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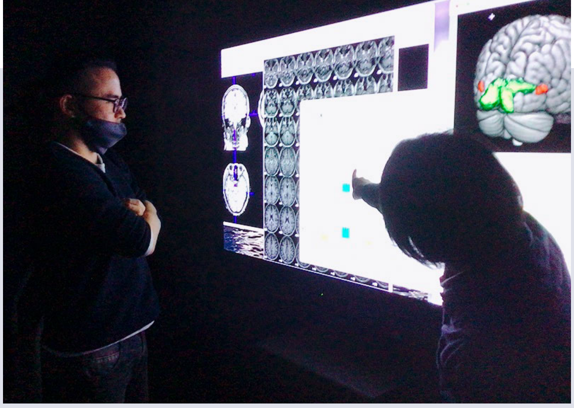
NICT REPORT

New ICT technology strategy toward Society 5.0

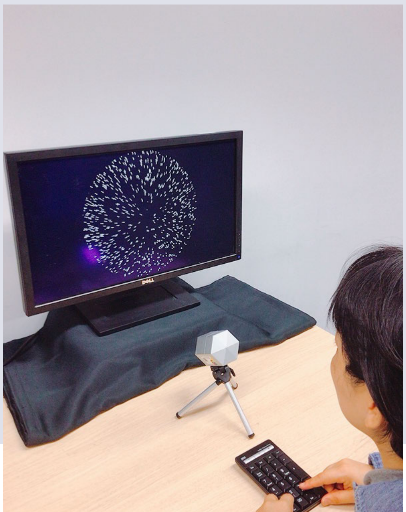
NICT National Institute of Information and Communications Technology



NICT CHARTER

Humanity has achieved progress as it has deepened its mutual understanding and shared its wisdom, overcoming barriers due to national, regional, ethnic, generational, and other differences. Communication is the most critical activity in human society, and information and communications technology (ICT) is the basis of that communication. ICT is also the infrastructure that supports humanity's advanced intellectual and economic activities.

The National Institute of Information and Communications Technology (NICT) promotes the full spectrum of research and development in ICT from basic to applied research with an integrated perspective, and thus promotes the advancement of Japan as an intellectual nation that leads the international community. Moreover, NICT forms close ties with the academic and business communities in Japan as well as with research institutes overseas and returns its R&D findings to society in a broad range of fields. In this way, NICT contributes to the creation of lifestyles that are affluent and safe, a society that is full of intellectual creativity and dynamism, and a world that values harmony and peace.



Message from the President

Last year saw a continuation of the COVID-19 pandemic from 2020, and efforts to prevent further spread of infection resulted in huge changes in the work styles of people, with dramatic shifts from analog and face-to-face interaction to digital and remote. Many people started using and became more familiar than ever with information and communications technology (ICT) such as video conferencing systems used for work-at-home, vaccination reservation systems, COVID-19 contact tracing apps, and simulations for predicting the number of infected people. At the same time, issues in existing work rules and workflows, as well as problems such as poor usability and compatibility of deployed systems, became more widely recognized.

As Japan's only national research and development agency specializing in the field of ICT, the National Institute of Information and Communications Technology (NICT) promotes ICT R&D from an integrated perspective, from the basic to the applied, while collaborating with universities, industry, local governments, and domestic and overseas research institutions and aiming to generate innovation by giving back to society with the results of our R&D. Furthermore, by flexibly responding to social issues on a global scale and using systems that integrate cyberspace and physical space, we aim to help realize a human-centered, sustainable, and inclusive society; in other words, a safe and secure Society 5.0.

Under the 5th medium- to long-term plan, which launched in April 2021, in addition to our main mission of promoting R&D and open innovation in five priority areas (Advanced electromagnetic technology, Innovative networks, Cybersecurity, Universal communication, and Frontier science) based on a new ICT technology strategy, we will actively promote R&D in the four strategic research fields of Beyond 5G (B5G), AI, Quantum ICT, and Cybersecurity.

In B5G R&D, with a game-changing mindset, we aim to become an R&D Hub in Japan based on collaboration with R&D projects that were commissioned by the Beyond 5G R&D Promotion Project. In the field of AI we will further enhance multilingual voice translation technologies to provide simultaneous interpretation level functions by around aiming for a world without language barriers. In the field of Quantum ICT, we are promoting the activities of the Quantum ICT Collaboration Center with aiming to become an international research center for quantum security technology in the new building of the headquarters. In the field of cybersecurity we will promote the activities of the Cybersecurity Nexus to build integrated cybersecurity knowledge and human resource training infrastructure, aiming to be a "nexus" between industry, academia, and government. In August of last year, we published two white papers in the two fields, B5G and quantum ICT respectively. We will continuously update the contents of these white papers in the future to strengthen both our own R&D and our information communication capabilities, thus deepening our collaboration with research institutes and companies in Japan and overseas.

In addition, NICT will accelerate the spread of its R&D results throughout society by promoting activities to utilize the advanced technologies developed by NICT for businesses and other organizations, and creating a testbed environment for the open use of research-result data. We will also enhance activities such as NICT Quantum Camp (NQC) and SecHack365 for training the next generation of ICT human resources.

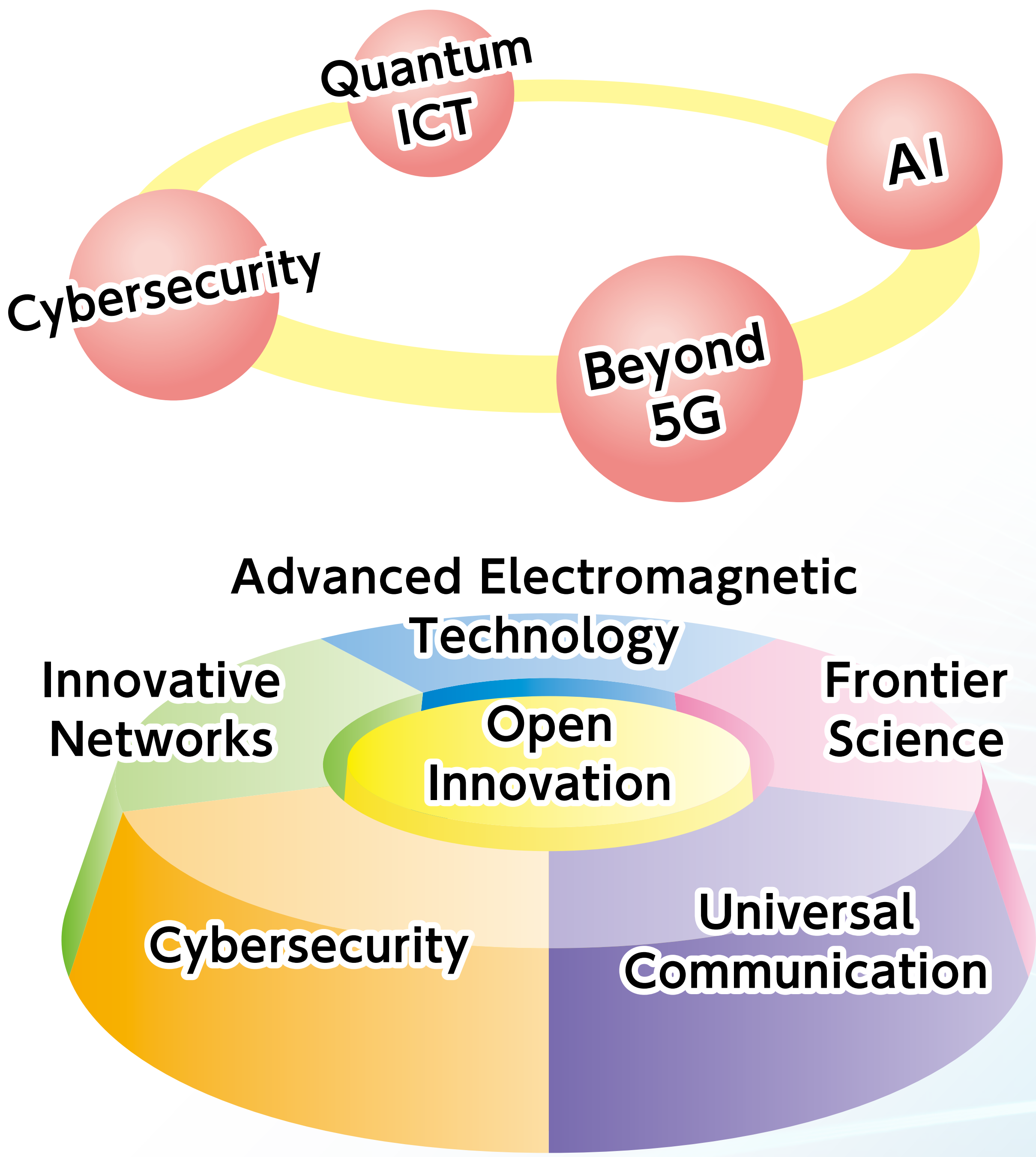
In terms of our management policies, in addition to the previous "COC" consisting of Collaboration, an Open mind and open innovation and a Challenging spirit, we have added two new key concepts: the digital transformation (DX) of NICT itself; in other words, the DX not only of business process but also R&D processes, and Computing & Communication for Carbon Neutral. We will further develop these policies under the banner of "COC 2.0."

NICT will continue to strive to further develop the ICT field by promoting collaborative activities between industry, academia, and government, while also cooperating and working with other stakeholders and welcoming opinions from a wide variety of people in Japan and overseas. We appreciate your support and cooperation.

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.

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Advanced Electromagnetic Technology Area

Radio Research Institute

Director General　TAIRA Kazumasa

The Radio Research Institute promotes research and development to enable the various features of electromagnetic waves to be utilized in society. Through the early and precise understanding of changes in the climate and space environment, and accurate assessments of social conditions, as well as enabling highly accurate predictions of the future by using the results of these assessments, the Institute aims to provide smart lifestyles in the real world.

The Institute's organization is composed of three Research Centers and a General Planning Office (Fig. 1).

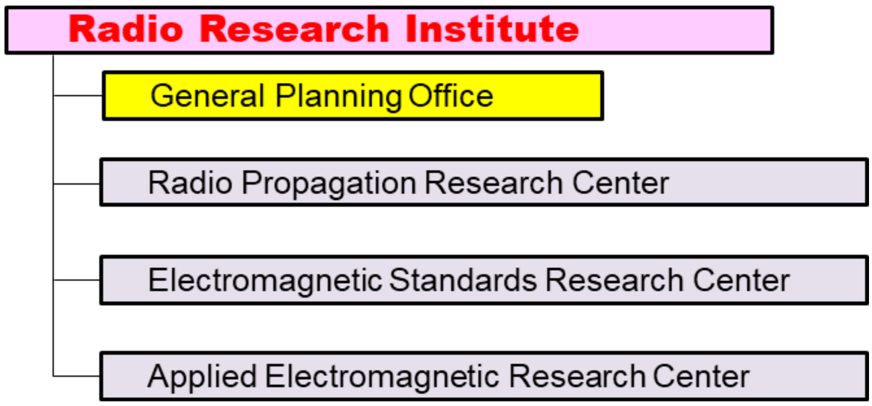


Fig.1 : Organization of Radio Research Institute

Radio Propagation Research Center

In the field of remote sensing technology, the Center conducts research and development on technology for observing phenomena such as rainfall, wind, water vapor, and clouds from the ground at high spatiotemporal resolution (Fig. 2). One of the most well-known technologies for precipitation observation is phased array weather radar. The Center also conducts the research and development required for improving prediction technology that integrates these observations to promote knowledge about the early warning and development mechanism of sudden and extreme natural phenomena, such as torrential rain or tornadoes. They are also promoting research and development on aircraft-mounted synthetic-aperture radar (airborne SAR) technology that is also useful for assessing conditions in the event of natural disasters such as earthquakes or volcano eruptions. Their research utilizes radar devices with resolution ranking among the best in the world and will contribute to real-world applications. Furthermore, the Center's research and development has focused on the technology required for interpreting conditions, such as identifying changes in the ground surface and structures, and they encourage the utilization of the observed data.

In the field of satellite remote sensing technology, to improve the accuracy of monitoring and prediction of global climate and weather, the Center conducts research and development on advanced remote sensing technologies that are mounted in satellites to observe the atmospheric environment on a planetary scale, including precipitation, clouds, and wind. They are also focusing on advanced analysis technologies using data from observations that estimate physical quantities related to phenomena such as precipitation and clouds. With regard to the Cloud Profiling Radar (CPR) mounted in the EarthCARE satellite, a joint mission between Europe and Japan, the Center verified the estimated Doppler velocity with numerical simulations (Fig. 3). The Center also developed methods for improving the precipitation judgment algorithm for the Dual-frequency Precipitation Radar (DPR) mounted in the satellite of GPM, an international mission that is led by the United States and Japan.

In the field of the space environment technology, the Center's research and development aims to provide daily monitoring and forecasting of space weather phenomena such as radiation and high-energy particles mainly originating from the sun, and disturbances in the magnetosphere and ionosphere, as well as to improve the accuracy of these operations. For the purpose of space environment measurements and high-precision forecasts to more accurately understand the status of ionospheric disturbances that have a large impact on radio wave propagation, the Center improved the automated scaling technology for ionogram data based on AI, and implemented a data assimilation algorithm in the atmospheric and ionospheric model (GAIA). The Center enhanced magnetospheric simulators using solar wind data as one of the inputs to contribute to the space environment monitoring and forecasting that are essential to the safe operation of artificial satellites. The Center also developed a risk estimation system for spacecraft charging (surface/internal) using magnetospheric simulations in collaboration with Osaka Prefecture University and JAXA (Fig. 4). Furthermore, the Center jointly developed with Nagoya University an ensemble solar wind arrival prediction system that reproduced the shock waves caused by arriving solar winds by simulations. The aim of such research and development is to improve high-precision early warning systems based on solar radio wave observations and solar wind simulations.

