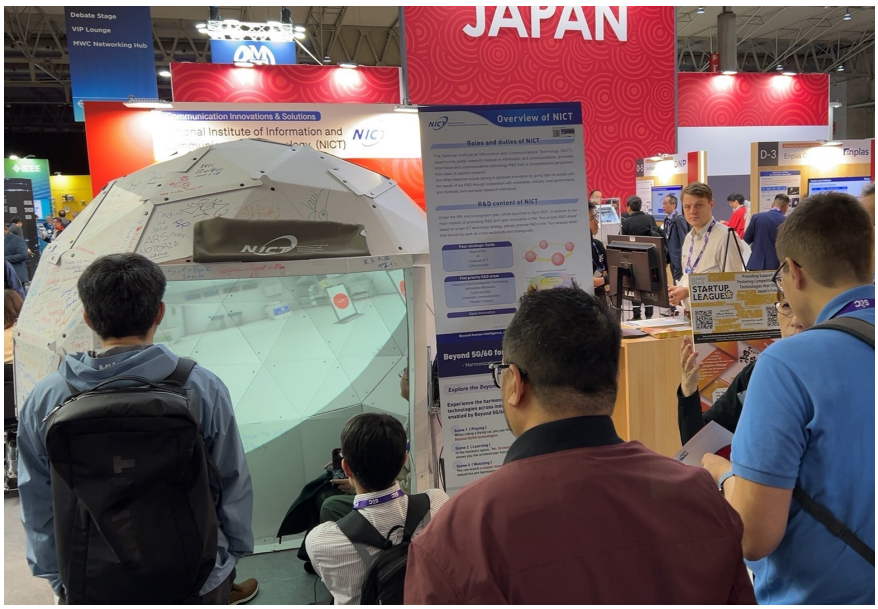


Fig.4 : NICT exhibition booth at MWC Barcelona 2024 (Feb. 2024, Barcelona, Spain)

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director HOMMA Yuichi

The ICT Deployment and Industry Promotion Department is comprehensively responsible for promoting the information and communications industry, with the aim of revitalizing industries, realizing an inclusive society where everyone can lead safe, secure, and fulfilling lives, and promoting the penetration of information and communication services into daily life through the utilization of information and communication technologies, which form the foundation of social and economic activities. In particular, through initiatives such as the Entrepreneurs' Koshien and Entrepreneurs' Expo, as well as collaborations with cooperation competitions and startup support organizations, we aim to discover and incluvate the next generation of ICT talent and support the commercialization of ICT startups originating in regional areas. Aiming to achieve an information barrier-free environment, we are promoting projects to facilitate the use of telecommunications and broadcasting for people with physical disabilities, contributing to improving their convenience. We also promote foundational technology research in the private sector, support NICT-originated ventures that contribute to disseminating NICT's research results, and support international exchange through the invitation of overseas researchers and support for international research meetings in the field of information and communication.

Support for Creation and Development of Regional ICT Startups

The Entrepreneurs' Koshien was held on March 13, and the Entrepreneurs' Expo on March 14, 2024, at Marunouchi Building Hall & Conference Square in Chiyoda, Tokyo. From FY2023, in addition to the Minister for Internal Affairs and Communications Award, a new NICT President's Award was established, replacing the previous Jury's Special Award.

Of the 10 companies at the Entrepreneurs' Koshien, FairMed/Kobe University (represented by FUKUDA Sumire) presented a development project for an AI-based vascular surgery navigation system, and received the Minister for Internal Affairs and Communications Award. Sabotics/Kyushu Institute of Technology Graduate School (represented by ISOMOTO Kosei) presented Sabo, a work support robot for nursing facilities, and received the NICT President's Award (Fig. 1).

Of the 10 companies at the Entrepreneurs' Expo, Think Nature Co., Ltd. (Representative Director/CEO KUBOTA Yasuhiro), which presented a nature-positive business using biodiversity big data and AI, received the Minister for Internal Affairs and Communications Award. AiRato Inc. (CEO KADOYA Noriyuki), which presented an AI-based radiation therapy planning support service, received the NICT President's Award (Fig. 2).

Fig.1 : Entrepreneurs' Koshien award winners (left: Minister for Internal Affairs and Communications Award, right: NICT President's Award)

Fig.2 : Entrepreneurs' Expo award winners (left: Minister for Internal Affairs and Communications Award, right: NICT President's Award)

Promotion of a Barrier-free ICT Environment

In order to realize an information barrier-free environment where everyone can equally access communication and broadcasting services, we provide subsidies from the Ministry of Internal Affairs and Communications for the production of programs with subtitles, commentaries, and sign language, to assist visually and hearing-impaired individuals in viewing television broadcasts, and for projects that provide and develop services to enable individuals with physical disabilities to smoothly use communication and broadcasting services. We also provide information related to barrier-free information initiatives.

Through the operation of an NICT website on barrier-free information services, we provided useful information for individuals with physical disabilities and the elderly, related business operators, etc., as well as an overview of NICT's subsidy programs and the results of subsidized projects. Additionally, we operated Act-navi, an information accessibility support database (Fig. 3) constructed by the Ministry of Internal Affairs and Communications, providing information on needs, seeds, and experts related to the use of information and communication by individuals with disabilities.

Promotion of International Human Resource Exchange

We support international joint research and international human resource exchange in industry and academia to contribute to advancing Japan's information and communication technology and promoting R&D. Our specific initiatives include supporting travel and accommodation expenses for domestic research institutions and universities to invite outstanding overseas researchers to domestic research institutions and supporting partial expenses for international research meetings in Japan, thereby promoting exchanges between domestic and international researchers (Fig. 4).

In addition, we support the establishment of NICT-originated ventures that will implement NICT's research results in society and their development into businesses.

Fig.3 : Act-navi by NICT (Japanese only)

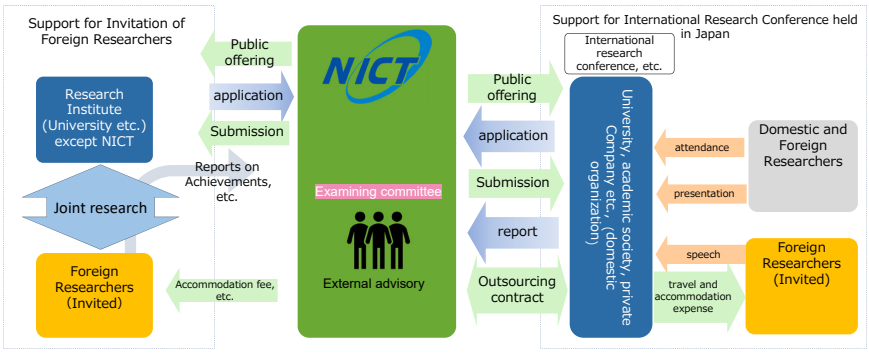


Fig.4 : Overview of International Human Resource Exchange

Research Highlights

Researchers

Research Highlights

Researchers

Frontier Science Area

Successful Development of the World's First Superconducting Wide-Strip Photon Detector

High-performance photon detection with superconducting strips over 200 times wider than conventional nanostrips

NICT invented a novel structure in a superconducting strip photon detector that enables highly efficient photon detection even with a wide strip, and succeeded in developing the world's first "Superconducting Wide-Strip Photon Detector (SWSPD)".

The strip width of the detector is over 200 times wider than that of conventional Superconducting NanoStrip Photon Detectors (SNSPDs). With this technology, we can solve problems such as low productivity and polarization dependence that exist in conventional SNSPDs. Our new SWSPD is expected to be applied to various advanced technologies such as quantum information communication and quantum computers, enabling their early social implementation.

This result was published in the U.S. scientific journal "Optica Quantum" on Thursday, October 26, 2023.

Photon detection technology is a strategic core technology capable of driving innovation in a wide range of advanced technology fields, such as quantum information communication and quantum computing, which are currently undergoing intense research and development globally, as well as live-cell fluorescent observation, deep space optical communication, laser sensing, and more. NICT has been developing an SNSPD with a strip width of 100 nm or less. As a result, we have successfully achieved high performance surpassing other photon detectors and have demonstrated its usefulness by applying it to quantum information communication technology. However, the fabrication of SNSPDs requires the formation of nanostrip structures using advanced nanofabrication technology, which introduces variations in detector performance and hinders productivity improvement. In addition, the presence of polarization dependence via the superconducting nanostrip meandering structure has also limited the range of applications as a photon detector.

In this work, NICT invented a novel structure called the "High Critical Current Bank (HCCB) structure" that enables highly efficient photon detection even when the strip width is widened in the superconducting strip photon detector, and succeeded in developing a SWSPD with a width of 20 micrometers (see Fig. 1), which is over 200 times wider than the conventional nanostrip photon detector, achieving high-performance operation for the first time in the world.

This SWSPD does not require nanofabrication technology and can be fabricated using highly productive general-purpose photolithography technology. Also, because the strip width is wider than the incident light spot irradiated from the optical fiber, it is possible to eliminate the polarization dependence seen in the nanostrip type detector. Based on performance evaluations of this detector, detection efficiency in the telecommunication wavelength band (λ=1,550 nm) was 78 %, which is comparable to that of the nanostrip type. Furthermore, the timing jitter was measured at 28 ps, which is better than that of the nanostrip type.

This achievement enables the fabrication of photon detectors with a higher level of productivity and performance compared to the nanostrip type, which has been positioned as an indispensable photon detection technology in advanced technology fields such as quantum information communication. Such technology is expected to be applied to various quantum information communication technologies and serve as an important basic technology for realizing networked

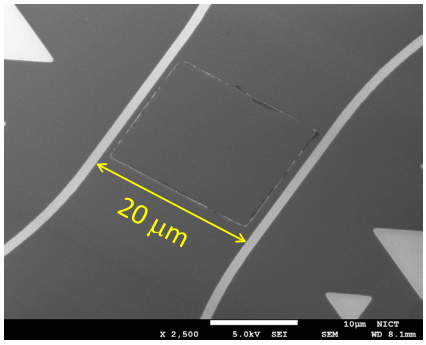


Fig.1 : Developed Superconducting Wide-Strip Photon Detector (SWSPD)

quantum computers promoted in JST's Moonshot Goal 6.

In the future, we will further explore the HCCB structure within the SWSPD to detect photons with high efficiency, not only in the telecommunication wavelength band, but also in a wide wavelength band from the visible to the mid-infrared. We will also try to further expand the size of the photon receiving area to broaden applications such as deep space optical communication technology, laser sensing, live cell observation, and more.