To enable the use of space weather information in civil aviation operations, the International Civil Aviation Organization (ICAO) selected the ACFJ consortium, consisting of Japan, Australia, Canada, and France, as one of ICAO Global Space Weather Centers. The new service started in November 2019. Also, the Center started 24/7 operations of space weather monitoring and forecasting from December 2019.

Electromagnetic Standards Research Center

In the field of electromagnetic environment technology, the Electromagnetic Standards Research Center conducts research and development on Electromagnetic Compatibility (EMC), which is the ability of electrical and electronic devices and communication systems to operate without mutual effects which can deteriorate their functions and performances, in terms of electromagnetic, impacts, and on Biomedical EMC that enables the safe and secure use of new wireless systems as well as current ones. These activities aim to help build safe and secure electromagnetic environments in response to diversified utilization of radio waves.

In the field of advanced EMC measurement technology, the Center conducted studies about the following subjects:

- Electromagnetic interference with wireless communication systems due to electromagnetic noise generated from energy-saving electrical equipment
- Development for broadband and highly efficient antennas used for RF immunity tests in close proximity according to new international standards
- Development of high-speed spectrum measurement devices for unwanted (spurious) waves containing broadband frequency components emitted from radar or similar equipment, and measurement methods and test sites for radiated disturbances (electromagnetic noise that is radiated into space and interferes with communication) at 30 MHz or below that are emitted by household appli-

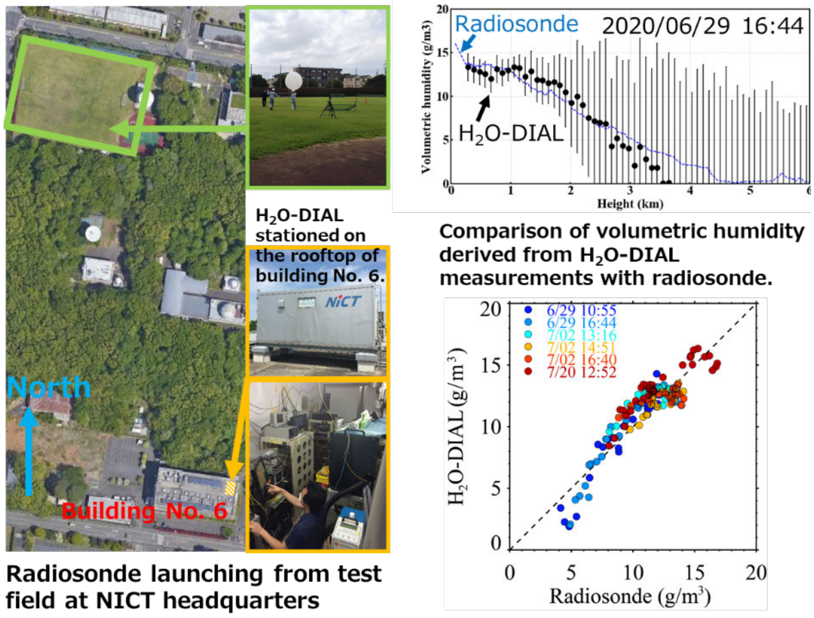


Fig.2 : Validation of H_2O-DIAL-derived water

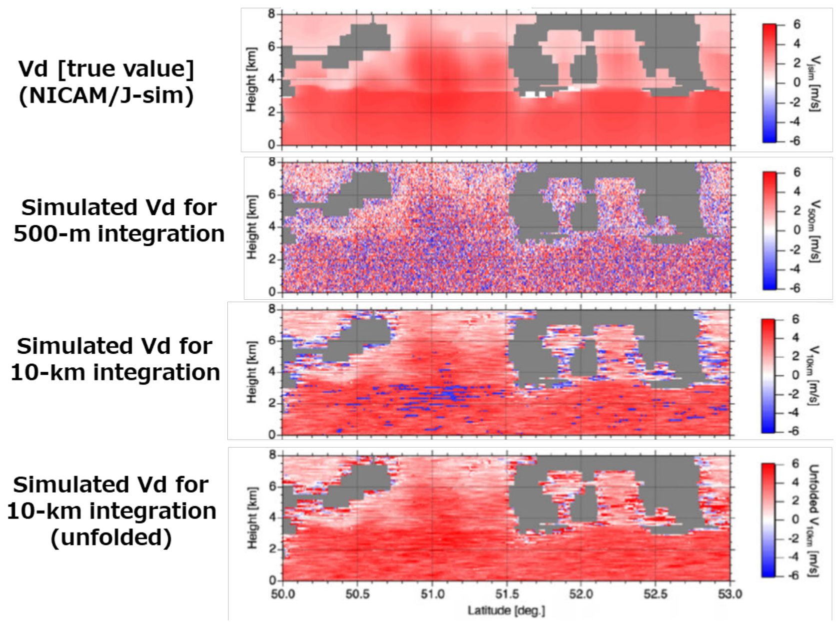


Fig.3 : Assessments of doppler velocity errors of EarthCARE/CPR with numerical simulations

ances or similar devices

- Metamaterial radio wave scattering walls that improve millimeter wave propagation characteristics in technologies such as 5G

The Center also studied calibration technology for measurement instruments such as RF power meters for extremely high frequency radio waves and calibration techniques for electric field probes corresponding to broadband modulation signal waveforms such as LTE, as well as studying improvements in the ground reflection characteristics of broadband spurious test sites for equipment such as a marine radar.

In the field of Biomedical EMC technology, to develop evaluation technology for radio wave exposure on a human body up to the terahertz band (100 GHz to 10 THz), the Center studied the construction of an electrical constant database up to the submillimeter wave band (300 GHz or higher) and the mechanism of interaction with living tissues in the terahertz band. They also studied microstructure tissue modeling for multi-scale exposure evaluation and numerical exposure simulations. Furthermore, the Center developed and improved (accelerated) evaluation methods for checking whether human body exposure from 5G devices or 4G/LTE devices comply with RF safety guidelines (Fig. 5). In order to provide a comprehensive picture of the radio wave exposure levels in real daily lives and contributions to risk communication, the electric field strengths near mobile phone base stations were measured and compared to past measurements in the same locations.

In the field of space-time standards technology, the law establishing NICT requires that generating, maintaining and disseminating Japan Standard Time are core operations of NICT, and the Center aims to further improve the accuracy and reliability of standard time and frequency. The Center develops technologies for the practical use of Japan Standard Time and standard frequencies; and they also develop optical frequency standards, and the comparison and transmission technologies that are required for the evaluation and dissemination of standards.

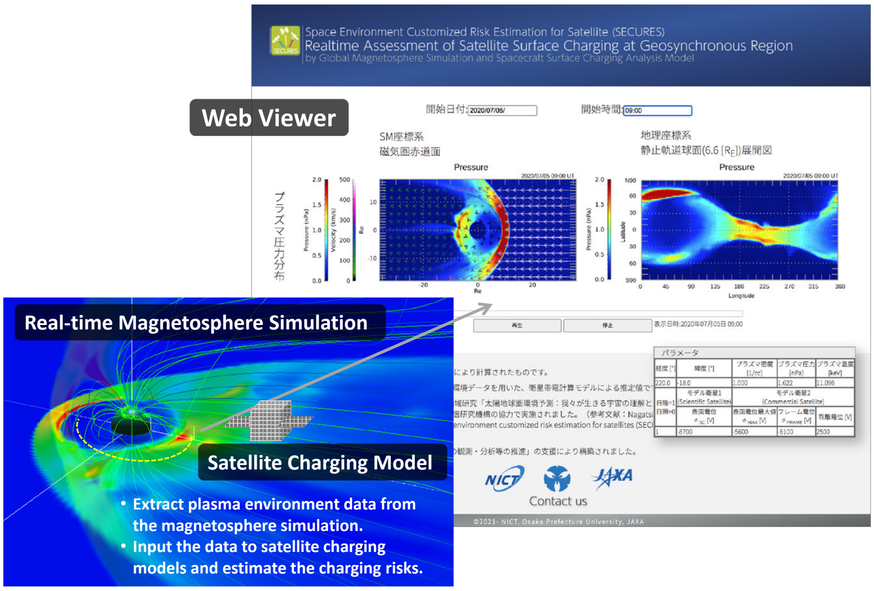


Fig.4 : Space Environment Customized Risk Estimation for Satellite (SECURES)

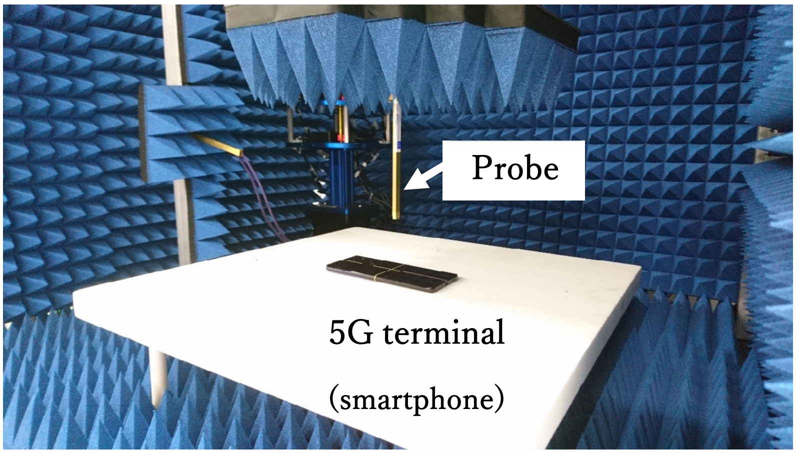


Fig.5 : Measurement system for a compliance test of a 5G terminal to RF safety guidelines.

In research and development for next-generation frequency standards, the calibration data of International Atomic Time obtained by a Strontium (Sr) optical lattice clock at NICT for the previous four years was compared to the calibration data provided by eight primary frequency standards worldwide that contributed to International Atomic Time calibration in the same period. The Center was able to evaluate the absolute frequency of the clock transition with an uncertainty of 1.8×10^{-16}, and published a paper describing the results (Fig. 6). In contrast, for the indium ion (In^{+}) optical frequency standards, improvements to the evaluation of systemic uncertainty enabled measurement at the 10^{-16} level and a comparison of frequency with the Sr optical lattice clock at NICT was conducted. The Center also developed a compact and highly accurate frequency counter in terahertz region, which can measure broadband exceeding four octaves. Additionally, the Center developed a method of short-range wireless two-way comparisons as well as a compact atomic clock to build resilient time synchronization networks. The Center initiated research for distributed time synchronization technology.

Applied Electromagnetic Research Center

In the field of digital optics technology, the Applied Electromagnetic Research

Center performed precise measurements and improvements for wavefront accuracy inside printers with the aim of achieving industrial application of hologram printing technology (HOPTEC). They compensated the distortion occurring in the demagnification optics of printers, improving the accuracy of the printed optical elements. In the field of precision measurements based on holography, the Center developed a new digital holographic imaging system that combines a wavelength-dependent phase-modulation array and a monochrome image sensor, and they succeeded in observing 3D images of optical objects with multiple wavelengths (such as labeled molecules) (Fig. 7). In the application of communication using HOPTEC elements, the Center confirmed that elements designed to operate in near infrared light (852 nm) were able to function.

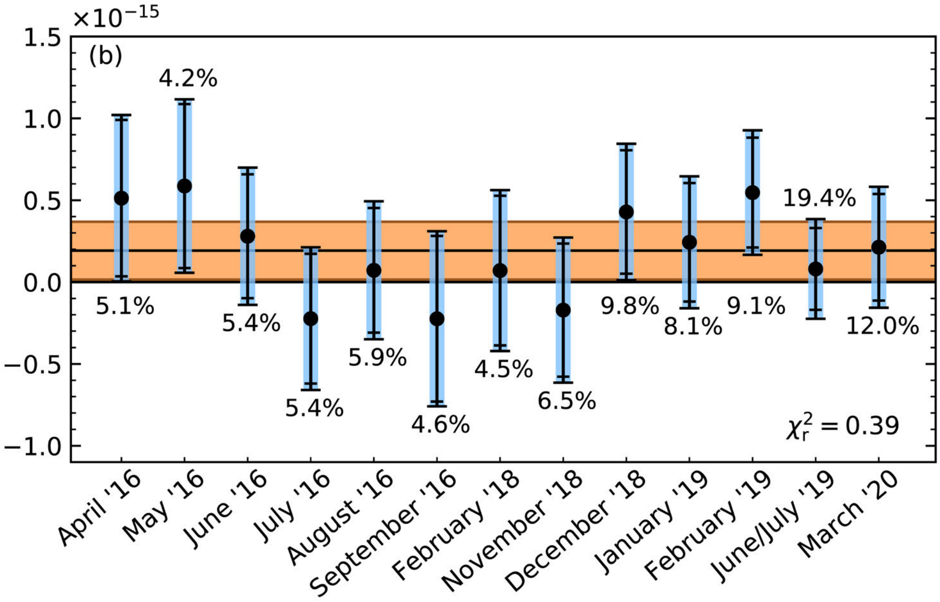


Fig.6 : Absolute frequency measurement of the strontium optical clock transition

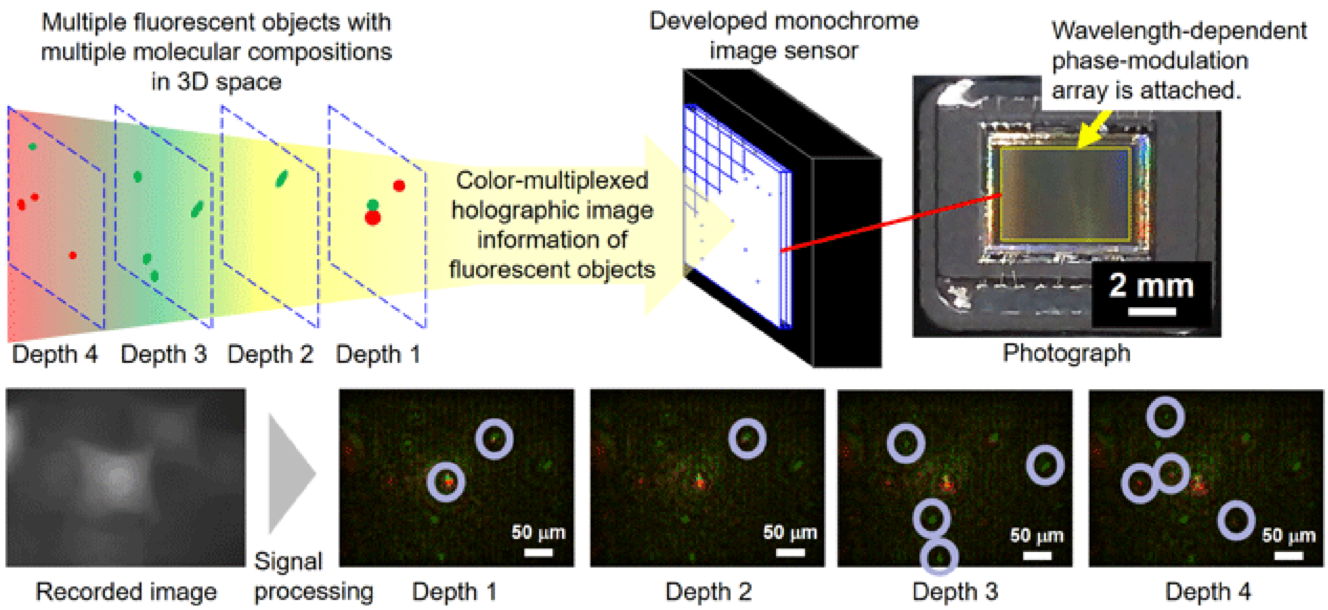


Fig.7 : Holographic microscope

Innovative Networks Area

Network Research Institute

Director General HARAI Hiroaki

In April 2021, the former Network Systems Research Institute, Wireless Networks Research Center, Resistant ICT Research Center, and Advanced ICT Device Laboratory were integrated into the Network Research Institute (Fig. 1).

The Network Research Institute conducts R&D on establishing networks toward Beyond 5G, which is required to build innovative networks capable of responding to the rapid increase in communication traffic, securing communication quality, and diversification of services.

In particular, we conduct R&D on computing and AI-enabled networking technology, next-generation wireless technology, photonic network technology, optical and radio convergence technology, space communications fundamental technology, and resilient ICT technology as key technologies for this purpose. The Institute will also aim to promote standardization activities, disseminate R&D results, and implement them in society (Fig.2).

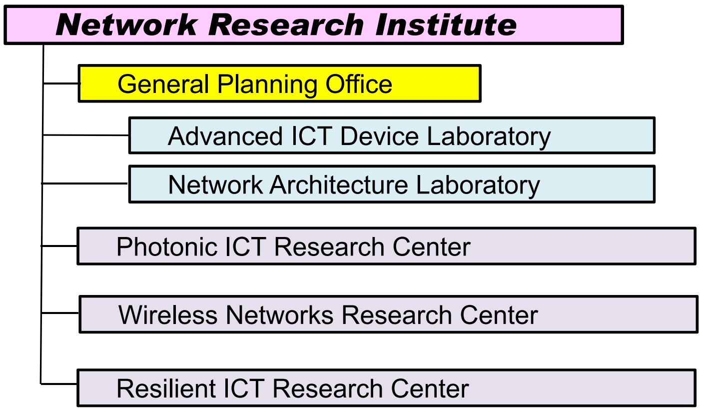


Fig.1 : Organization of Network Research Institute

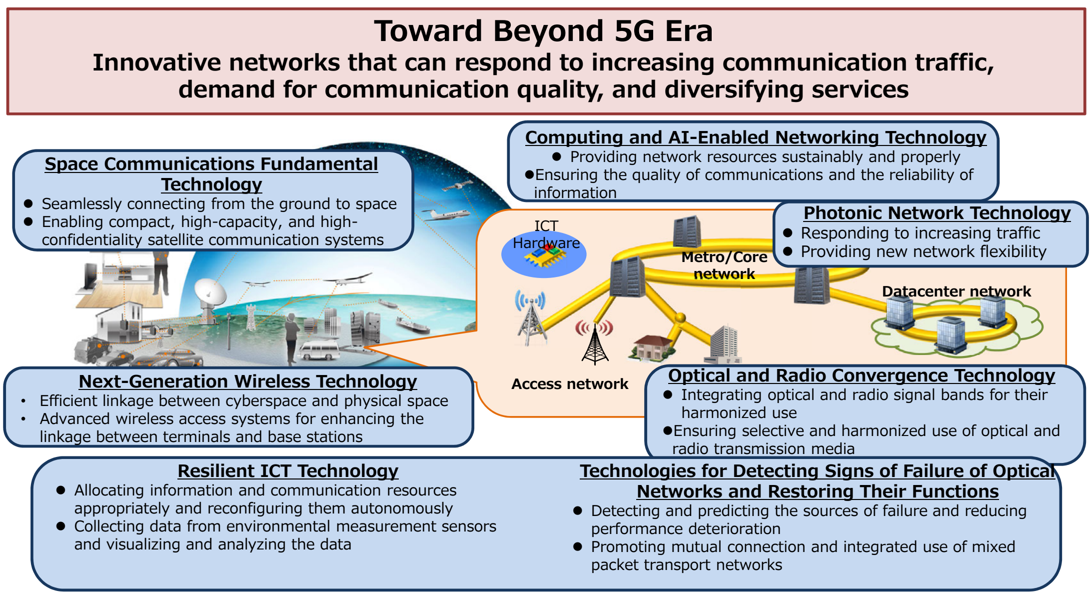


Fig.2 : Key Technologies Targeted by Network Research Institute

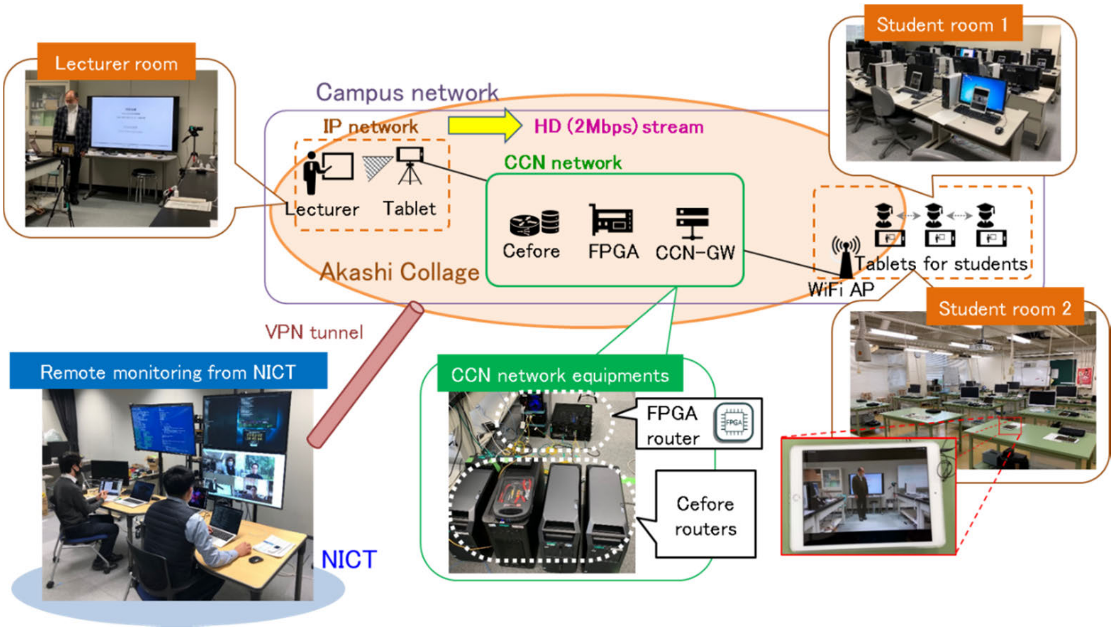


Fig.3 : Outline of systems in remote classroom

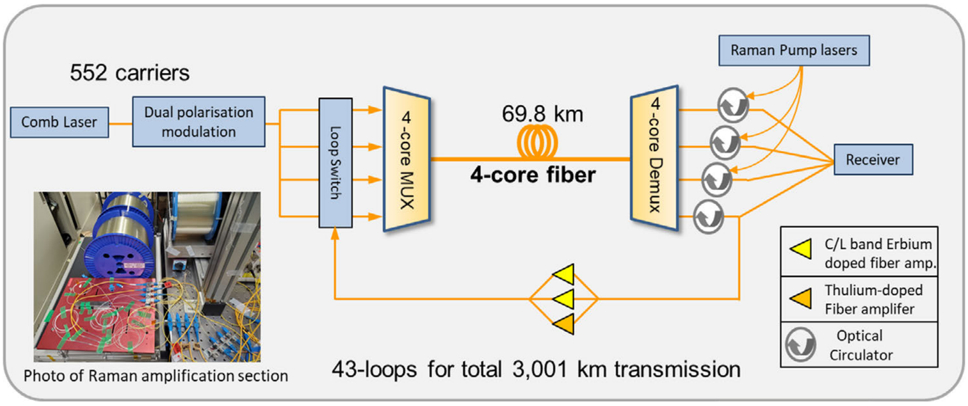


Fig.4 : Schematic diagram of the 4-core optical fiber transmission system

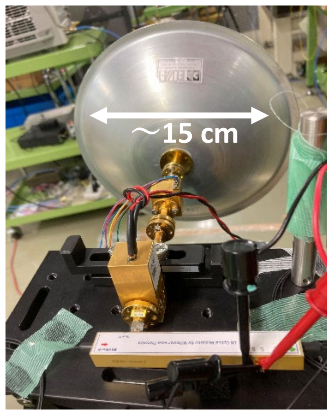


Fig.5 : Proof-of-concept demonstration system for photonic downconversion

Network Architecture Laboratory

To realize dependable communication services over different kinds of networks in the Beyond 5G era, NICT has been pursuing the research and development of federated computing and AI-enabled networks. NICT has developed the autonomic resource control architecture (ARCA) technology to automatically construct and switch network slices depending on the dynamic traffic demands of application services. The functions of ARCA in the experimental network of a carrier were validated in this study. In addition, we applied our ICN-based network software, Cefore, to advanced online learning systems, indispensable to the new normal. In collaboration with National Institute of Technology, Akashi College, we successfully proved that this multicast-capable online learning system delivers better real-time performance than that of the conventional system (Fig. 3).

Photonic ICT Research Center

Photonic Network Technology

We constructed a 4-core optical fiber transmission system that makes full use of wavelength division multiplexing technology by combining different amplifier technologies (Fig. 4) and successfully conducted a transmission demonstration with date-rate of 319 terabits per second, over a distance of 3,001 km. Using a common comparison metric of optical fiber transmission, the data-rate distance product of 957 petabits per second x km, is a world record for optical fibers with a standard outer diameter.

Photonic Access Technology

We demonstrated 130-Gbit/s millimeter-wave signal transmission using radio over fiber (RoF) technologies. Combining the RoF technology and conversion devices between radio and optical signals realizes the direct reception of transmitted millimeter-wave signals into the optical fiber transmission line by the photonic down-conversion technique (Fig. 5). These results will help to reduce energy consumption and simplify radio receivers in mobile base stations, which will be installed in huge numbers in the Beyond 5G era.

Wireless Networks Research Center

The Wireless Networks Research Center conducts research and development on wireless network technologies that can connect in any situation or environment by integrating non-terrestrial networks (NTN) and terrestrial systems to achieve seamless global expansion through three dimensional networks from the ocean to outer space.

The Wireless Systems Laboratory is conducting research and development on three sub projects; wireless network control and management technology, wireless network adaptation technology, and technology for improving the reliability of wireless networks. In the field of wireless network control and management technology, in order to contribute to systematizing 5G/Local 5G, the Laboratory is conducting research and development on architecture and base station design and prototypes to enhance the availability of 5G/Local 5G based on the deployment of private microcells, and has provided some demonstrations such as shortening connection times in railroad environments and transmitting high-resolution images for disaster prevention applications. The Laboratory is also conducting research and development on wireless emulation technology that is expected to be fundamental technology for supporting Beyond 5G networks. The developing wireless emulation platform supports the basic functions of 5G NR and IEEE 802.11ax (Fig. 6). In the field of wireless network adaptation technology, as a part of the activities of FFPJ (Flexible Factory Project), a research project formed jointly with private-sector companies, the Laboratory has taken the lead in conducting demonstrations and tests for acquiring data at actual factories and contributed to the standardization of IEEE 802 in collaboration with Germany's DFKI. In the field of technology for improving the reliability of wireless networks, the Laboratory has continued research and development on Device-to-Device (D2D) communication technology which is a wireless access method that does not depend on centralized control by a base station or similar facility, and performed demonstrations for application in systems that watch over elderly people in depopulated rural areas. Activities have also focused on developing systems allowing small shipping vessels to detect each other to enable safer operations of small boats. Also, the Laboratory has continued development and testing of relay control and location information sharing systems for drones by applying the D2D-based communication system.