Note

Part of this work was supported by Japan Science and Technology Agency (JPMJMS2066), and Japan Society for the Promotion of Science (22H01965).

Reference

[1] Masahiro Yabuno, Fumihiro China, Hirotaka Terai and Shigehito Miki, "Superconducting wide strip photon detector with high critical current bank structure," Optica Quantum, Vol.1, Issue 1, pp.26-34, 2023, URL:https://doi.org/10.1364/OPTICAQ.497675, DOI: 10.1364/OPTICAQ.497675

Innovative Network Area

World Record: 402 -Tb/s Transmission in a Standard Commercially Available Optical Fiber

Achieved with novel technologies to open new wavelength regions for future optical communication infrastructure

An international joint research team led by the Photonic Network Laboratory of NICT, demonstrated a record-breaking aggregate optical transmission bandwidth of 37.6 THz to enable a new data-rate record of 402 terabits per second in a standard commercially available optical fiber.

This record was achieved by constructing the first optical transmission system covering all the transmission bands (OESCLU) of the low-loss window of standard optical fibers. The system combined various amplification technologies, some developed for this demonstration, including six kinds of doped fiber optical amplifiers, and both discrete and distributed Raman amplification. Novel optical gain equalizers also allowed access to new wavelength bands that are not yet utilized in deployed systems. The newly developed technology is expected to make a significant contribution in expanding the communication capacity of the optical communication infrastructure as future data services rapidly increase demand.

The results of this experiment were accepted as a post-deadline paper at the 47th International Conference on Optical Fiber Communications (OFC 2024) and presented by Ben Puttnam on Thursday, March 28, 2024, at the San Diego Convention Center, California, USA.

The growth of internet and data-services has driven demand for optical transmission bandwidth. To meet this demand, multi-band wavelength division multiplexing (WDM) technology, where new spectral windows are used to increase optical fiber transmission bandwidth, has become a popular research topic. Utilizing new transmission windows in deployed fibers also offers a potentially significant benefit in the near-term as a method of extending the life of existing fiber systems to provide additional transmission capacity

without the large capital expenditure associated with new fiber deployment. However, moving away from the lowest loss regions of standard silica fibers requires new amplification schemes beyond the standard erbium (E-) doped fiber amplifier (DFA) that is a staple of C-band or C+L-band systems. Previously, S/C/L-band transmission has been explored with various amplifier solutions. In addition to thulium (T-) DFAs and semiconductor optical amplifiers (SOAs), distributed and discrete Raman amplification have been used, with maximum estimated data-rates of 256 Tb/s utilizing almost 20 THz bandwidth. Even wider transmission demonstrations have used bismuth (B-DFAs) for O-band and lumped Raman amplifiers for U-band channels for 119 Tb/s with a cumulative bandwidth of 25 THz. E-band BDFAs were also used with distributed Raman amplification for E/S/C/L-band transmission over 27.8 THz with <320 Tb/s GMI estimated data-rate, as shown in Table 1.

In this demonstration, we utilized six DFA variants for gain in O/E/S/C/L-bands with discrete (U-band) and distributed Raman amplification along with novel optical gain equalizers for profile shaping in O/E bands, and expanded dense wavelength division multiplexed (DWDM) transmission with 37.6 THz (275 nm) optical bandwidth. As highlighted in Table 1, the generalized mutual information (GMI) estimated data-rate after 50 km transmission was 402 Tb/s, which exceeds the previous highest single-mode fiber (SMF) data-rate by over 25 % and the aggregate transmission bandwidth of 37.6 THz is also a 35 % increase.

NICT will continue to promote research and development into new amplifier technologies, components and fibers to support new transmission windows for both near and long-term applications. NICT will also aim to extend the transmission range of such wideband, ultra-high-capacity systems and their compatibility for field deployed fibers.

Table 1 : Comparing previous wideband transmission demonstrations

	Transmission capacity [GMI] (Tbit/s)	Number of wavelengths							Total bandwidth (THz)	Modulation format
		O-band	E-band	S-band	C-band	L-band	U-band	Total		
March 2022	226	---	---	317	215	261	---	793	19.6	S,C,L-band: 256QAM
October 2023	321	---	315	315	200	267	---	1097	27.8	E-band: 64QAM S,C,L-band: 256QAM
This result	25% up **402.2**	302	314	318	195	253	123	1,505	35 % up **37.6**	O-band: 16QAM E,U-band: 64QAM S,C,L-band: 256QAM

Reference

Benjamin. J. Puttnam, Ruben. S. Luis, Ian Phillips, Mingming Tan, Aleksandr Donodin, Dini Pratiwi, Lauren Dallachiesa, Yetian Huang, Mikael Mazur, Nicolas K. Fontaine, Haoshuo Chen, Dicky Chung, Victor Ho, Danele Orsuti, B. Boriboon, G. Rademacher, L. Palmieri, Ray Man, Roland Ryf, David T. Neilson, Wladek Forysiak, and Hideaki Furukawa,"402 Tb/s GMI data-rate OESCLU-band Transmission," Optical Fiber Communications Conference (OFC) 2024, Post Deadline Session

Frontier Science Area

Successful Secret Key Sharing and Highly Confidential Communication between International Space Station and Ground

Anticipated to enable practical use of quantum cryptography in satellite communication

NICT, the Graduate School of the University of Tokyo, Sony Computer Science Laboratory, Next Generation Space System Technology Research Association (NESTRA), and Skyperfect JSAT have successfully demonstrated secure communication (as based on information theory) between the International Space Station (ISS) in low Earth orbit (LEO) and a transportable optical ground station on Earth, sharing over 1 million bits of a secret key in a single path overhead.

In this experiment (Fig. 1), the R&D team developed the SeCuRe lasEr communicaTionS terminal for LEO (SeCRETS), and it was installed on the Kibo Exposed Facility of the ISS. SeCRETS emitted a signal light modulated with random data (key data) at a 10 GHz clock rate towards the Earth, which was successfully received by the 35 cm diameter reflector telescope on the transportable optical ground station installed at NICT headquarters (Koganei, Tokyo). The optical ground station, together with a 1.5-m-diameter ground-fixed station telescope located 25 m away, measured the intensity of the signal and beacon lights to estimate the beam spread on the ground. To minimize the risk of information being leaked to potential eavesdroppers to an infinitesimally small level, the received random data was processed for key distillation between the ISS and the ground station, successfully generating over 1 million bits of a secret key in a single path overhead.

Photo data from orbit was encrypted using a one-time pad with the distilled cryptographic key, transmitted via radio communication from the ISS, and then successfully decoded on the ground to retrieve the photo data.

The success of this demonstration indicates technical prospects for sharing fast and highly confidential cryptographic keys via optical communication from low Earth orbit satellites with any ground station.

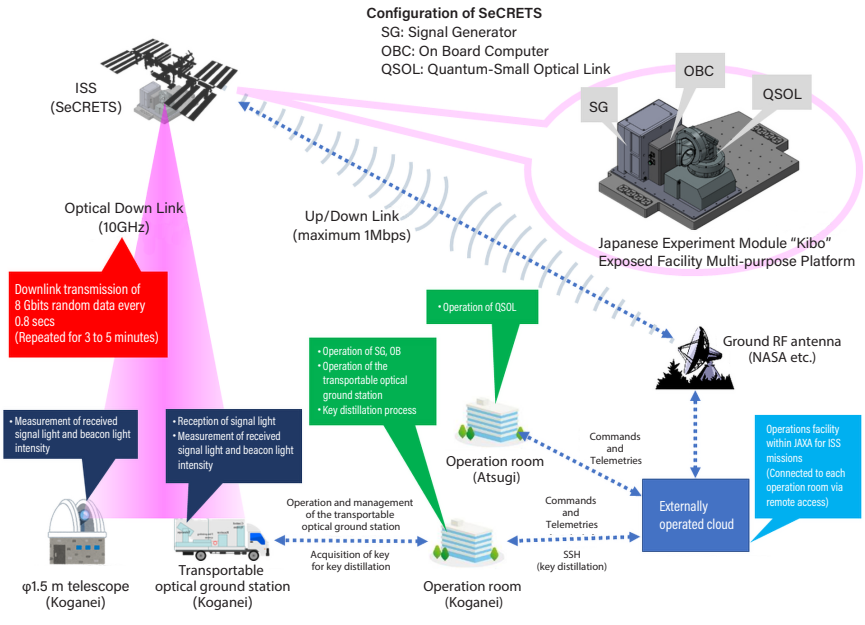


Fig.1 : Overview of the Experiment

Putting this technology to practical use will, in principle, make it possible to share cryptographic keys securely anywhere on Earth and prevent leaks in communications, thereby enabling highly confidential communication of critical information for national security and diplomacy. We aim to develop this technology further and achieve the societal implementation of satellite quantum cryptography systems for users that handle confidential information.

Open Innovation

5G System and Beyond 5G System with Full-Duplex Technology Evaluated using a Digital Twin Wireless Emulator in a Virtual Environment

A research group led by Professor HARADA Hiroshi and Associate Professor MIZUTANI Keiichi at Kyoto University's Graduate School of Informatics ("Kyoto University"), in collaboration with NICT's ICT Testbed Research and Development Promotion Center, has developed a digital twin wireless emulator to evaluate Beyond 5G systems incorporating full-duplex (FD) technology in a virtual environment. They successfully evaluated and visualized the effects of FD introduced to 5G by emulating scenarios involving terminal movement by inputting urban 3D spatial data, the placement of base stations and terminals, and terminal movement patterns. This achievement allows for system validation that simulates real-world environments using the emulator, eliminating the need to install wireless devices in physical spaces for testing. It is expected to facilitate the evaluation of throughput improvement characteristics resulting from system implementation.

- Developed an orchestrator on the wireless emulator that enables emulation in various scenarios using virtual nodes equipped with base station and terminal functions compatible with 5G New Radio (NR) and that is deployable on actual devices
- Linked the wireless emulator's function for generating radio propagation characteristics based on the positions of virtual nodes to develop a virtual wireless link emulator function that generates and adds fading and interference at the physical layer level between virtual nodes
- Developed orchestrator scenarios for emulating standard 5G and FD operation and created a viewer function to evaluate and visualize data transmission paths and transmission performances

In the era of Beyond 5G, significantly more devices will communicate utilizing a wide range of frequencies from the microwave band to the millimeter-wave band. From the perspective of installation costs, there are clear limitations when conducting evaluations using only real wireless devices in actual field environments. As frequencies suitable for mobile communication become increasingly congested, research and development efforts are advancing to find ways to utilize these limited resources effectively. In current 5G cellular systems, technologies such as multiple-input multiple-output (MIMO), which employs multiple antennas, have been researched, developed, and implemented to improve frequency utilization efficiency. However, fundamental measures such as revisiting duplexing

methods are essential to further enhance this efficiency.