The Space Communication Systems Laboratory is conducting research and development for optical ground systems and optical devices embarked on satellites that enable optical communication between the ground and the satellite at a speed class of 10 Gbps, as well as in fields such as improving communication quality. Furthermore, in the field of satellite communication using radio waves, the Laboratory is targeting ground systems and various communication devices to embark on the Engineering Test Satellite 9 (ETS-9), which is scheduled for launch in 2023 (Fig. 7).

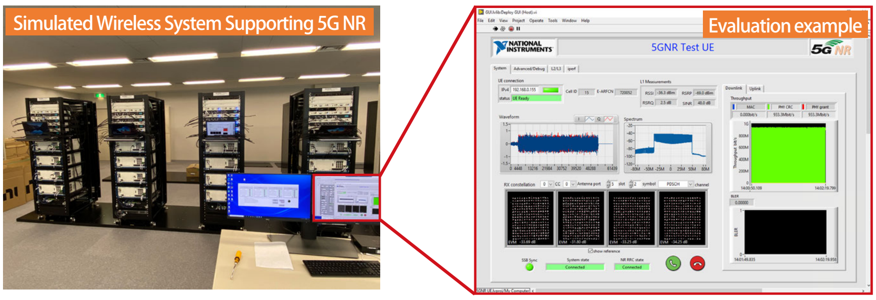


Fig.6 : Simulated wireless system supporting 5G NR

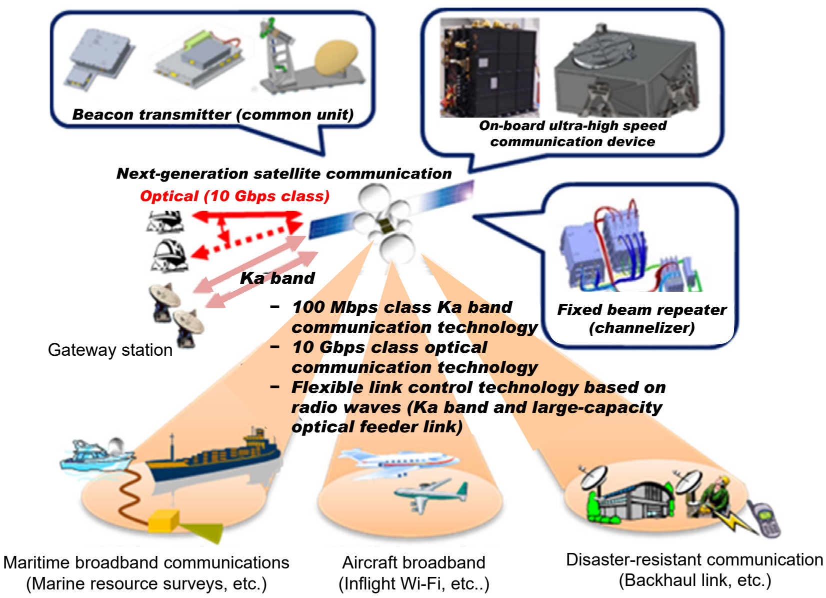


Fig.7 : Flexible link technologies onboard ETS-9

Resilient ICT Research Center

The Resilient ICT Research Center's field of research and development is ICT that improves resiliency against disasters and failures. The Center also conducts research and development for resilient ICT (in terms of response capabilities and recovery capabilities) that will not collapse in the face of events that exceed expectations, as well as research and development for ICT that improves resiliency in everyday social life. Specific technologies subject to research and development include the following:

- Wireless network technology that establishes communication even in spaces where it was previously difficult by combining image data with wireless communication performance prediction based on AI and optimal application of communication resources based on quantum annealing machines.
- Optical network technology that provides functions for detecting and suppressing signs of failure based on AI and telemetering, including physical state information.
- Edge cloud technology that enables flexible configurations on these networks, from single units to any scale desired by the user.
- Natural environment measurement technology that detects sudden changes in natural phenomena by comprehensively analyzing and visualizing multiple types of observation data such as images and sound waves.

The Center is also involved in various other activities and demonstrations to strengthen national infrastructure, including partnerships with domestic and overseas governments and with industry and academia, in order to promote the social use of such technologies.

Advanced ICT Device Laboratory

The Advanced ICT Device Laboratory provides a research environment for innovative device technologies to research groups both inside and outside NICT, and promotes research on device technologies such as optical and radio wave convergent device technology for the Beyond 5G era. The Device Laboratory also contributes not only to the development of device technology, but also to the training of young researchers and engineers for the future. In FY2020, the Device Laboratory recorded use by 162 researchers from 35 external organizations, covering a wide range of research fields from basic research on materials to social applications of communication systems.

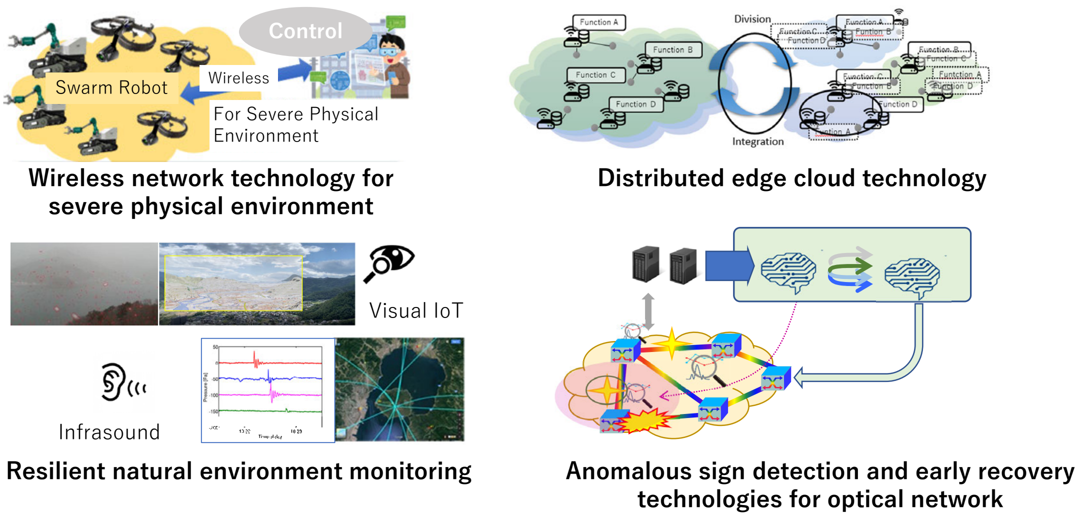


Fig.8 : Research activities of Resilient ICT Research Center

Fig.9 : Clean room at Advanced ICT Device Laboratory

Cybersecurity Area

Cybersecurity Research Institute

Director General MORIAI Shiho

Global cyberattacks exploiting the vulnerabilities of IoT devices and similar equipment have increased over the years, and targeted attacks against companies and public institutions have proliferated. Furthermore, as the utilization of big data to solve social problems has expanded, so has the importance of improving technology to maintain the security of such data. To address these social problems, the Cybersecurity Research Institute conducts research and development on leading edge and practical cybersecurity technologies and cryptographic technologies that support social safety and security from a theoretical perspective.

In April 2021, the Cybersecurity Research Institute changed to a new organization by integrating the National Cyber Training Center and National Cyber Observation Center with the previous Cybersecurity Laboratory and Security Fundamentals Laboratory, and adding the new bodies of Cybersecurity Nexus and General Planning Office (Fig. 1).

Cybersecurity Technologies

In the field of cybersecurity technologies, the Institute expanded cyberattack observation networks that collect and accumulate a wide range of information related to cybersecurity, such as the incident analysis center NICTER. They also further advanced and performed regular operations of active cyberattack observation technologies such as the STARDUST infrastructure for luring cyberattacks. As a result of advancements in various machine learning engines, research related to the classification of IoT malware and research related to attack detection and threat prediction using Graphical Lasso (GLASSO) were featured in academic journals (IEEE Open Journal of the Computer Society and IEICE Transactions on Information and Systems).

Fig.1 : Organization of Cybersecurity Research Institute

The Institute further developed the collection of data such as various communication logs, malware related information, vulnerability information, event information, and incident information to realize the CURE cybersecurity universal repository, while also further advancing and performing regular operations for CURE itself. To strengthen functionality to improve automated countermeasure technology based on CURE, features such as natural language security reports and MITRE ATT&CK were integrated with the system to enable cross-sectional analysis (Fig. 2).

Cryptographic Technologies

In the field of cryptographic technologies, the Institute is conducting research on technologies for secure data utilization and security evaluations of cryptographic schemes to prepare for the age of quantum computing.

With regard to secure data utilization technology, the Institute advanced the social implementation of the DeepProtect privacy-preserving deep learning system that performs deep learning without disclosing the content of data sets owned by multiple participants. They continued research and development on cryptographic primitives

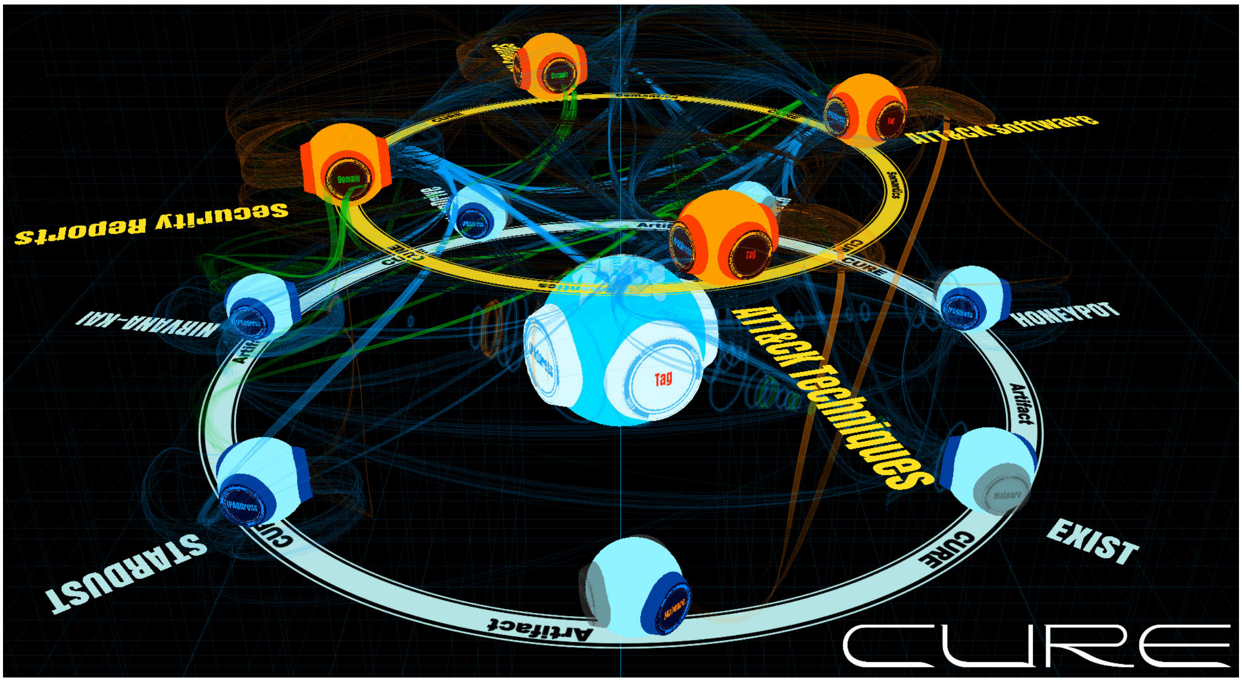


Fig.2 : Enhancement of CURE: advanced visualization engine
The light blue globe at the center is the CURE main unit, and the outer light blue and orange small globes represent databases that store corresponding artifacts and semantics. The CURE main unit performs cross-cutting analysis based on tags for the IP address, domain, malware, and natural language, and when it finds the matching information, it draws a link between the databases.

that will satisfy new social needs, while also performing activities that give back to society by partnering with companies and universities to conduct implementations and evaluations that contribute to security and privacy protection in fields such as IoT systems. Specifically, the Institute participated in a joint project between industry, government, and academia by working with Interstellar Technologies, Inc. and Hosei University to conduct experiments for secure communications technology used by small satellites and small rockets. They also conducted joint research with TIS Inc., proposing an encrypted cache system that can use any TLS cipher suite, and also evaluating performance when post-quantum cryptography is applied.

With regard to security evaluations for cryptographic schemes to prepare for the age of quantum computing, the Institute is conducting research to use quantum computing to solve the discrete logarithm problem, one of bases of cryptographic technology security that support the modern information society. Specifically, they partnered with Keio University, Mitsubishi UFJ Financial Group, and Mizuho Financial Group to take on the challenge of solving the discrete logarithm problem using the "IBM Quantum" quantum computer, and they were the first in the world to succeed in such solution experiments (see Research Highlights).

Cybersecurity Trainings

In April 2017, the Institute established the National Cyber Training Center for cybersecurity training. This organization plans and conducts practical cyber training that fully utilizes resources such as NICT's technological knowledge, research results, and research facilities.

In the field of security operator training, the Institute conducted two exercise programs in order to enable security operators at governmental agencies, private companies, and other organizations to develop the capability to immediately respond to incidents when under cyberattack. These were the CYDER practical cyber defense exercises using actual devices, and the Cyber Colosseo training for the Tokyo 2020 Olympic and Paralympic Games. More than 13,000 people had participated in CYDER by FY2020, making it one of the largest-scale exercise programs in Japan (Fig. 3). In FY2020, past CYDER materials were made available for a limited period as an emergency measure in the novel coronavirus pandemic and as a part of CYDER educational activities. While ensuring all precautions were taken against infection, 106 exercise sessions were held in all 47 prefectures of Japan, and 2,648 people received training. The Institute also started full-scale operation of the CYDERANGE cyber exercise automation system. This enables cyber exercise environments or other systems that are finely optimized to individual courses for local government or national agencies to be developed and operated quickly and at low cost.

In FY2020, the schedule for Cyber Colosseo was postponed due to the growing coronavirus pandemic and the resulting postponement of the Tokyo 2020 Games, and some of the Colosseo College lectures for supplementing the exercises were made available online. The final number of participants over four years was 571 people in Colosseo exercises and 1,717 people in the Colosseo College. The operation finished after achieving the target number of trainees in the original plan.

In the field of security innovator training, the Institute conducted SecHack365 with the aim of training young people aged 25 years or under to become high-level human resources through a long-term hackathon lasting a year. FY2020 was the fourth year of this program, and it had to be postponed due to the coronavirus pandemic, but it was finally held online with the same contents as the previous in-person events. The hackathon's 43 trainees were selected from 225 applicants, and the program included periods called "event week" for making a product and "event day" when everyone participated.

Surveys of IoT Devices with Improper Setting of Passwords, etc.

The Institute established the National Cyber Observation Center in response to increased severity of cyberattacks via malicious use of IoT devices and similar equipment after the amendment of the NICT Act (five-year time-limited measures) that added the survey of IoT devices with weak password settings and other actions to the work of NICT. This survey started from February 2019. To strengthen the activities, in September 2020, the Institute received approval from the Ministry of Internal Affairs and Communications to add IDs/passwords and IP addresses to the survey. From October 2020, they conducted the survey based on this approval, and as a result, the number of notification warnings sent to internet service providers (ISPs) increased to about six times the level before strengthening the activities.

In FY2020, the survey targeted about 112 million IP addresses at 66 ISPs, and even though the survey was canceled in April due to the coronavirus pandemic, approximately 12,804 targets were subjected to user alerts (Fig. 4). The progress of the survey is released monthly on the NOTICE website (https://notice.go.jp/en/status).

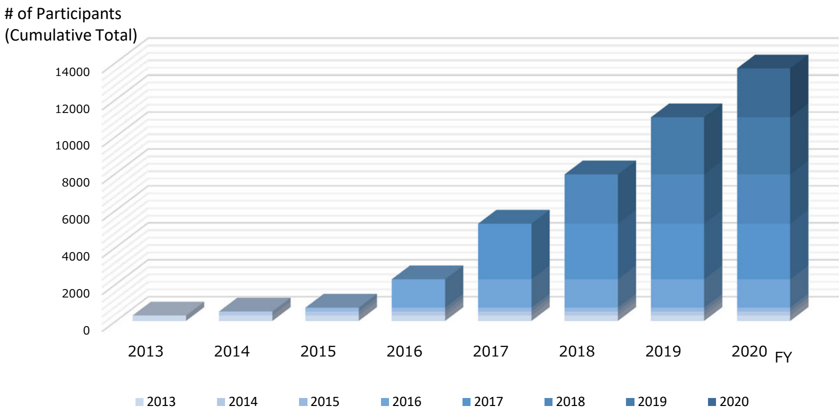
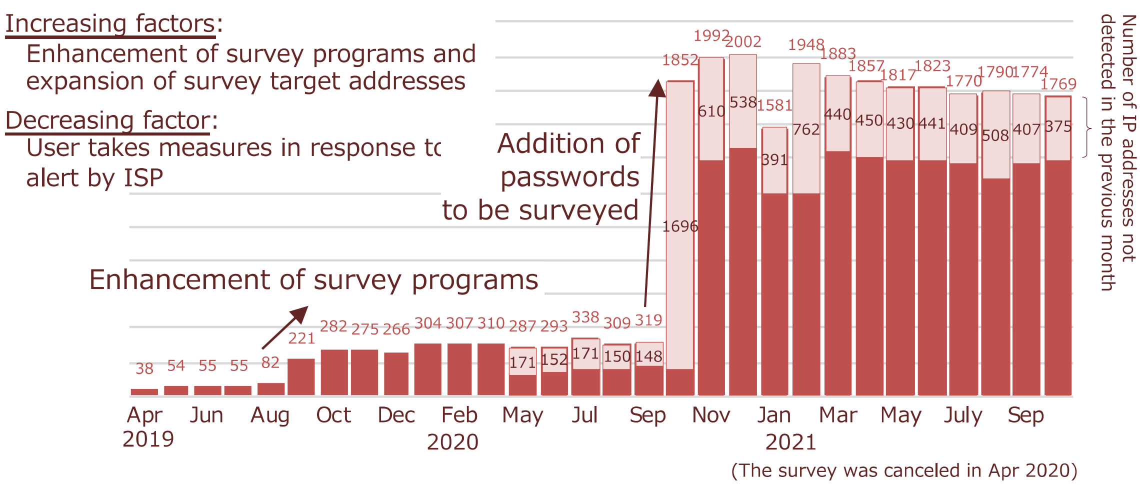


Fig.3 : Progress of CYDER

- NOTICE conducts a monthly survey of IoT devices which can be logged-in using specific easily guessed IDs and passwords
- **66 ISPs** have participated in the NOTICE projects as of October 2021. A survey on about **112 million IP addresses** of the ISPs was conducted.
- **1,769 IP addresses/Devices were successfully logged-in to with weak password settings** and were subject to user alert and ISPs have been notified (October 2021).
  Ref) Total number since FY2019: 27,653
  Devices in which password could be entered: 96 thousand



Number of IP addresses which were subject to user alert

Fig.4 : Progress of NOTICE project

Development of a Government-Industry-Academia Cybersecurity Base

In April 2021, a new organization called Cybersecurity Nexus was established as a place for cybersecurity collaboration between industry, government, and academia. Cybersecurity Nexus collects, accumulates, analyzes, and provides cybersecurity information in Japan and builds a common infrastructure for training cybersecurity human resource across society as a whole, with the aim of becoming a "nexus" between industry, government, and academia.

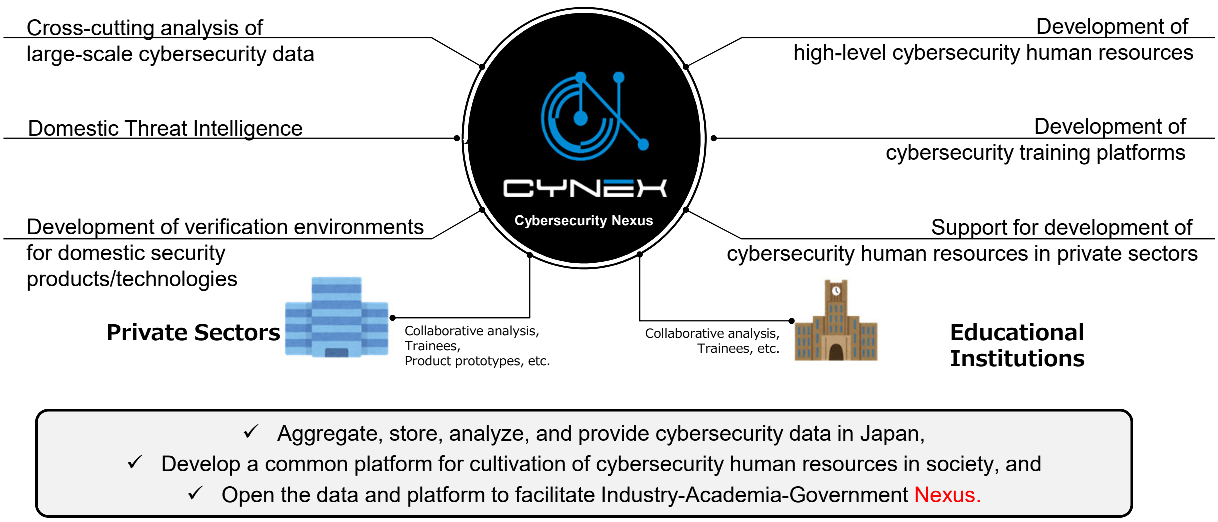


Fig.5 : Development of Industry-Academia-Government Cybersecurity Nexus

Universal Communication Area

Universal Communication Research Institute

Director General　UCHIMOTO Kiyotaka

The Universal Communication Research Institute (UCRI) aims to achieve universal communication that fosters mutual understanding among people. UCRI has developed an AI research platform based on a high-quality, large-scale database specialized for particular fields and focused on the Japanese language, and promotes research and development of the following three core technologies using this platform. Multilingual communication technology which enables low-latency AI simultaneous interpretation that can be used for business situations; data-driven intelligent communication technology which enables spoken dialog systems to use virtual personalities to converse with users based on their interests and backgrounds; and smart data analytics technology, which enables real-world analyses and predictions by connecting all kinds of public and private sensing data from various fields. Furthermore, UCRI is dedicated to developing technologies to uplift the quality of communication required for the social implementation of these three technologies. UCRI is composed of three research centers: Advanced Speech Translation Research and Development Promotion Center; Data-driven Intelligent System Research Center; and Big Data Integration Research Center. These are joined by the Advanced Reality Technology Laboratory, and the General Planning Office: (Fig. 1).

Advanced Speech Translation Research and Development Promotion Center (ASTREC)

In the field of multilingual communication technology, ASTREC has released and is continuing to improve the multilingual speech translation app VoiceTra, as an opportunity to verify the results of its research and development, and in order to accelerate the development of software that will lead to social implementation. Fig. 2 shows the activities for the enhancement of VoiceTra that were performed in FY2020. In particular, by adding speech synthesis for the Nepali language and speech recognition and speech synthesis for the Mongolian language, ASTREC completed the implementation of speech recognition, translation, and speech synthesis for all 15 priority languages in the Global Communication Plan 2025 (https://www.soumu.go.jp/menu_news/s-news/01tsushin03_02000298.html, hereinafter "GC Plan 2025").

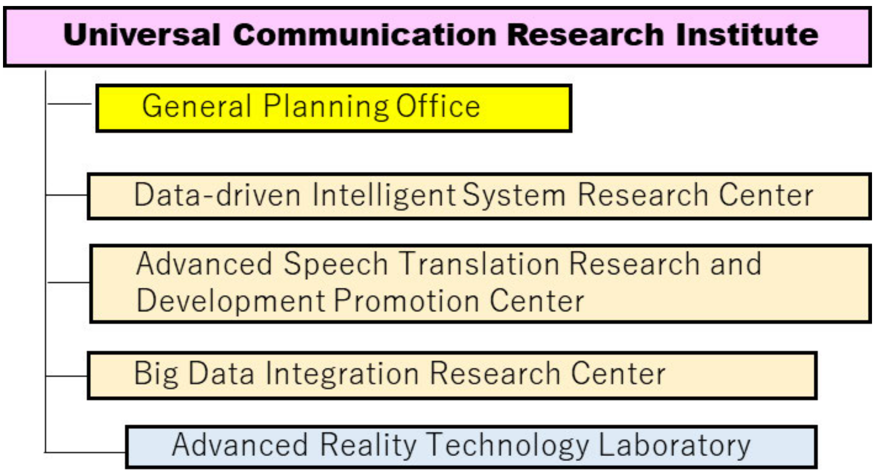


Fig.1 : Organization of Universal Communication Research Institute

ASTREC has been conducting research and development to improve and expand machine translation technology targeted at the 2020 Tokyo Olympic and Paralympic Games, and research continued even after the dates for the event were postponed. ASTREC improved the accuracy of machine translation systems in multiple languages and fields by enhancing the machine translation algorithm and strengthening two types of bilingual corpora. The machine translation algorithm was enhanced through SMT (Statistical Machine Translation), RNN (Recurrent Neutral Net), and TF (Transformer), and then further combined with "fine-tuning" adaptive technology and highly granular "example-based" adaptive technology, which proved that these methods could improve the translation accuracy systematically in each targeted field. As a notable example, by ensuring universality via the bilingual corpora for written language in multiple fields that have been accumulated from the Hon'yaku (Translation) Bank (https://h-bank.nict.go.jp/) and then performing adaptations with the bilingual corpora for spoken language, the machine translation system achieved 80% in translation accuracy rate— a practical level in the fields of travel, medical care, disaster prevention, and daily life, for the 10 languages in the Global Communication Plan (https://www.soumu.go.jp/main_content/000285578.pdf). This has been implemented in the multilingual speech translation app VoiceTra and updates in the engines of the translation system for written text TexTra (https://mt-auto-minhon-mlt.ucri.jgn-x.jp/), and more languages and fields were supported, thereby completing technology transfers without delay and achieving promising results.

Direct licensees for software and databases resulting from ASTREC's research and development increased by another three (three persons), and many updates were made to the license contract in adding languages or new functions to the existing license.

Under the 5th Medium-to-Long Term Plan that has started from FY2021, ASTREC will promote research and development of multilingual communication technology based on the GC Plan 2025 to improve the quality of translation by taking into account the context, speakers' intensions, and diverse sources of information, for instance, from the surrounding conditions. The aim is to achieve automatic simultaneous interpretation on a practical level that can be used even in situations such as business and international conferences. In consideration of Japan's governmental policies on the acceptance and coexistence of foreign human resources, and in anticipation of the Osaka-Kansai Japan EXPO 2025, ASTREC will continue to promote social implementation of simultaneous interpretation systems adapted to new social needs and diverse user interfaces.