Against this backdrop, the dynamic full-duplex cellular system ("proposed FD"), a new communication system toward Beyond 5G, known as the dynamic full-duplex cellular (DDC) system, that incorporates FD technology, has attracted significant attention. Theoretical and simulation analyses have demonstrated the system's effectiveness in increasing throughput, and verification experiments have been conducted to advance the development and practical implementation of actual wireless devices. However, comparing existing systems with proposed FD under identical conditions in real field environments such as base station installations and mobile terminal placements has been challenging. To address these challenges, Kyoto University and NICT have researched and developed a wireless emulator capable of simulating and evaluating large-scale radio frequency utilization systems in a virtual environment as part of a project commissioned by the Ministry of Internal Affairs and Communications. This wireless emulator incorporates various radio wave utilization systems as software functions called "virtual nodes" By inputting urban spatial data and radio device placement data, it operates radio propagation and transmission characteristics in a digital twin within the virtual environment, enabling communication testing without emitting actual radio waves.

To achieve wireless emulation in the form of a digital twin for 5G NR systems and Beyond 5G systems incorporating proposed FD, research and development focused on the following three areas:

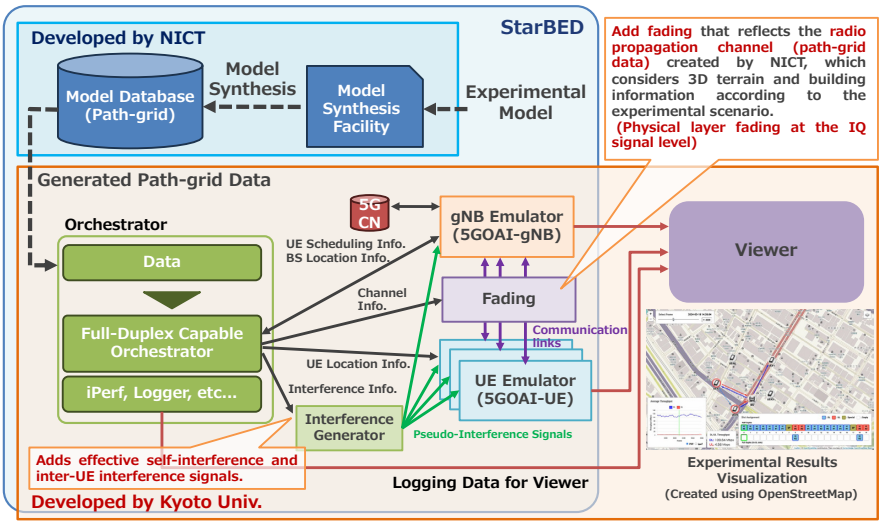


Fig.1 : Overview of the Developed Wireless Emulator

(1) An orchestrator capable of emulating scenarios involving virtual nodes with base station and terminal functions compatible with standard 5G NR, as well as and proposed FD operation (Fig.1)
(2) A virtual wireless link emulator function that reflects radio propagation characteristics based on the placement of virtual nodes within the wireless emulator and generates and adds fading and interference at the physical layer between virtual nodes (Fig.1)
(3) A viewer function for visualizing the results of emulations involving standard 5G NR and proposed FD operation

Using these developments, a virtual environment modeled after Yokohama's Minato-mirai area in Kanagawa was created, in which one base station and five terminals were deployed using virtual nodes Both the current 5G system and a Beyond 5G system based on proposed FD were operated within this setup. Of the five terminals, one was set to move along a major road, during which terminal scheduling, including FD application status, dynamically changed in accordance with its position. This evaluation successfully demonstrated improved throughput due to proposed FD.

This validation confirmed that simulation experiments of the Beyond 5G system incorporating proposed FD could be conducted on the wireless emulator by reflecting urban spatial data without using real wireless devices. Future efforts will focus on performance evaluations in locations beyond those tested in this experiment and on extending its applications to high-frequency bands, such as millimeter waves, which are allocated as 5G NR spectrums.

Reference

[1] Kazuki Takeda, Keiichi Mizutani, Hiroshi Harada, "Open-Source Software-Based Beyond 5G Emulator for Evaluating Dynamic Full-Duplex Cellular System," in Proc. 2024 IEEE 100th Vehicular Technology Conference (VTC2024-Fall), pp. 1–5, Oct. 2024.

Cybersecurity Area

Development of a Custom Notification Feature for the CURE Security Information Integration Platform

Contributing to improving organizational security through "Watcher" notifications

NICT Cybersecurity Institute has developed a custom notification feature called Watcher for its CURE security information integration platform. Configuring Watcher notifications to cover IP addresses, domain names, and other information related to an organization makes it possible to receive alerts, based on the vast amount of data on CURE, about attacks on that organization, thereby enhancing organizational security.

The Watcher custom notification feature has been developed as a new feature of CURE (Fig.1). Configuring Watcher notifications to cover the above types of information will allow an organization to receive instant alerts as soon as anything relevant appears within CURE.

Information that can be covered by Watcher notifications includes IP addresses (IP Addr), domain names (Domain), hash values (Hash), email addresses (Email), and keywords (Tag).

For example, if the range of IP addresses used by an organization is input into Watcher, a notification will be used if any of them appear on the list of malicious IP addresses collected by CURE. This might indicate that an organization's IP address has been flagged as malicious due to its involvement in a cyberattack, requiring an immediate internal investigation.

Furthermore, once an organization's domain name is input into Watcher, if AmpPot, one of CURE's information sources, detects a DRDoS attack directed at that domain, that organization (which is being attacked) will be notified. It is difficult for individual organizations that have been subjected to attacks involving large amounts of traffic, like DRDoS attacks, to isolate the cause of the attacks, making external notifications valuable for early detection and decision-making regarding countermeasures.

In addition, hash values can be used to check whether malware sent to an organization has been captured in CURE's honeypot information sources or referenced in security vendor reports. Email addresses can be configured to help detect if any addresses used by an organization have been included in leaked information from external services. Finally, tags can be used to detect declarations of DDoS attacks on an organization by attack groups on social media or to verify whether an organization's products or services have been mentioned in security reports.

Watcher enhances organizational security by providing alerts, based on

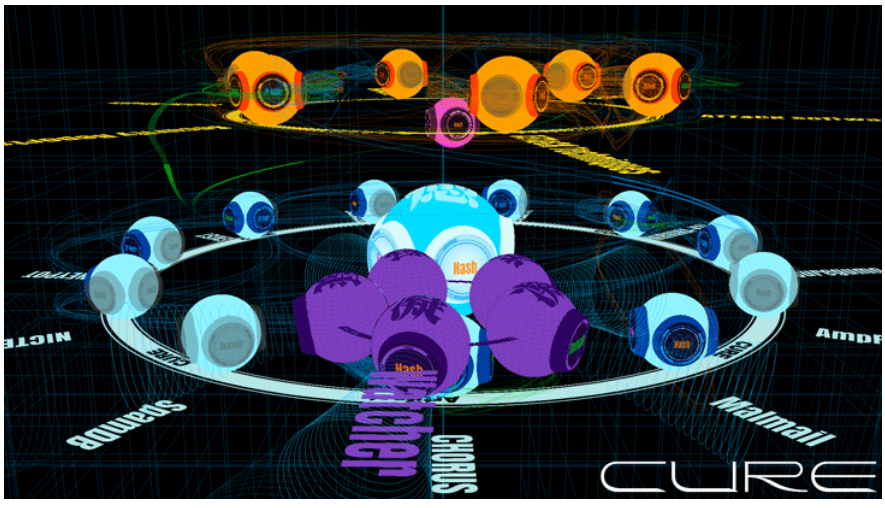


Fig.1 : CURE overview

the vast amount of data on CURE, about attacks related to an organization.

A dynamic exhibit of CURE Watcher was presented at Interop Tokyo 2024, held at Makuhari Messe from June 12 (Wed.) to June 14 (Fri.), 2024.

CURE is openly available to organizations participating in CYNEX Alliance, a cybersecurity industry-academia-government collaboration hub. The new Watcher feature is planned to be rolled out gradually.

Universal Communication Area

Developed a 21-language, Fast and High-Fidelity Neural Text-to-Speech Technology That Works on Smartphones

The Universal Communication Research Institute of the NICT has successfully developed a 21-language, fast and high-fidelity neural text-to-speech technology. The development of this technology has made it possible to synthesize one second of speech at a high speed of just 0.1 seconds using a single CPU core, which is about eight times faster than the conventional methods. This technology also enables fast synthesis with a latency of 0.5 seconds on a mid-range smartphone without network connection (see Fig.1).

Furthermore, the developed 21-language neural text-to-speech models are installed on the server of VoiceTra, a multilingual speech translation application for smartphones operated by NICT, and have been made available to the public. In the future, the technology is expected to be introduced into various speech applications, such as multilingual speech translation and car navigation through commercial licensing.

The Universal Communication Research Institute, NICT, is conducting R&D of multilingual speech translation technology to realize spoken language communication that transcends language barriers. The outcomes of R&D have been released to the public as a field experiment on VoiceTra, a speech translation application for smartphones, and many other implementations have been made in society through commercial licensing. Text-to-speech technology, which can synthesize the translated text as human speech, is very important for the realization of multilingual speech translation technology, as well as automatic speech recognition and machine translation. The synthesized sound quality of text-to-speech has improved dramatically in recent years thanks to the introduction of neural network technology, and it has reached a level comparable to that of natural speech. However, the huge

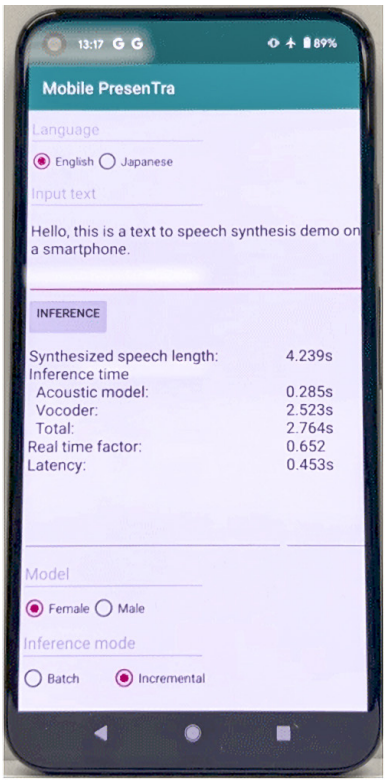


Fig.1 : Text-to-speech model implemented on a mid-range smartphone
(Movie: https://youtu.be/VckvQvhlcSs)

amount of calculation required was a major issue, making it impossible to synthesize on a smartphone without network connection.

Furthermore, NICT is currently conducting R&D on multilingual simultaneous interpretation technology. In simultaneous interpretation, it is necessary to output the translated speech one after another without waiting for the speaker to finish. Therefore, it is essential to further accelerate text-to-speech for automatic speech recognition and machine translation.

Reference

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[2] H. Yamashita, T. Okamoto, R. Takashima, Y. Ohtani, T. Takiguchi, T. Toda and H. Kawai, "Fast neural speech waveform generative models with fully-connected layer-based upsampling," IEEE Access, vol. 12, pp.31409-31421, 2024.
[3] T. Okamoto, Y. Ohtani and H. Kawai, "Mobile PresenTra: NICT fast neural text-to-speech system on smartphones with incremental inference of MS-FC-HiFi-GAN for low-latency synthesis," Proc. INTERSPEECH, Sept. 2024, pp.1870–1874. (Show & Tell)

Advanced Electromagnetic Technology Area

First images from Cloud Profiling Radar (CPR) onboard Earth Cloud Aerosol and Radiation Explorer (EarthCARE) "Hakuryu": World's First Measurement of Vertical Cloud Motion from Space

The Japan Aerospace Exploration Agency (JAXA) and NICT have released the first images from the Cloud Profiling Radar (CPR) on board Earth Cloud Aerosol and Radiation Explorer (EarthCARE) (Japanese nickname: Hakuryu), which was jointly developed with the European Space Agency (ESA) and launched at 7:20 a.m. (JST) on May 29, 2024. The CPR is the world's first spaceborne Doppler radar in the W-band (94 GHz) and was jointly developed by JAXA and NICT. The commissioning phase of the CPR is currently underway, and the first observations were conducted on June 12 and 13. The CPR observed the cloud area in a stationary front, called the Baiu front, over the ocean at east of Japan, measured the internal structure of the cloud, and succeeded in the world's first measurement of vertical cloud motion from space. The images below are a visualization of the measured data obtained by radar observation as a cloud cross-section.

At around 13:36 on June 13, 2024 (JST),

the CPR observed a cloud area in the Baiu front over the ocean at east of Japan. The CPR measured the cloud distribution reaching an altitude of approx. 13 km, and found the characteristic that the Doppler velocity increases downward at altitudes below approx. 5 km (Fig.1). This can be considered to indicate the high falling speed of the raindrops. Conventionally, these data can be obtained only by ground radar or airborne radar with limited observation areas, but the CPR onboard the EarthCARE satellite enables uniform observation of the entire Earth.

It is expected that the CPR's observations of various cloud regions, including the Baiu front, will contribute to elucidating the mechanism by which cloud droplets grow into precipitation. In addition, the effect of clouds on the climate system is greatly influenced by factors such as cloud height, overlapping patterns, and cloud type. Therefore, using the CPR to measure vertical distributions of clouds, including their vertical motions on a global scale, will contribute to elucidating the effects of clouds on the climate system.

JAXA and NICT will continue to conduct the commissioning phase of the CPR (for about six months) and then move to the mission operation phase. Data will be made available on the JAXA G-Portal and ESA website. ESA is currently conducting the initial functional verification of the ESA's three sensors on the EarthCARE satellite. Images combining data from the CPR and ESA sensors were released on October 4, 2024 (JST). Data provision is scheduled to begin from January 14, 2025.

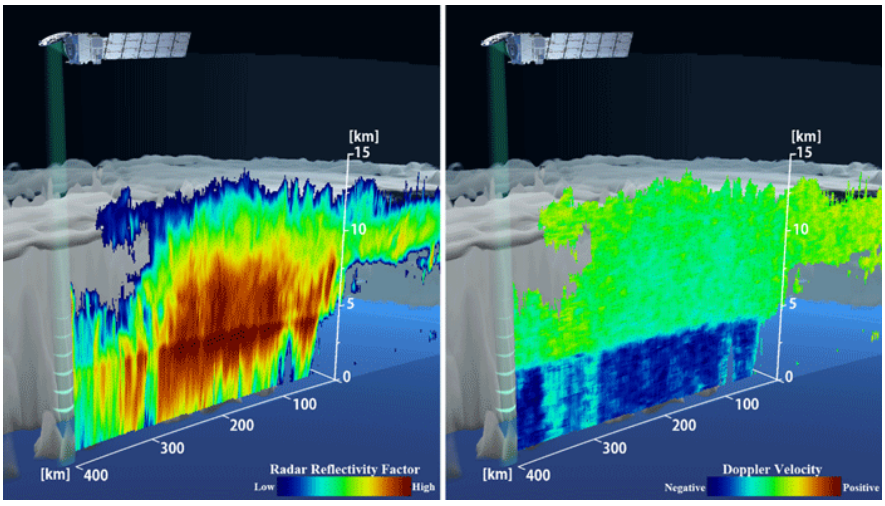

Fig.1 : Three-dimensional diagram showing the vertical profile of the radar reflectivity factor (left) and Doppler velocity (right) by the CPR. (Horizontal distribution of clouds calculated using data from geostationary meteorological satellite Himawari-9. Himawari-9 data provided by the Japan Meteorological Agency). ©: JAXA/NICT/ESA)

Advanced Electromagnetic Technology Area

NICT Clarifies Electromagnetic Field Level from 5G Mobile Phone Base Stations

First public research institution in the world to measure Electromagnetic Field exposure levels around 5G base stations

Since 2019, NICT has been conducting Japan's first large-scale, long-term measurements of radio wave exposure levels in living environments.

The measurements were of Electromagnetic Field (EMF) exposure levels from commercially operated fifth-generation (5G) mobile phone base stations, taken at multiple locations. While mobile phone operators have already been taking measurements, this is the first time in the world that a public research institution has measured Electromagnetic Field Level around 5G base stations in commercial service from a neutral stance. Measurements of the two frequency bands used in 5G—6 GHz and below (FR1) and the 28 GHz band (FR2)—showed that the levels are comparable to or lower than those of other mobile phone systems (4G).

NICT conducted spot measurements of EMF exposure levels from 5G mobile phone base stations in Tokyo and its suburbs. While mobile phone operators have already been taking measurements, this marks the first time a public research institution has measured Electromagnetic Field Level around 5G base stations in commercial service for FR1 and FR2 from a neutral stance. Measurements for FR1 were conducted at 51 locations (51 points) in Tokyo and its suburbs, while FR2 measurements were conducted at 3 locations (15 points) in central Tokyo.

For FR1 measurements, an electric field probe was used, adhering to the measurement procedures defined in Japan's Radio Act. For FR2 measurements, a 28 GHz antenna was used instead. Measurements were also conducted while downloading data to mobile phone terminals (smartphones) near the measurement locations. For FR1, 6 GB of data, and for FR2, 10 GB of data were downloaded in around 1 minute. The data obtained from the measurements were statistically processed and compared with past measurement results.

Comparing the presence or absence of data downloads revealed that the levels were about 70 times larger for FR1 and about 1,000 times larger for FR2 when data was downloaded (Fig.1). The levels when downloading data were comparable or lower compared to past measurement results of conventional (4G) mobile phone base stations. Levels were low in both cases compared to Japanese radio radiation protection guidelines (less than about 1/10,000 of the median).

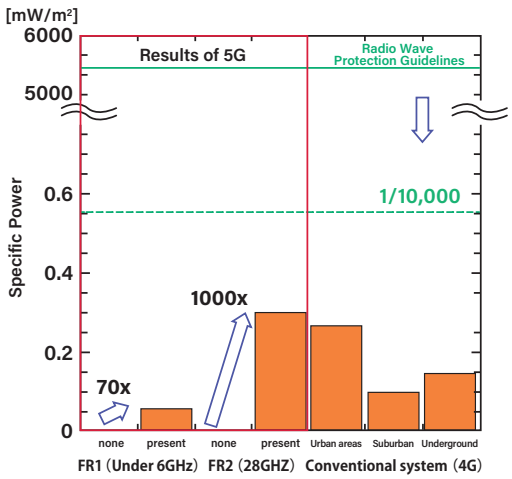

Fig.1 : Measurement Results of EMF Exposure Levels (Median)
(none; smartphone power off, present; downloading data to smartphone)

Reference

[1] Sen Liu, Kazuhiro Tobita, Teruo Onishi, Masao Taki, and Soichi Watanabe, "Electromagnetic field exposure monitoring of commercial 28 GHz Band 5G base stations in Tokyo, Japan", Bioelectromagnetics, URL: https://doi.org/10.1002/bem.22505 DOI: 10.1002/bem.22505

[2] Kazuhiro Tobita, Teruo Onishi, Sen Liu, Masao Taki, and Soichi Watanabe, "Electric Field Measurements Around 5G FR1 Mobile Phone Base Stations," EMC Japan/APEMC Okinawa 2024

Innovative Network Area

World's First Successful Outdoor Multiple Simultaneous Connections Experiment using a Quantum Annealing Machine

Development and demonstration of a hybrid algorithm of quantum and digital processing

NICT has developed a new computation method (called "the algorithm") that combines a quantum annealing machine and a classical digital computer and demonstrated a successful experiment of signal separation processing using Uplink non-orthogonal multiple access (NOMA) technology, one of the promising technologies in next-generation mobile communication systems.

In current fifth-generation (5G) mobile communication systems, communication is conducted using one base station antenna per terminal station at the same frequency and time. However, the next generation of mobile communication systems is expected to have 10x more simultaneous connections than 5G. Using this algorithm, NICT confirmed in a simulation that at least seven terminal stations can be connected simultaneously to each base station antenna, and demonstrated simultaneous connection with four terminal stations through an outdoor experiment. This was the world's first online demonstration of multiple simultaneous connections technology (non-orthogonal multiple access technology) in the field using an algorithm that employs a quantum annealing machine.