Fig.2 : Enhancement of VoiceTra

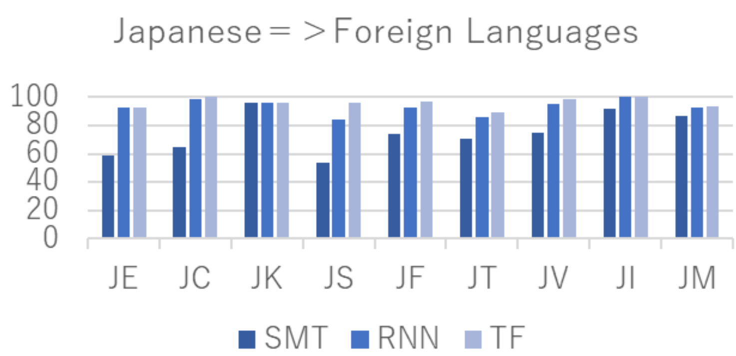


Fig.3 : Highly accurate translation achieved by expanding bilingual corpora and improving algorithms (Example of translation from Japanese to multiple languages)

Data- driven Intelligent System Research Center (DIRECT)

In the field of data-driven intelligent communication technology, DIRECT is promoting the development of the large-scale Web information analysis system WISDOM X; the next-generation speech dialog system WEKDA; as well as the joint development with KDDI Corporation, NEC Solution Innovators, Ltd., and The Japan Research Institute, Limited, of the multimodal spoken dialog system for elderly care MICSUS, with the support of the Cross-ministerial Strategic Innovation Program (SIP) (Second Phase) "Big-Data and AI-Enabled Cyberspace Technologies." Deep learning technologies have been deployed in WISDOM X and a trial version has been released (website: https://www.wisdom-nict.jp/).

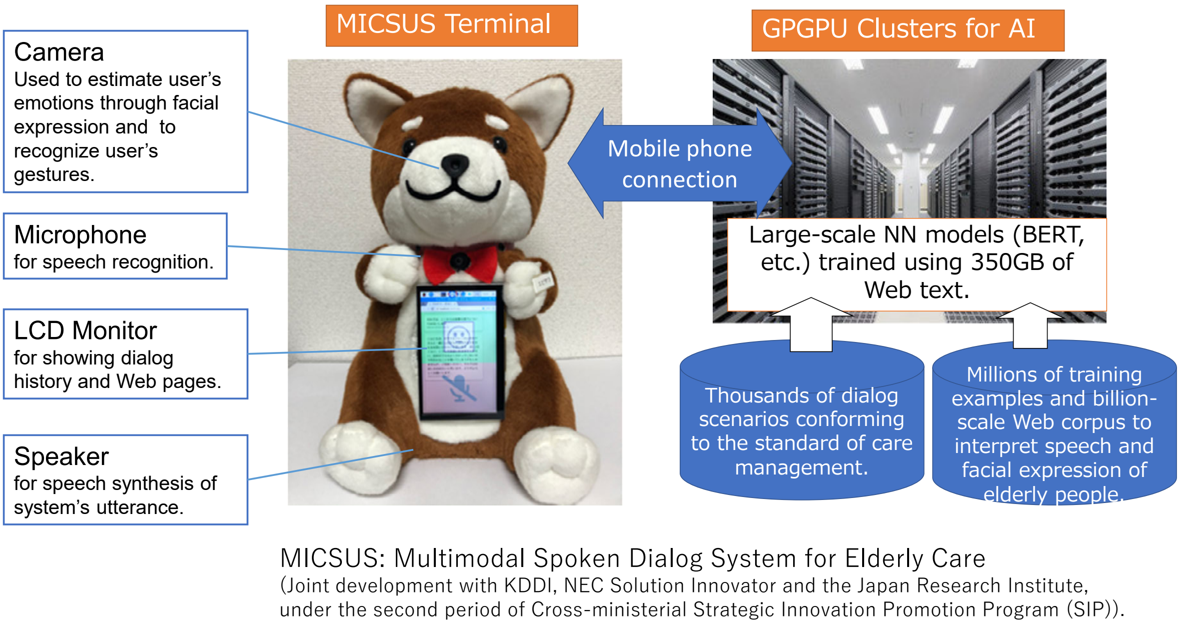


Fig.4 : MICSUS: Multimodal Spoken Dialog System for Elderly Care

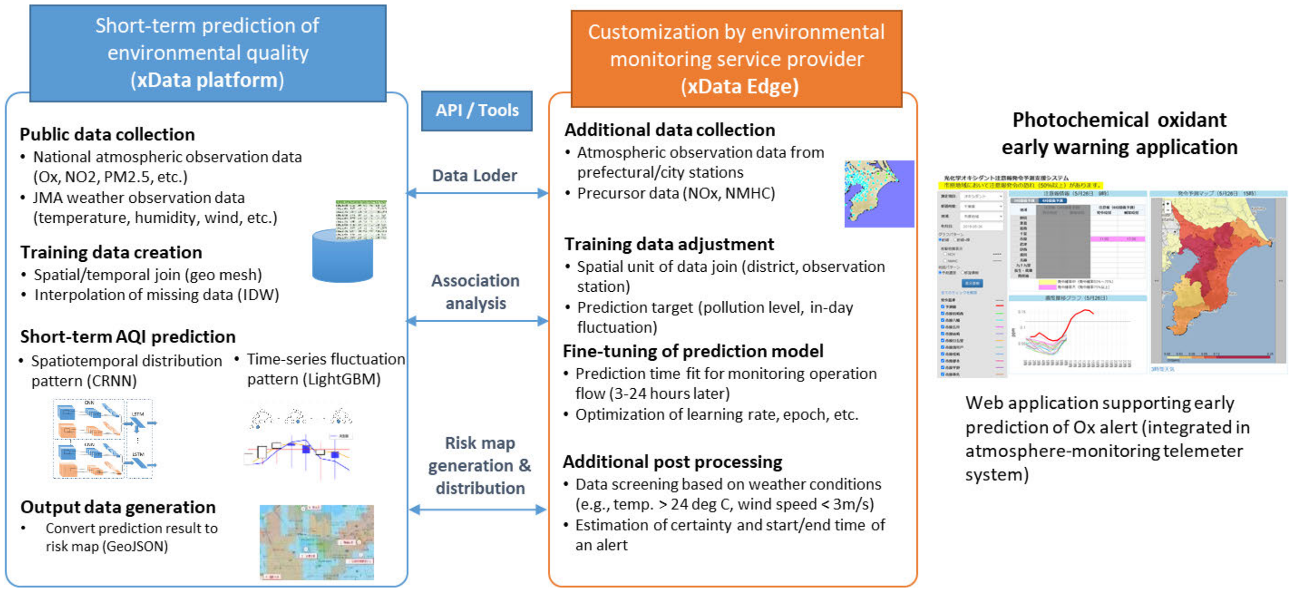


Fig.5 : An example of collaborative application development using xData platform

This deep learning version make use of a large-scale neural network called BERT — which has attracted attention in recent years — trained with a large amount of Web text data (approximately 350 GB) and a large amount of high-quality learning data developed at NICT. Together with an in-house improved version that combines BERT with adversarial learning, the accuracy of responses was improved to support a wider range of questions than the previously released non-deep-learning version.

The purpose of MICSUS is to reduce the burdens of elderly care which has recently been recognized as a major social issue. MISCUS not only attempts to lessen work burdens in the care industry by using AI to replace tasks such as checking the health condition and lifestyle habits of elderly people who live at home, it also supports chatting over a wide variety of topics to keep the users motivated to speak, as it is known that a higher frequency of communication is key to maintaining a healthy life. This chat function from WEKDA utilizes the previously described WISDOM X technology and the dialog function of the KACTUS chat engine that was developed by KDDI. In between health checks, the system can provide responses across a wide range of topics and can also answer to questions of elderly people based on information extracted from a huge number of Web pages (Fig. 4).

Big Data Integration (BDI) Research Center

In the field of smart data analytics technology, in order to promote the social implementation of a cross-data analysis (xData) platform, the BDI Research Center has been developing technology that enables distributed collaborative development among users of the platform by utilizing a wide range of cross-data analysis base models (e.g., environmental quality short-term predictions, mobile environment risk predictions, and environmental sleep quality predictions) on the platform that were developed from their own research and hackathons (Fig. 5). The Center developed a distributed development environment for xData analysis models called xData Edge where users can collect their own data, adjust association analysis and prediction models, and customize data distribution using the xData platform API, In a field experiment for countermeasures against environmental problems, xData Edge, in which API and development tools were together packaged in a virtual environment (Docker) was deployed in the servers and cloud environments of platform users (demonstration partners), allowing them to develop multiple xData analysis models in parallel, thereby demonstrating the effectiveness of distributed development using xData Edge. Also, by feeding back some of the data and processes customized by the users into the system, a co-creation type of development was achieved where users upgrade and expand xData analysis models while linking them with their own research. As an example, a field experiment was conducted to provide support for countermeasures against environmental problems at local governments, smart cities, etc.

Fig.6 : Demonstration of safe and comfortable route navigation by predicting mobility environment risk based on xData analysis

Frontier Science Area

Advanced ICT Research Institute

Director General WADA Naoya

In FY2021, besides two existing research centers, Kobe Frontier Research Center and Koganei Frontier Research Center, the Center for Information and Neural Networks (CiNet) at Suita district in Osaka was joined to the Advanced ICT Research Institute to establish a new organization. This maximizes the Institute's strength and potential over wider a range of research areas than before, energetically driving forward innovative research activities in the pursuit of ICT in future (Fig. 1).

Kobe Frontier Research Center

In the field of superconductive ICT technology, to enable the wider application of superconducting single photon detectors (SSPD), the Center achieved detection efficiency of over 90% at a dark count rate of 1 count per second or less for 850 nm band SSPD. The Center also achieved a detection efficiency of 80% in 16-pixel SSPD + SFQ multiplexed signal processing, and successfully developed high-speed responses with a time interval of 1 ns. In the research and development of nitride superconducting qubits that are the foundational technology of quantum communication, the Center established technology for creating fully epitaxial nitride Josephson junctions (Fig. 2) and demonstrated coherence time exceeding 20 μs.

In the field of nano-scale functional assembly ICT technology, in order to develop broadband THz detection devices to achieve next-generation wireless communication, the Center developed the world's first general-purpose transfer process technology for EO polymer films. The Center developed prototypes of EO polymer waveguide THz detectors with ground electrodes and demonstrated direct modulation using 100 GHz electromagnetic waves, establishing a ToF (THz over Fiber) technology platform that will help move to the era Beyond 5G / 6G.

In the field of Bio-ICT technology, the Center is conducting research and development for basic technology that extracts and uses various types of information that utilizes the excellent properties of biomaterials such as molecules and cells. The objective is to provide sensing that conforms to the senses of living things, thus improving QOL.

Fig.1 : Organization of Advanced ICT Research Institute

In research and technological development for information detection systems using biomaterials, the Center succeeded in creating a molecule sorter that branches in the Y shape required for building a DNA circuit, and demonstrated that two types of molecular transporters could actually be sorted.

In the field of biological function control and evaluation technology, the Center carried out the research and development of fluorescence microscope technology for the highly accurate measurement of biomaterial responses. The Center developed a new calculation method for implementing adaptive optics that removes optical effects by complex light refraction generated in deep part observation of biological tissue and restores the resolution after acquiring a regular 3D image (Fig. 3).

In the field of deep-ultraviolet (DUV) ICT technology, the Center is conducting research and development for AlGaN-based DUV light-emitting diodes (LEDs) for applications in areas such as non-line-of-sight (NLOS) solar-blind optical communications, air purification, water disinfection, and surface sterilization. The external quantum efficiency and optical output power in electrically injected AlGaN-based DUV-LEDs are severely limited by their

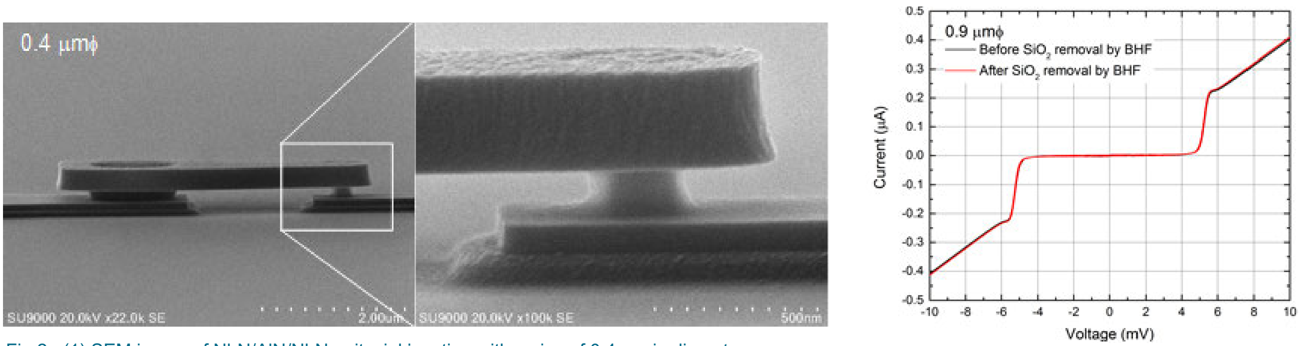


Fig.2 : (1) SEM image of NbN/AlN/NbN epitaxial junction with a size of 0.4 μm in diameter
(2) Current-voltage characteristics before and after SiO_2 removal by BHF

poor carrier injection efficiency (CIE). To solve this problem, the energy band diagrams and hole distributions around the hole injection layer of DUV-LEDs were explored both theoretically and experimentally. We then proposed and demonstrated a new approach to introduce a local piezoelectric field by controlling the strain relaxation during the epitaxial growth of DUV-LEDs, which can provide abundant holes to be injected into the active regions and can enhance the CIE by a factor of approximately two times (Fig. 4).