NOMA technology requires solving large-scale combinatorial optimization problems involving tens of thousands of combinations. However, NICT has demonstrated that applying this algorithm can reduce the computation time required for signal separation processing to about one-tenth of the time of conventional methods. If this algorithm is put into practical use, it is expected that the next generation of mobile communication systems will be able to perform combinatorial optimization problems (such as large-scale beamforming) that were previously hindered by the massive amount of computations required in a short time.

The number of simultaneous connections in the next generation of mobile communication systems is expected to increase by more than 10 x compared to 5G. The non-orthogonal multiple connection technology is attracting attention for its potential to achieve this. In 5G, each base station antenna supports one terminal station at the same frequency and time. This new technology makes it possible to support multiple terminals. However, since the base stations receive superimposed signals transmitted from multiple terminal stations, signal separation processing is required at each terminal station. As the number of terminal stations increases, the combinations of received signals increase exponentially, demanding more time for signal separation processing.

Quantum annealing machines have attracted attention for their ability to solve combinatorial optimization problems at a high speed, but they are poor at performing general-purpose calculations. Signal processing for next-generation mobile communication systems, including non-orthogonal multiple access technology, requires not only large-scale combinatorial optimization problems but also general-purpose calculations. Therefore, the biggest current challenge is how to create a practical computational method that can effectively leverage the strengths of quantum annealing.

NICT has developed a practical computational method (the algorithm) by hybridizing a quantum annealing machine and a classical computer and has applied it to signal processing used in radio communications, conducting online demonstrations (Fig.1).

The algorithm uses the quantum

annealing machine, which excels at computing combinatorial optimization problems, as a sampling mechanism to produce candidates (which may not be correct). After obtaining multiple candidates within microseconds, it then applies post-processing using a classical digital computer (a technology unique to NICT) to obtain solutions that accurately follow statistical distributions, regardless of its limited number of samples. This method does not simply connect two different computers—it is designed to leverage the strengths of each computer. It can also be applied to various signal processing issues and is not limited to combinatorial optimization problems.

In the experiment, NICT applied the algorithm to signal separation processing for Uplink NOMA technology, which is attracting attention for extending multi-connectivity in next-generation mobile communication systems by 10x compared to 5G. The challenge in signal separation for non-orthogonal multiple access technology is that the number of combinations (Mk) is determined by the modulation multi-valued number (M) and the number of simultaneously communicating terminals (K), leading to an exponential increase in computation. An additional challenge is that as the number of terminal stations simultaneously connecting to a base station's antennas increases, it makes it so that simple linear equations cannot be used to solve these problems anymore.

However, NICT confirmed the algorithm's effectiveness in solving these problems through computer simulations and outdoor experiments.

This achievement demonstrates the feasibility of applying a practical computation method using a quantum annealing machine to signal processing in radio communications, contributing to the realization of the multiple simultaneous connection performance required by next-generation mobile communication systems (10x greater than 5G). Going forward, NICT will continue to improve and demonstrate computational methods to achieve this 10x increase. Solving large-scale combinatorial optimization problems is also necessary for large-scale beamforming in next-generation mobile communication systems, and this algorithm is expected to be applicable to this challenge.

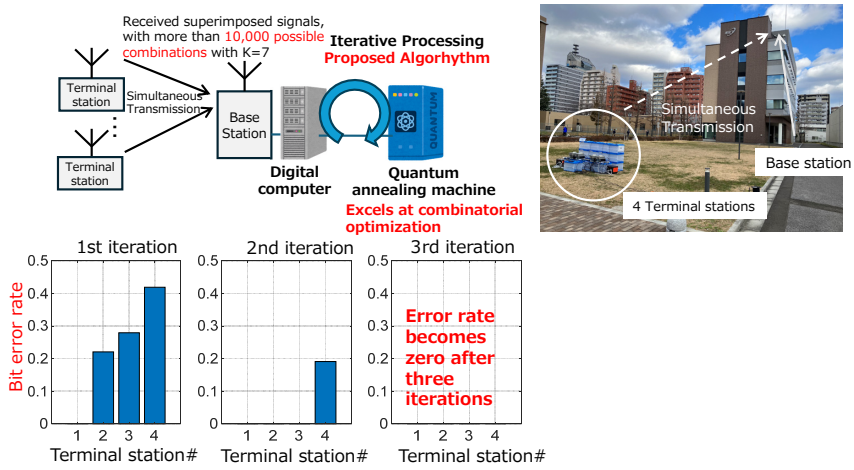

Fig.1 : Configuration of the Uplink NOMA experimental system using a quantum annealing machine (including photos), and the results of principle verification

Reference

Kouki Yonaga and Kenichi Takizawa, "Quantum Annealing-Aided Multi-User Detection: An Application to Uplink Non-Orthogonal Multiple Access," Proc. of IEEE International Conference on Communications 2023,
URL: https://ieeexplore.ieee.org/abstract/document/10279631
DOI: 10.1109/ICC45041.2023.10279631

Frontier Science Area

World's First Superconducting Flux Qubit Operating without Magnetic Fields

A significant step towards miniaturizing quantum circuits for quantum computers

NICT, NTT Corporation (NTT), Tohoku University, and Nagoya University succeeded in developing a new type of superconducting flux qubit that operates without magnetic fields.

Conventional superconducting flux qubits require an external magnetic field generated by bulky coils or an additional local flux bias line near the qubit. The newly developed superconducting flux qubit using a ferromagnetic Josephson junction (named π-junction) demonstrates the realization of a flux qubit operating without magnetic fields. The qubit lifetime lasts for microseconds, which is the longest among superconducting qubits with ferromagnetic π-junction. By further improving the ferromagnetic junction material in the future, this π-junction and flux qubit that can operate without magnetic fields may become essential elements of high-performance quantum devices that are indispensable for quantum computers.

This result was published in the British scientific journal "Communications Materials" on October 11, 2024[1].

Quantum computers are expected to play a crucial role in future information technology in various fields, from material and pharmaceutical development to information security. Among the promising technologies, superconducting qubits stand out for their relatively easy control of quantum states. Josephson junctions, which are essential components of superconducting qubits, provide anharmonicity to the circuit, enabling qubit operation.

Transmon qubits[2], widely used today for superconducting quantum computers, have low anharmonicity, which may cause problems such as frequency crowding when integrating many qubits.

On the other hand, flux qubits [3, 4], which use three Josephson junctions, have higher anharmonicity and can mitigate frequency crowding problems (Fig.1(a)). However, flux qubits require external coils to apply half a magnetic flux quantum ($\Phi_0 = 2.07\times10^{-15}$ Wb) to the superconducting loop for optimal operation, leading to challenges like low-frequency noise from the coils or the need for additional control lines for each qubit, hindering large-scale integration.

To address this, researchers at Tohoku University, proposed incorporating a π-junction into the flux qubit (Fig. 1(b)). This π-junction, which uses a ferromagnetic Josephson junction, generates a 180-degree (π) phase difference without external magnetic fields, allowing the qubit to reach its

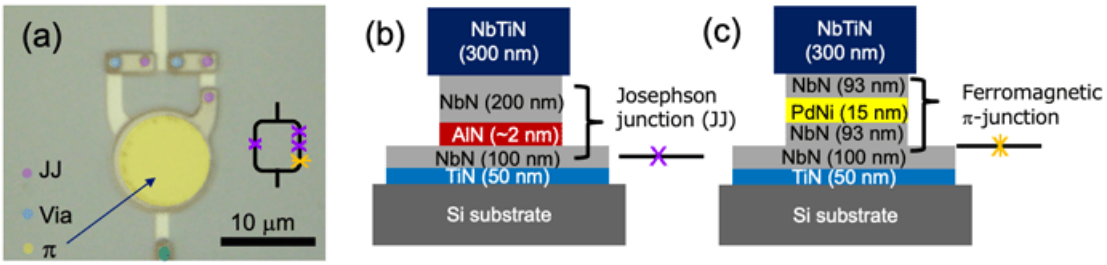

Fig.1 : (a) Optical microscope image of the developed π-junction flux qubit with false color for the clarification. The Josephson junctions (JJ), π-junctions, and via-holes are shown in purple, yellow, and blue, and the circuit diagram on the right shows three Josephson junctions (x, purple) and a π-junction (*, yellow).
(b) Structure of a Josephson junction made of the all-nitride superconductors.
(c) Structure of a π-junction formed on a niobium nitride (NbN) base electrode.

optimal operating point spontaneously. This is expected to reduce external noise, simplify the circuit, and make qubit integration easier.

In this study, we combined NICT's nitride superconducting qubit technology, based on niobium nitride (NbN) grown on silicon substrates (as reported in the NICT press release on September 20, 2021), with the technology for ferromagnetic Josephson devices (as reported in the NICT press release on November 15, 2017). This integration allowed us to develop a flux qubit with a π-junction. We successfully demonstrated that this flux qubit with a π-junction can operate optimally without magnetic fields and elucidated its coherence properties.

Looking ahead, we aim to optimize the circuit structure and fabrication process to further extend the coherence time and improve the uniformity of device characteristics, with an eye toward future large-scale integration. Our goal is to develop a new platform for quantum hardware that could surpass the performance of conventional aluminum-based qubits. By improving the materials and structure of the ferromagnetic junction, we hope to develop a π-junction flux qubit with a longer coherence time that can operate without magnetic fields. Such advancements could make it a critical component in various quantum technologies, including quantum computer chips.

Reference

[1] Sunmi Kim, Leonid V. Abdurakhimov, Duong Pham, Wei Qiu, Hirotaka Terai, Sahel Ashhab, Shiro Saito, Taro Yamashita, and Kouichi Semba, "Superconducting flux qubit with ferromagnetic Josephson π-junction operating at zero magnetic field," Communications Materials, vol.5, Article Number 216, Oct. 2024, https://doi.org/10.1038/s43246-024-00659-1 DOI: 10.1038/s43246-024-00659-1

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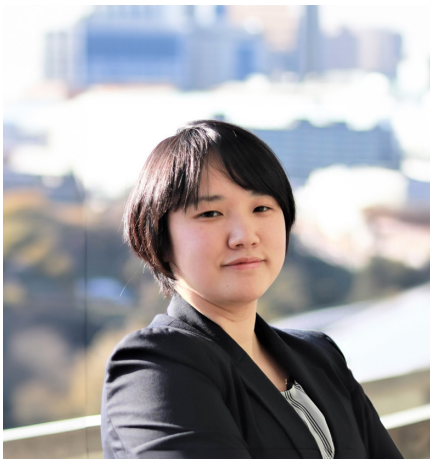
[3] S. Kim et al., "Enhanced-coherence all-nitride superconducting qubit epitaxially grown on Si substrate", Commun. Mater. 2, 98, 2021.

[4] L. V. Abdurakhimov et al., "A long-lived capacitively shunted flux qubit embedded in a 3D cavity". Appl. Phys. Lett. 115, 262601, 2019.

Researchers

Person 1



OHORI Fumiko
Senior Research Engineer,
Wireless Systems Laboratory,
Wireless Networks Research Center,
Network Research Institute

She was born in the Aizu area of Fukushima. She received her Ph.D. degree from Osaka University in 2024. She is currently a Senior Technical Researcher in NICT and is engaged in the research and development of wireless communication stabilization.

Ph.D. (Information Science and Technology).

Flexible Society Project: Supporting Social Activities with Stable Wireless Communications

The use of wireless communications to improve productivity is rapidly advancing in factories. However, mobile robotic systems such as Automated Guided Vehicles (AGVs) play critical roles in transport and storage of parts and products, and communication failures that occur in these systems can cause severe interruptions in factory workflow and reduce production efficiency [1]. The same problem exists in Germany, which is leading Industry 4.0, and it is an issue that should be treated as a global problem, not one limited to factories in Japan.

To address this issue, we are taking a needs-based approach found in real factories. Specifically, we verified that the AGV can switch seamlessly to adapt to rapid and dynamic changes in the wireless environment. In addition to stable running by switching between more than 80 wireless LAN APs installed indoors [2], stable running by switching between carrier 5G and local 5G has been verified. Both carrier 5G, which can communicate over a wide area, and local 5G, which can be set up based on the site even in areas where signal reception is difficult, enable stable communication over the entire AGV travel route. With the aim of addressing international issues, seamless communication was verified at a factory in Germany in collaboration with Japanese joint research partners and German researchers (Fig. 1).

Both experiments used Smart Resource Flow (SRF) Wireless Platform [3] for wireless stabilization as the core technology. Other activities include proposing international standardization to enable smooth introduction to overseas factory locations, and publishing white papers, case studies, and guidelines to share knowledge widely [4].

Fig.1 : Discussions and wireless communication experiments on the use of 5G at a German crane factory by a joint project between SCOPE (Grant no. JPJ000595) of Japan and EmKoI4.0 of Germany

[1] F. Ohori, S. Itaya, T. Osuga and T. Matsumura, "Evaluation of Productivity and Wireless Channel Load for 3D Storage System in Smart Factory," IEEE Access, vol. 12, pp. 156549-156560, 2024.
[2] F. Ohori, H. Yamaguchi, S. Itaya, and T. Matsumura, "A Machine-Learning-Based Access Point Selection Strategy for Automated Guided Vehicles in Smart Factories," Sensors, vol. 23, no.20, 8588, 2023.
[3] Flexible Factory Partner Alliance, "SRF Wireless Platform Technical Specifications Version 1.1.0," FFPA Specification, Oct. 2021, https://www.ffp-a.org/contact-spec-en/
[4] NICT, "Publications by FSPJ", https://www2.nict.go.jp/wireless/en/ffpj.html

Q&A

What is the most interesting point in your research?

What is interesting is that we can conduct research while considering a series of steps from visiting actual sites, measuring and interviewing, researching actual issues, and implementing the research results in society.

What has been your happiest moment with your current research theme?

The findings obtained through our research have been widely published as white papers and guidelines, and we have received good feedback. This made me realize the value of our research and that we are approaching a real problem and working toward a solution.

What is the goal of this research theme?

The aim is to enable stable wireless communications while allowing a wide variety of wireless systems to coexist in fields where wireless communications are introduced, such as logistics, medical care, and infrastructure, as well as on manufacturing sites.

Researchers

Person 2

HAGURA Nobuhiro
Senior Researcher,
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Advanced ICT Research Institute

Born in 1980, he earned a Ph.D. from Kyoto University, completed postdoctoral research at University College London, and joined NICT in 2016. His research focuses on brain mechanisms underlying efficient human-environment interaction.

Unveiling the Brain's Dynamic Interaction between Action and Perception

My research focuses on understanding brain mechanisms that enable efficient interaction with the environment. Our findings challenge the notion that perception is solely based on sensory input, revealing that actions play a critical role in shaping perception. For example, we demonstrated that time feels longer when preparing for an action, akin to baseball players perceiving a slowing ball when preparing to hit[1]. We also showed that decision-making is influenced by physical effort: people prefer less effortful options, similar to the fox in Aesop's fable that deemed unreachable grapes undesirable[2]. These examples highlight how actions affect perception and decisions.

Recently, we started to investigate the reverse relationship Fig.1: how perception and decision-making shape actions. Using a motor learning paradigm, we examined whether the brain treats identical physical actions differently depending on decision difficulty[3]. Participants performed a left-right motion discrimination task, followed by a straight reaching movement to the target in that direction. What the participants had to learn was to make a straight movement against robotic perturbations given during the movement. Interestingly, actions learned after easy decisions performed well only under similar conditions, and the same was true for difficult decisions. This suggests that the brain distinguishes actions based on decision context, even when the movements appear identical externally. To excel in both scenarios, training must occur under both conditions.

Our research uncovers novel interactions between perception, decision-making, and action systems in the brain. These insights may inform new methods for motor learning, enhance understanding of how we adapt to our environment, and guide the design of intuitively usable devices.

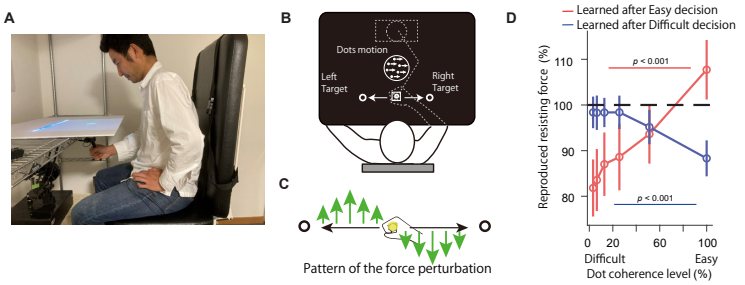


Fig.1 : Experiment setup (A, B, C) and the result (D). Participants sat in front of a screen holding a robotic handle (A). They observed a visual motion of dots on the screen, decided on the direction of the motion and moved the handle toward a target in the direction of the decision (B). During this movement, the robot applied a perturbing force (C). Participants learned to compensate for this force to make a straight movement. Participants' ability to compensate for the force was restricted to the specific decision context (easy or difficult) in which they learned it (D).

1. Hagura N*, Kanai R, Orgs G, Haggard P. Ready steady slow: action preparation slows the subjective passage of time. Proceedings of the Royal Society B; Biological Sciences. 279: 4399-4406. 2012
2. Hagura N*, Haggard P, Diedrichsen J. Perceptual decisions are biased by the cost to act. eLife, pii: e18422. 2017
3. Kisho Ogasa, Atsushi Yokoi, Gouki Okazawa, Morimichi Nishigaki, Masaya Hirashima, Hagura N*. Decision uncertainty as a context for motor memory. Nature Human Behaviour. 8: 1738–1751. 2024

Q&A

What is the most interesting point in your research?

Common belief holds that seeing is passive and acting is mere muscle activity. However, our research reveals that what we see is shaped by how we act, and actions depend on environmental context. Uncovering this counterintuitive nature of human behavior is one of the most interesting aspects of my work.

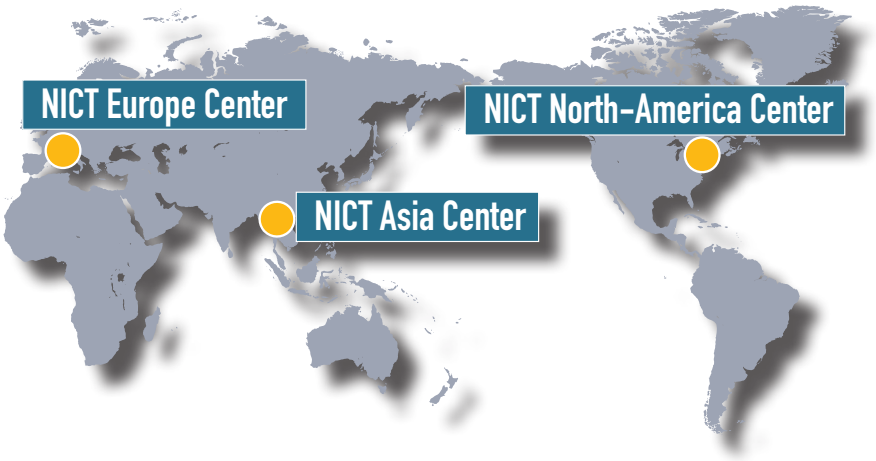
What has been your happiest moment with your current research theme?

In one experiment, we observed phenomenon X. However, a slight, seemingly trivial modification in a control experiment completely altered the results. This unexpected outcome initially confused us but ultimately led to one of the most significant findings of my career. That was a very rewarding experience.

What is the goal of this research theme?

Our goal is to uncover how the brain processes information to enable efficient interaction with the environment. By "learning" from the brain, we aim to contribute to developing more efficient information processing methods and designing devices that can be used intuitively.

NICT Overseas Centers



Disseminating NICT's Accomplishments Globally

As hubs to support NICT's international expansion, NICT has established the North American Center in Washington, D.C., the USA, the Europe Center in Paris, France, and the Asia Center in Bangkok, Thailand. At each of these overseas centers, along with spreading information and publicizing NICT's research and development accomplishments, we gather the latest information on ICT policy and research and development trends in each region that can only be obtained on the ground by networking with experts and specialists. In addition, we find cooperative research partners and develop relationships with them, provide planning and assistance to enable cooperative research to progress smoothly, and manage communications with said partners.