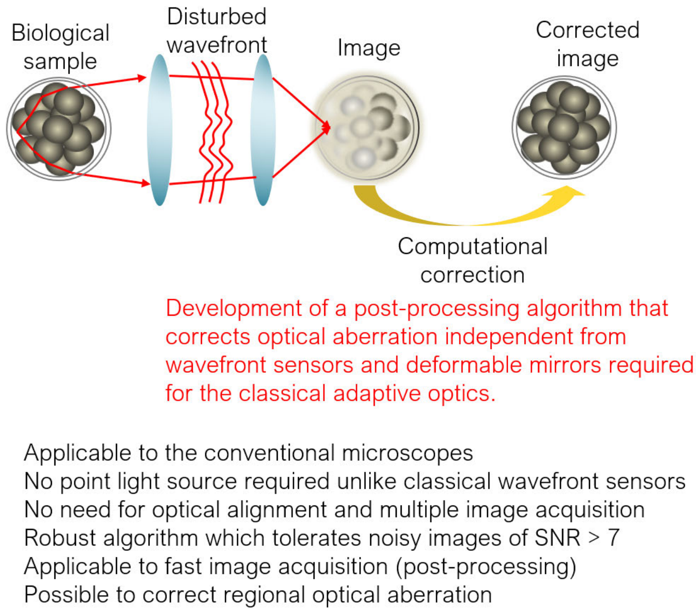


Fig.3 : Computational adaptive optics for deep biological imaging

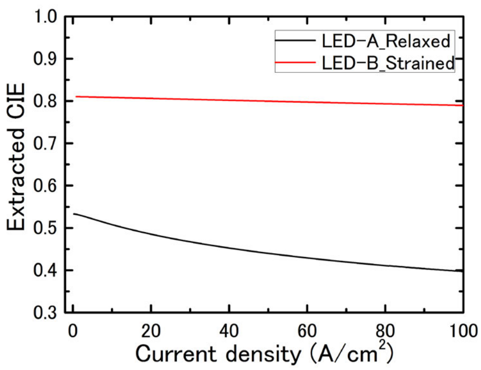


Fig.4 : Experimentally extracted current injection efficiencies of DUV-LEDs

Koganei Frontier Research Center

In the field of ultra-high frequency ICT technology, for such developments as semiconductor devices and passive elements for achieving terahertz-wave integrated circuits (ICs), the Center is continuing to develop 300 GHz band wireless transmitters and receivers using silicon CMOS ICs, as well as producing such technologies as the power control ICs that are required for the systematization. Meanwhile, the Center evaluated the output performance of GaN-based HEMTs, which are compound semiconductor electronic devices and exhibit a maximum oscillation frequency (f_{max}) of 287 GHz, and it confirmed high output power density (output power P_{out} per gate width W_g = 1 mm) of 0.75 W/mm or higher at a frequency of 70 GHz, which is more than seven times the level of InGaAs-based HEMTs produced by NICT that have f_{max} of 400 GHz or higher. The Center also developed elemental technologies required for 300 GHz wireless video transmission systems. In the research and development of highly stable light sources applicable to wireless communication and measurement systems in ultra-high frequency (THz) ranges, the Center succeeded in generating an optical Kerr comb using a silicon nitride microresonator. Based on this technology, they generated terahertz waves more than 100

GHz and the output/frequency characteristics were evaluated (Fig. 5).

In the field of green ICT devices, the Center is promoting joint research and development with universities and companies both in Japan and internationally to develop such devices as high-frequency devices, extreme environment ICT devices, and high-efficiency power devices by utilizing the characteristics of a new semiconductor material called Ga_2O_3 that was discovered independently by NICT. The Center conducted joint research with the University of Bristol and Cardiff University in the United Kingdom about high-frequency power output characteristics for Ga_2O_3 field effect transistors (FETs) that recorded the world's highest maximum oscillation frequency (f_{max}) of 27 GHz. For Ga_2O_3 FETs with a gate length of 300 nm, and a maximum RF output power density of 0.58 W/mm was obtained.

The Center also performed research to improve the reliability and mass productivity of lateral Ga_2O_3 FETs. The Center tried to reduce buffer leakage by performing Mg- or Fe-ion implantation doping to a region near the Ga_2O_3 substrate surface before performing epitaxial growth of the Ga_2O_3 buffer and channel layers on it; the doped Mg and Fe are expected to serve as deep acceptors or traps compensating interfacial Si donors. As a result, it was confirmed that in the Fe-doped devices, the buffer leakage was greatly reduced to a level where no problems were caused when applied in analog devices such as amplifiers (Fig. 6).

In the field of quantum ICT technology, the Center implemented a third-party authentication function with security based on information theory in the secret sharing distributed storage system on the Tokyo QKD Network. This distributed storage system was also incorporated into the facial recognition system that the Center had continued demonstrating since the previous year. The system is used to protect the data server that is used by Japan's national team of sports players to store medical records and other data. These field demonstrations were successful. On the same system, the Center implemented systems for the distributed storage of biometric data used for facial recognition and for the distributed storage of electronic medical records that complies with the standards for handling medical information (SS-MIX). These demonstrations for social implementation were successful. In the field of quantum-optical technology, the Center developed a new method to improve the indistinguishability of photons generated by an ultrafast entangled photon pair source using temporal filtering, and successfully observed a high-visibility two-photon interference at a repetition rate of 3.2 GHz, which is the world's highest rate (Fig. 7).

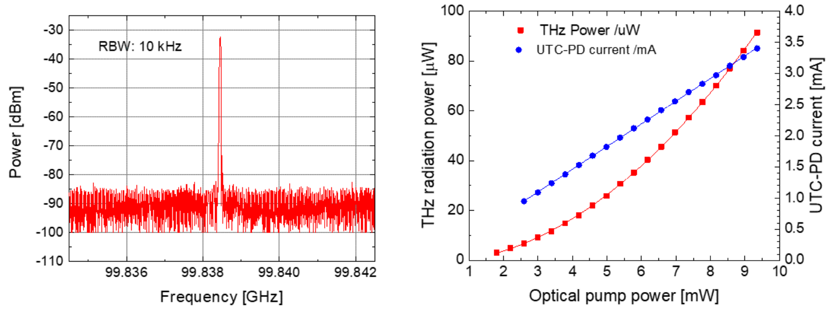


Fig.5 : Measured characteristics of terahertz signal generated from micro-comb. 100 GHz-signal spectrum (left) and optical input dependence of 100 GHz signal output (right)

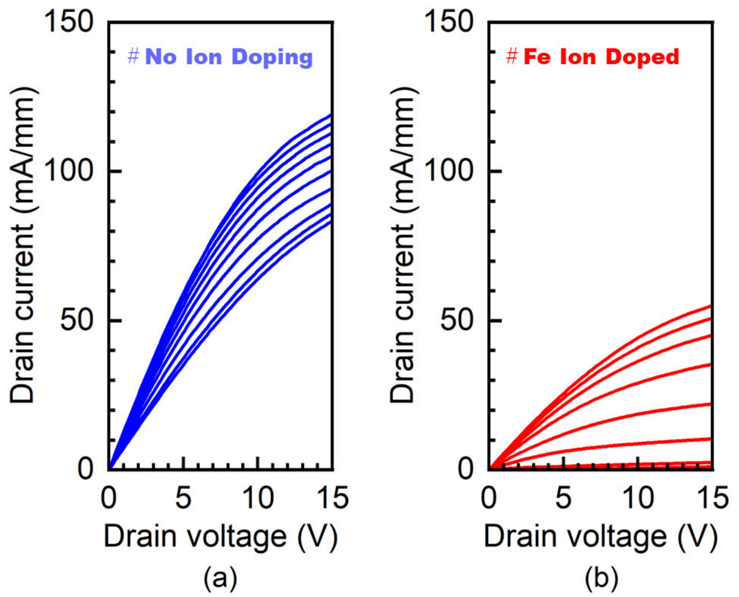


Fig.6 : Ga_2O_3 characteristics evaluation
Effect of Fe ion implantation doping on substrate for horizontal Ga_2O_3 FET
(a) Without Fe ion implantation,
(b) With Fe ion implantation. Drain leak current is greatly reduced by performing Fe ion implantation.

Center for Information and Neural Networks(CiNet)

In the field of neural network and communications technology, CiNet develops technologies that maintain and improve the motor and sensory capabilities of individuals. CiNet is continuing research and development in fields such as motion correction systems and virtual human musculoskeletal models with the aim of applying them to prevent motor function decline in elderly people and to help rehabilitation. CiNet has also partnered with Osaka University to conduct research and development with the aim of realizing and

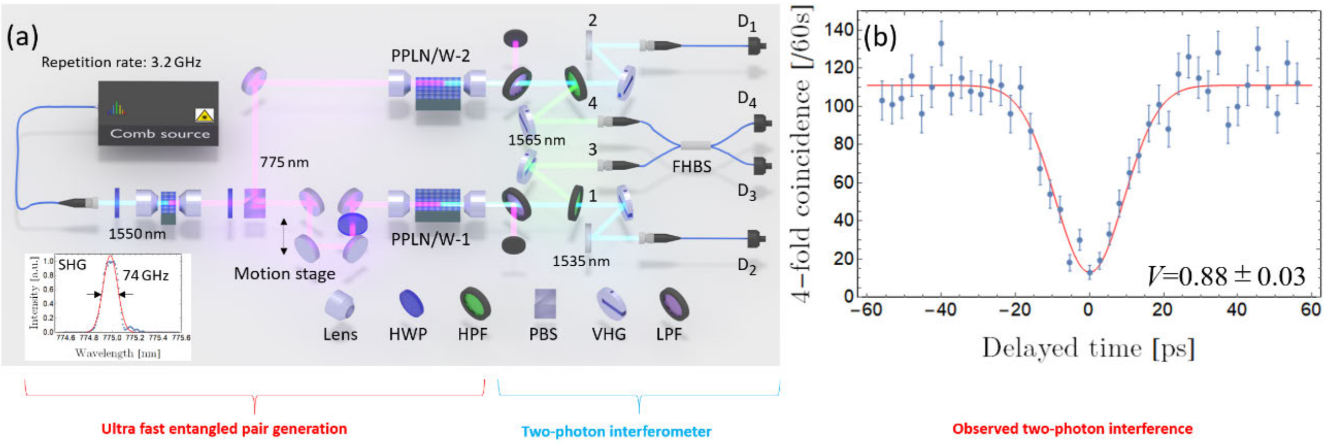


Fig.7 : The two-photon interference experiment using ultrafast entangled photon pair sources. (a) Experimental setup. (b) Observed two-photon interference

advancing a fully implantable wireless electrocorticogram (ECoG) measurement system for BMI. Regarding the electrodes for ECoG measurement, CiNet created a prototype of a surface electrode array that is much denser and has more electrodes (electrode diameter 0.05 mm, electrode interval 0.3 mm) compared to the electrode array currently used in clinical applications (electrode diameter approximately 4 mm, electrode interval approximately 10 mm). A total of 1,152 electrodes were arranged on a flexible substrate made of Parylene C (polychloroparaxylylene: thickness 0.02 mm). By directly connecting the surface electrode array to printed circuits boards equipped with 18 neural signal processing LSIs (64 channels, amplification and AD conversion), the number of wires from the 1,152 electrodes was reduced (Fig. 8).

In the field of neural information engineering technology, CiNet advanced the identification of brain activity related to English listening proficiency to build a model based on machine learning. This made it possible to estimate the approximate level of English proficiency immediately from the brain response when listening to English. CiNet is also researching internal brain networks related to individual differences in working memory used to store and process information on a short-term basis in everyday life. It was shown that individual differences in working memory appear in internal brain networks that manifest themselves in brain activity when at rest and not doing any particular task. CiNet also advanced the development of APCMA, which is a communication algorithm that imitates the activity of nerve cells. This technology is expected to be used in IoT, and testing was conducted by performing simulations with thousands of units and developing hundreds of devices.

In the field of brain function analysis technology, CiNet performed a wide range of brain function measurements by fully utilizing four MRI devices and one MEG device, and also developed new measure-

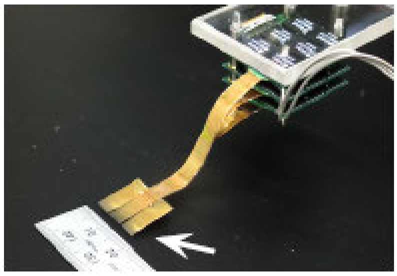


Fig.8 : The high-density neural sensor developed by CiNet. The flexible sheet (white arrow) has 1,152 electrodes on its surface for precise measurement.

ment methods. CiNet completed a method that divides the brain tissue of gray matter/white matter and cerebral arteries in a short calculation time using the contrast of the MRI brain structure images. The division of cerebral blood vessels with this method improves the accuracy of brain function and volume analysis, and the results were published as an original paper in the NeuroImage journal.