Specifically, the North-America and Europe Centers gather and analyze the latest information on policies and technological trends related to cutting-edge ICT such as wireless systems and cyber security, quantum communication, and AI in order to effectively and efficiently advance international research cooperation and international standardization activities at NICT. We provide this information and analysis to the relevant departments within NICT such that it may be used effectively in NICT's research activities. We also explain NICT's research and development initiatives to each region's government agencies, research facilities, universities, organizations, and other stakeholders, striving to network with them. As part of the international expansion of NICT's research and development accomplishments, along with hosting NICT's own international seminars, we also proactively participate in events such as international exhibitions.

In addition, at the Asia Center, along with gathering regional information in Southeast Asia and developing networks with relevant agencies, we promote and support collaborative research projects through the activities of ASEAN IVO (ICT Virtual Organization of ASEAN Institutes and NICT), a virtual research-cooperation organization with research facilities and universities within the ASEAN area. We also strive to improve NICT's presence in the region by participating in exhibits and assisting with workshops through the coordination and cooperation of the relevant departments within NICT. Furthermore, we act as an intermediary for the utilization of NICT's research and development accomplishments on the basis of the research needs of the ICT field in the region.

Here, the general directors of each overseas center introduce their centers' recent Activities.

NICT Overseas Centers

Asia Center

Director of Asia Center
SAKUDA Yoshihiro

https://www.nict.go.jp/en/global/overseas_centers/asia

The Asia Center is primarily focused on strengthening ties with research institutes and universities, supporting NICT's R&D activities, and disseminating NICT's information externally, in Southeast Asia region. The Asia Center has been adapting to changes in the R&D environment around information and communication fields while advancing various initiatives for over two decades, ever since the establishment in 2002.

In March 2024, we amended our Collaborative Research Agreement with Chulalongkorn University (CU) to expand the scope of research including optical sensing technologies in the healthcare domain. In November 2024, CU and NICT jointly held the CU-NICT Workshop on Photonic Network Research. Opening remarks were provided by Dean of the Faculty of Engineering Dr. Witaya Wannasuphoprasit, Head of the Electrical Engineering Department Dr. Chaodit Aswakul, Director General of the NICT Network Research Institute Dr. HARAI Hiroaki, and Director of the NICT Asia Center Mr. SAKUDA Yoshihiro. Research presentations covered photonic network-related technologies and a broad range of other topics, including optical wireless communication and biosensing technologies.

A signing ceremony was also held in November 2024 to renew the MoU signed between NICT and Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA), with President Dr. TOKUDA Hideyuki from NICT and Executive Director Dr. Pakorn Apaphant from GISTDA signing the MoU. Through this MoU, it is expected that the partnership between the two organizations in the field of space weather would be further strengthened, and that NICT's presence and space environment measurements in Southeast Asia would be more enhanced among other benefits.

The Asia Center continues to proactively participate in exhibition-related events to disseminate information externally. At the National Science and Technology Fair in August 2024, we displayed overviews of NICT's activities and exhibitions on research collaborations with Thai universities and public research institutions. During the Fair, Thai Minister of Higher Education, Science, Research, and Innovation Ms. Supamas Isarabhakdi visited the venue, allowing Vice President Dr. YANO Hiroyuki to explain the NICT's research collaboration activities in Thailand. Explanations to a wide range of visitors were also provided in Thai with assistance of King Mongkut's Institute of Technology Ladkrabang (KMITL).

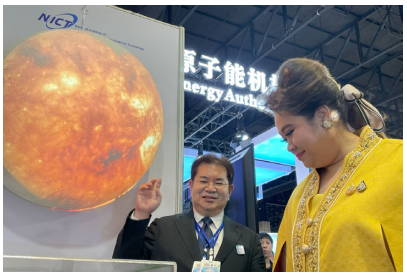
At the KMITL Innovation Expo in March 2024, the Asia Center provided exhibitions related to research collaboration in space weather and demonstrations of VoiceTra.

In addition, we are actively pursuing initiatives aimed at research collaboration, such as providing reports at various science and technology-related meetings.

The Asia Center will continue to support research collaboration and disseminate information on NICT's initiatives focused on Southeast Asia.

MoU signing ceremony with GISTDA

CU-NICT Workshop on Photonic Network Research 2024



National Science and Technology Fair 2024

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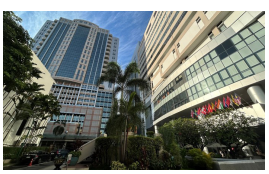
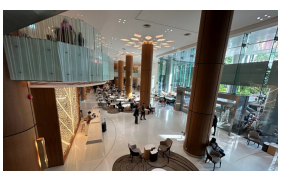
Luxury Hospital in Bangkok





Exterior and lobby of Bumrungrad International Hospital

Bangkok is home to several large private international general hospitals, including Bumrungrad International Hospital. Many affluent patients visit from neighboring countries and the Middle East, and English is generally spoken, with Japanese interpreters also available. Hospital facilities are extensive, with lobbies resembling luxury hotels. The atmosphere in their waiting rooms and patient rooms is like being in a hotel. They also have no noticeable medicinal odors. Despite being hospitals, they are places you'd almost want to visit.

NICT Overseas Centers

North-America Center

Director of North-America Center
MAEDA Kyotaro

https://www.nict.go.jp/en/global/overseas_centers/north_america

The North-America Center was established in October 2000. Our current office is located near the heart of Washington, D.C., within walking distance of the White House and federal government agencies. Additionally, we are only a few minutes' walk from the Washington, D.C. offices of other National Research and Development Agencies of Japan, JST, JSPS and AMED.

The North-America Center focuses on the following three activities:

(1) Promoting joint research with U.S. research institutes and other partners
(2) Collecting, analyzing, and reporting information on U.S. government policies including budgets and regulations related to R&D in the field of telecommunications, as well as R&D trends at research institutes, universities, and private companies
(3) Publicizing and promoting NICT R&D results through participation in exhibitions and conferences

In terms of specific fields, we are particularly focused on Beyond 5G/6G and quantum science and technology, which have been highlighted as areas for strengthening collaboration in documents from various Japan-U.S. summits. Furthermore, considering the rapid development and societal penetration of generative AI in recent years, we analyze the latest AI trends and related cybersecurity issues while fostering Japan-U.S. collaboration in these areas. These efforts include advancing discussions with relevant U.S. government agencies and participating in related conferences in the United States.

In September 2024, we held the NICT Forum in Washington, D.C., for the first time in ten years(Fig.1). The Forum was attended by various participants, including government officials, researchers, and business professionals in the Japan-U.S. information and communications sector. Through the discussions, we were able to share the latest information on NICT and cybersecurity among the participants and gain insights from diverse perspectives.

Beyond research and development, startup companies play a significant role in the overall U.S. economy and society, not just in the field of information and communications technology. The North-America Center has, therefore, been conducting venture surveys, focusing particularly on Silicon Valley, to gather and analyze information about startup companies leveraging advanced technologies, including Beyond 5G/6G and quantum science and technology.

It is worth noting that the official name of our office is the North-America Center, not the Washington, D.C., Office. In line with this spirit, since 2024, we have expanded our activities to Canada, focusing on the same areas of work as in the U.S. We are particularly promoting joint research with Canadian research institutions.

The United States held its presidential election in November 2024. The increasingly complex international landscape has also significantly influenced a range of government policies and R&D directions in the United States. Even under such circumstances, the North-America Center aims to accurately grasp the situations in the U.S. and Canada, disseminate information about Japan effectively, and bridge research efforts between Japan and these countries, contributing to the development of ICT R&D in these regions..

Fig.1 : Presentation of Dr. TOKUDA at NICT Forum (September 2024)

Fig.2 : The Vicinity of the White House during the Official Visit of Prime Minister Kishida (April 2024)

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A Glimpse of the U.S. Presidential Election

As mentioned above, the United States held its presidential election in November 2024. Based on previous experiences, some restaurants in Washington, D.C., boarded up their glass windows to prepare for unforeseen incidents; however, the city remained calm immediately following the election.

As the election day approached, small groups of individuals began advocating for their views with placards on street corners. Unlike large, intense demonstrations, these were quiet efforts involving distributing flyers and calmly explaining their positions to those who stopped to listen. Some advocates even wore traditional ethnic attire and performed music from their home countries while expressing their perspectives on the U.S. presidential election, underscoring the presence of immigrants in the United States.

NICT Overseas Centers

Europe Center

Director of Europe Center
FUJINUMA Koichi

https://www.nict.go.jp/en/global/overseas_centers/europe

The NICT Europe Center relocated its office in January 2025. As with the previous office, it is located near the Champs-Élysées in the center of Paris. From there, our staff travel to various European countries to promote collaboration in research and development and assess trends.

The mission of the NICT Europe Center is to (1) promote and support international joint research through participation in international conferences and other events and deepen networks with European research institutes, government agencies, and industry organizations to promote collaboration; (2) support the international deployment of NICT's R&D achievements in the European region through information dissemination and public relations; and (3) collect, analyze, and report on R&D trends and policies in the ICT field at European research institutes, government agencies, universities, and companies in the European region.

In Europe, green and digital transitions are positioned as top priority policies, and large-scale programs are going forward to support these policies. These include Horizon Europe as a research innovation framework program, the Digital Europe Programme to promote implementation and expansion of digital technologies, and the Connecting Europe Facility to promote investment in network infrastructure across Europe. These programs include NICT's four strategic research fields of Beyond 5G/6G, quantum ICT, cybersecurity, and AI as priority fields, so it is an important mission of the NICT Europe Center to collect and analyze information on these European R&D trends and policies.

Furthermore, given a changing geopolitical situation and increasingly complex world affairs, there are many institutions in Europe that consider Japan to be an excellent partner that they can trust. Based on the above European trends, the NICT Europe Center acts as the main bridge between NICT headquarters and overseas institutions. With the aim of internationally expanding R&D such as Beyond 5G and quantum ICT, we are making an effort to discuss and exchange views with European research institutes, government agencies, and related parties, actively participate in related events, and network with concerned individuals.

In 2024, the Center collaborated and cooperated with the following: exhibition of B5G research results at Mobile World Congress 2024 in Spain in March, visit to INRIA in France by MIC and NICT in May, and participation in GPAI Innovation Workshop.

The Center will continue to work diligently to produce win-win relationships between NICT and European research institutions, utilizing the insights and networks it acquires in the region.

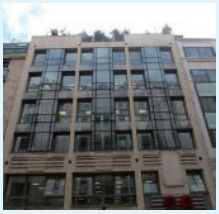

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Fig.1 : NICT`s exhibition at Mobile World Congress 2024 (Spain) (March 2024)

Fig.2 : Visit to INRIA in France by MIC and NICT (May 2024)

Fig.3 : Participation in GPAI Innovation Workshop (May 2024)

Paris after the Olympics and Paralympics

In the summer of 2024, Paris hosted the Olympic and Paralympic Games. Although there were concerns about terrorism beforehand, the Games were held with great fanfare in and around Paris, and the country was in a festive mood throughout the period of the Games, which ended successfully. There were opportunities to get tickets even at the last minute, and residents who remained in Paris over the summer were able to enjoy various opportunities to watch the matches and events. All tickets were digitized, and there was active use of cutting-edge ICT, especially by partner organizations, which provided many new insights from an ICT perspective.

After the Olympics, Paris returned to its daily life with various events held since the fall, including Paris Fashion Week, Art Week, and Christmas markets. While Paris feels the same, I have noticed some pleasant changes when travelling around, such as that the subway network, road infrastructure, and information displays have improved and become more convenient after the Olympics.

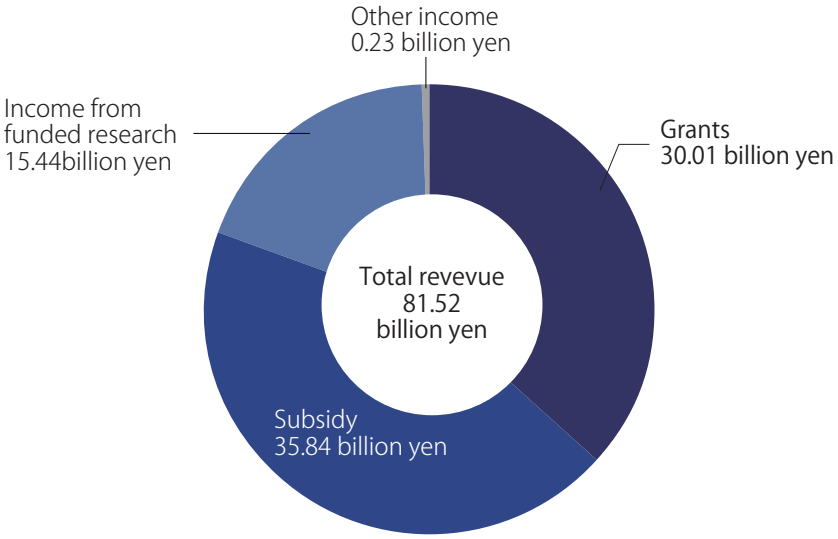
Fig.4 : Paralympics Closing Ceremony

Fig.5 : Japan winning gold in wheelchair rugby at the Paralympics

Budget

The original budget for FY2024

Income from funded research or others during the fiscal year is not included.



Total expenditure for FY2023 was billion yen in a reported basis.

Yen-dollar conversion ratio: 154.51yen/dollar (Aplil 2024)

Work Force

1,427 (as of April 1, 2024)
(Including fixed term employees)

History

● Communications Research Laboratory (CRL) ● Telecommunications Advancement Organization (TAO)

Oct.	1896	● Radio Telegraph Research Division is established as a part of the Electrotechnical Laboratory, Ministry of Communications
Jan.	1915	● Hiraiso Branch opens
May	1935	● Testing and Examination for Radio Equipment Type Approval starts
Jan.	1940	● Frequency Standard Radio Service (JJY) starts (Kemigawa)
June	1948	● Radio Physics Laboratory is integrated
Aug.	1952	● Radio Research Laboratory is established
May	1964	● Kashima Branch opens (30-m diameter Parabola Antenna Facility completed)
Aug.	1979	● Communications and Broadcast Satellite Organization (CBSO) is established
Aug.	1982	● Kimitsu Satellite Control Center opens
April	1988	● Reorganized from Radio Research Laboratory to Communications Research Laboratory(CRL)
May	1989	● Kansai Branch opens (Kobe)
Oct.	1992	● Renamed as the Telecommunications Advancement Organization (TAO) Commencement of advanced communication and broadcasting research and development
July	1997	● Yokosuka Radio Communications Research Center is established
July	2000	● Keihanna Info-Communication Research Center is established
Jan.	2001	● Ministry of Posts and Telecommunications becomes Ministry of Public Management, Home Affairs, Posts and Telecommunications
April	2001	● Communications Research Laboratory, Incorporated Administrative Agency is established
July	2001	● Promotion system on facilitating research and development in private basic technology commences
March	2002	● Satellite control operations are terminated
April	2003	● Partial takeover of operations of Promotion Center for Facilitating Research and Development in Private Basic Technology
April	2004	National Institute of Information and Communications Technology, an incorporated administrative agency (NICT) is established by merging CRL and TAO
April	2012	Resilient ICT Research Center is established
April	2013	Center for Information and Neural Networks(CiNet) is established
April	2015	Renamed as National Institute of Information and Communications Technology, National Research and Development Agency
April	2016	Cybersecurity Human Resource Development Research Center (Currently, National Cyber Training Center) is established
March	2021	Beyond 5G R&D Promotion Project starts
April	2021	Quantum ICT Collaboration Center is established

NICT Primary Facilities

Headquarters

Koganei-shi and Kodaira-shi, Tokyo

Radio Research Institute
Network Research Institute
Cybersecurity Research Institute
Big Data Integration Research Center
Koganei Frontier Research Center
Beyond 5G Research and Development Promotion Unit
Quantum ICT Collaboration Center
Open Innovation Promotion Headquarters

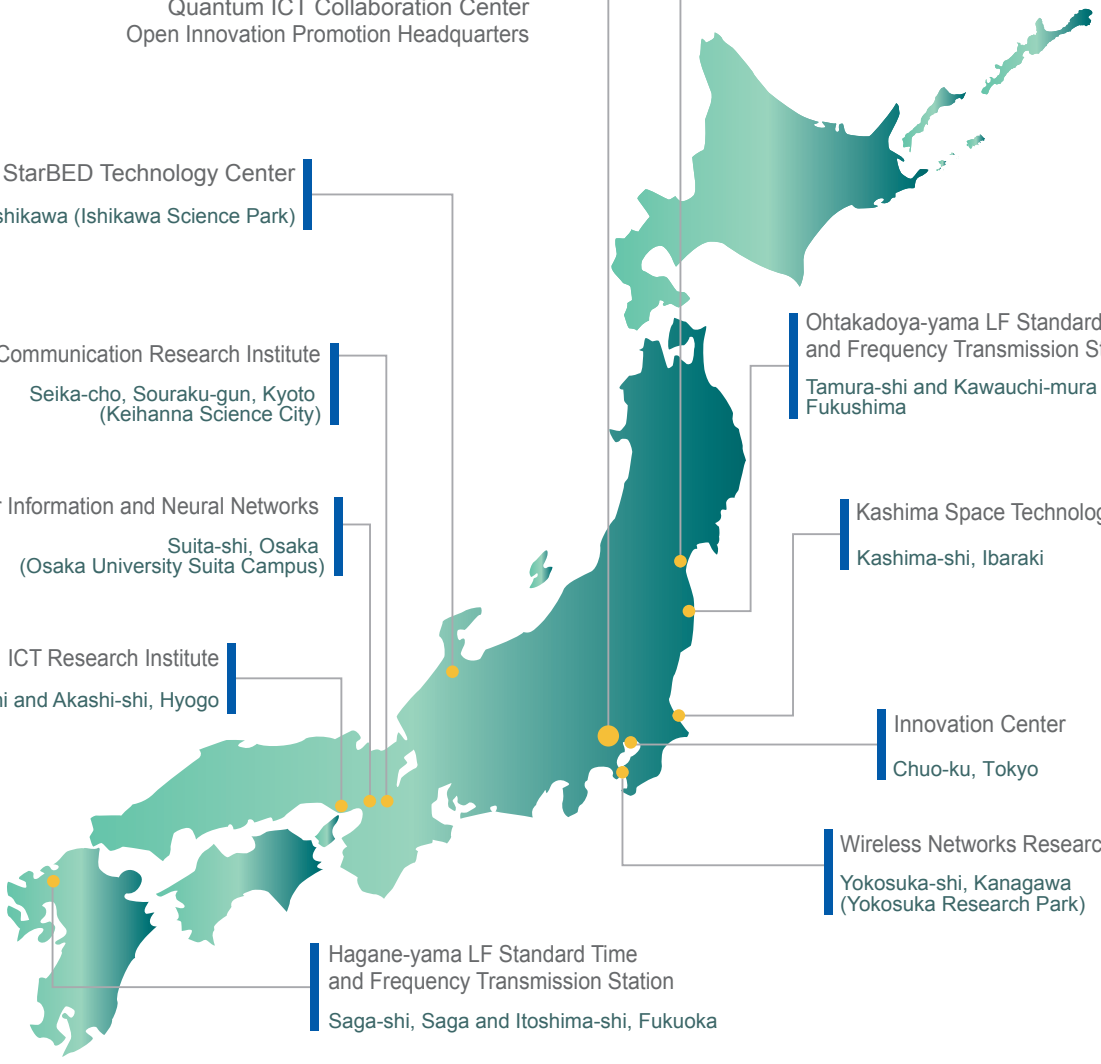
Resilient ICT Research Center
Sendai-shi, Miyagi
(Tohoku University Katahira Campus)

Hokuriku StarBED Technology Center
Nomi-shi, Ishikawa (Ishikawa Science Park)

Universal Communication Research Institute
Seika-cho, Souraku-gun, Kyoto
(Keihanna Science City)

Center for Information and Neural Networks
Suita-shi, Osaka
(Osaka University Suita Campus)

Advanced ICT Research Institute
Kobe-shi and Akashi-shi, Hyogo



Ohtakadoya-yama LF Standard Time
and Frequency Transmission Station
Tamura-shi and Kawauchi-mura Futaba-gun,
Fukushima

Kashima Space Technology Center
Kashima-shi, Ibaraki

Innovation Center
Chuo-ku, Tokyo

Wireless Networks Research Center
Yokosuka-shi, Kanagawa
(Yokosuka Research Park)

Hagane-yama LF Standard Time
and Frequency Transmission Station
Saga-shi, Saga and Itoshima-shi, Fukuoka

Okinawa Electromagnetic Technology Center
Onna-son, Kunigami-gun, Okinawa

Overseas Centers

Asia Center
North-America Center
Europe Center

https://www.nict.go.jp/en/global/overseas_centers/overseas_centers.html

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