B5G Field

Beyond 5G Research and Development Promotion Unit

Executive Director HOSAKO Iwao

The Beyond 5G Research and Development Promotion Unit was established in April 2021 as an organization that accelerates research and development while coordinating, both inside and outside of NICT, towards Society 5.0.

Activities in 2021

The Beyond 5G Research and Development Promotion Unit (hereinafter "B5G Unit") was launched in April alongside the start of NICT's Fifth Medium-to-Long-Term Plan, which lists "AI," "Beyond 5G," "Quantum Information and Communications," and "Cybersecurity" as four areas of research that should be strategically pursued (four strategic areas). Beyond 5G is one of these strategic areas, and the B5G Unit is a newly established organization. Beyond 5G spans an extremely wide range of technical fields and needs to be addressed by NICT as a whole (Fig. 1). We are expected to play a coordinating role by aligning all the various organizations in each area of research.

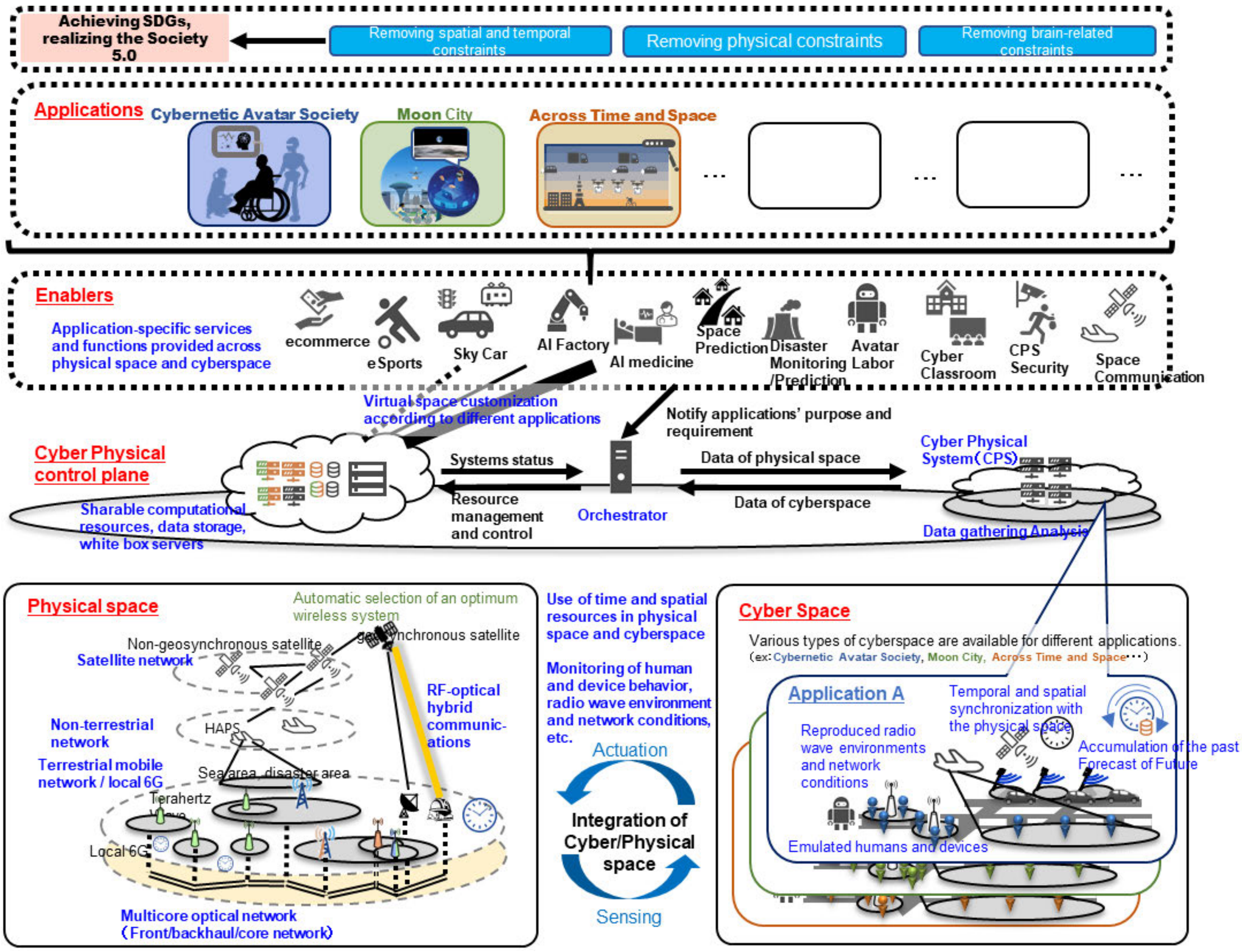


Fig.1 : Conceptional diagram of Beyond 5G / 6G technology

At the beginning, with the aim of promoting research and development of Beyond 5G, volunteers in various divisions of NICT gathered and held discussions about images of society and use cases that will be realized by Beyond 5G, as well as the necessary elemental technologies and the research and development roadmap to get there. These discussions were eventually compiled into a white paper and published in March 2021 as the "Beyond 5G / 6G White Paper (Japanese ver. 1.0)," and in August (English ver. 1.0).

At the same time as these discussions, NICT's Fifth Medium-to-Long-Term Plan was being formulated, and the idea to establish the organization was also conceived in parallel.

The B5G Unit includes the General Planning Office, Beyond 5G Design Initiative, and the Terahertz Technology Research Center (Fig. 2). The Beyond 5G Design Initiative specializes in the role of acting as a control tower for Beyond 5G. The Terahertz Technology Research Center is the section that actually promotes the research and development of the elemental technologies that will be essential for Beyond 5G. The center currently focuses on two areas of research; the development of a Terahertz wireless testbed and Terahertz measurement technology. In addition to these research activities, the center also promotes international standardization at ITU-R and IEEE 802.

In addition to these organizations, we are involved in several other projects. One of our current projects is to conduct research and development of radio wave emulators under the commission of a Ministry of Internal Affairs and Communications project called "Advancing Radio Wave Simulation System Technologies in Virtual Space." Radio wave emulators are real-time simulations of complicated and large-scale radio wave systems in a virtual space. Radio waves will need to be used in all fields, particularly in the world of Beyond 5G, which is why the large-scale verification of radio systems is extremely important and the reason why this project is under our Unit. Another reason is that it is a horizontal process that involves people from a variety of research institutes at NICT.

Fig.2 : Organization of Beyond 5G Research and Development Promotion Unit

Quantum ICT Field

Quantum ICT Collaboration Center

Director General SASAKI Masahide

Quantum ICT Collaboration Center was established in April 2021, aiming at investigating a new cross-disciplinary field of quantum security by merging quantum communication and cryptography, and network technologies. The center is also promoting construction of a quantum technology platform which integrates quantum computing, quantum communication and cryptography, and quantum metrology and sensing.

To this end, the Japanese government announced the Integrated Innovation Strategy. In this strategy, NICT was appointed to be Quantum Security Research Hub as one of eight research hubs. In cooperation with related research groups within NICT, we closely collaborate with other quantum innovation hubs, universities, companies, and public organizations in Japan and overseas, and work on basic research, technology deployment, open innovation, and development of quantum ICT workforces.

Activities in 2021

Quantum ICT Collaboration Center has three missions. The first is research and development on quantum basic technology, quantum security, satellite quantum communication, and quantum networks. The second is implementation and test activities, and development and operation of quantum open testbeds. The third is social implementation, international standardization, intellectual properties, evaluation, and international collaboration. We also hold the NICT Quantum Camp for development of quantum ICT workforces.

Quantum Secure Cloud Technology

Quantum secure cloud technology is an example of a new technological paradigm brought about by such convergence(Fig. 1). By combining quantum cryptography with secret sharing, quantum secure cloud technology enables secure data backup storage that will not leak secrets in the future and will not lose data even in a disaster. In addition, by incorporating post-quantum cryptography and secret computation, it is possible to prevent spoofing and falsification, and to utilize secure data for secondary use while keeping it secret. Quantum secure cloud technology is expected to enable the storage, exchange, and use of highly confidential data such as personal and corporate information accumulated in the medical, new materials, manufacturing, and financial sectors.

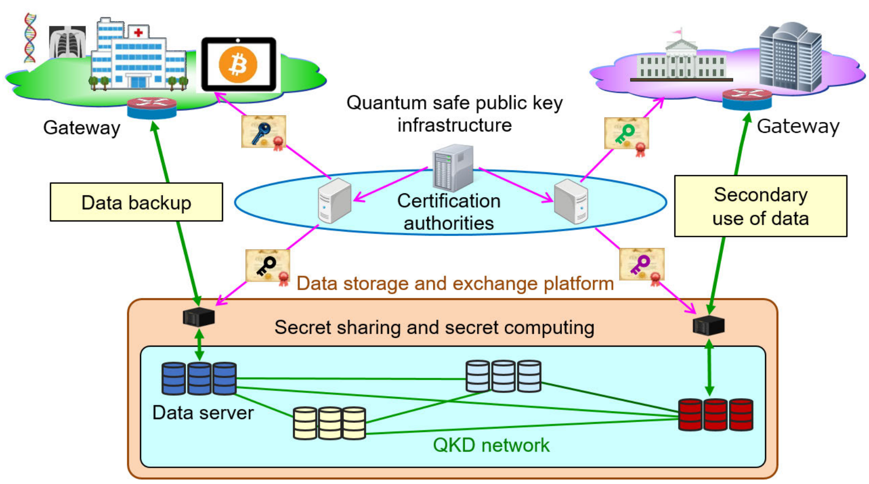


Fig.1 : Quantum secure cloud technology

Quantum Network

In addition, by equipping drones and satellites with technologies created in the quantum security field and deploying them in spatial and satellite optical communications, we will be able to realize a high-capacity and secure mobile communications network (quantum network) that covers space, the stratosphere, high altitudes, and terrestrial networks.

The radio spectrum used in today's mobile communications networks is already reaching its capacity, and it is not enough to support the rapidly increasing amount of data traffic. In contrast, the laser light used in spatial and satellite optical communications can transmit information in a much wider spectrum than radio waves, and because of its high directivity, it can increase the efficiency of power use. It also has the advantage of being able to significantly reduce interference, thus requiring no license. In addition, since there is little attenuation of light in space, it is possible to use quantum cryptography on a global scale, which was not possible with terrestrial optical fiber lines.

Finally, we aim to realize quantum network (quantum Internet) technology by combining these technologies with quantum computing and quantum metrology and sensing, and to build a quantum technology platform by integrating these technologies on the conventional network infrastructure (Fig. 2).

White Papers on Quantum Network

NICT has published a white paper that outlines domestic and international trends in quantum communications, the images and use cases of a society in which quantum networks will be realized, and the R&D roadmaps and promotion strategies that NICT is working to achieve.

Please see Quantum Network White Paper Summary for more details.

NICT Quantum Camp

NICT has started NICT Quantum Camp (NQC) to promote the next generation of quantum ICT researchers and engineers from FY 2020 (Fig.3). A unique feature of NQC is to provide not only lectures on quantum ICT but also hands-on training programs such as practice with quantum computer, and exploratory research course, under industry-academia-government collaboration.

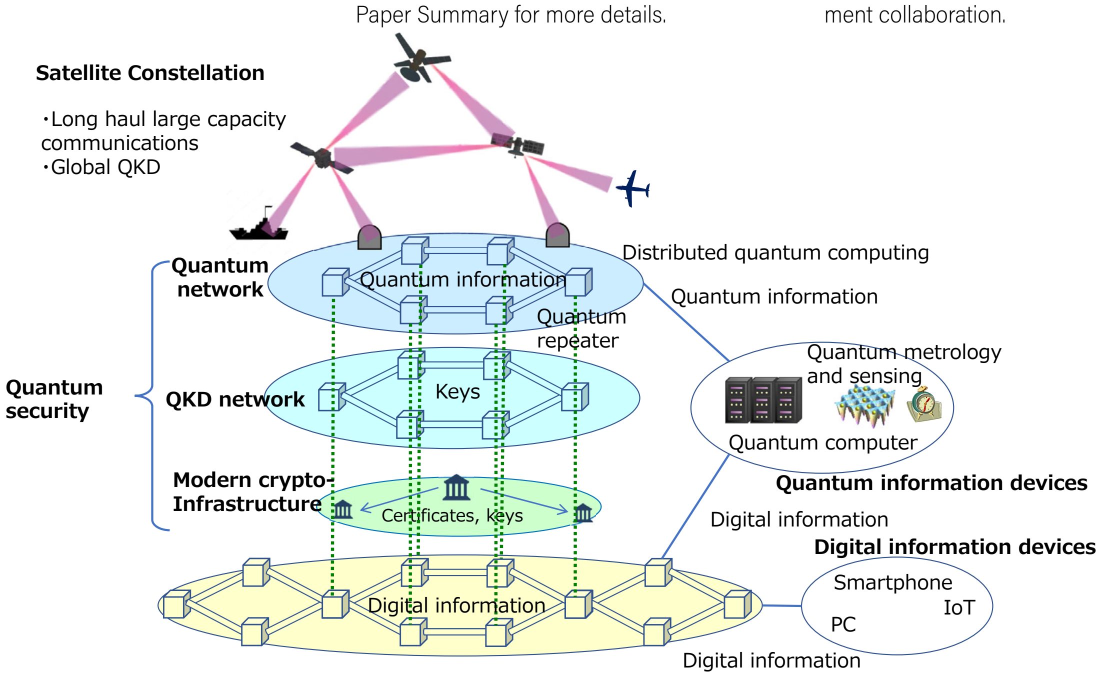


Fig.2 : Schematic structure of quantum technology platform

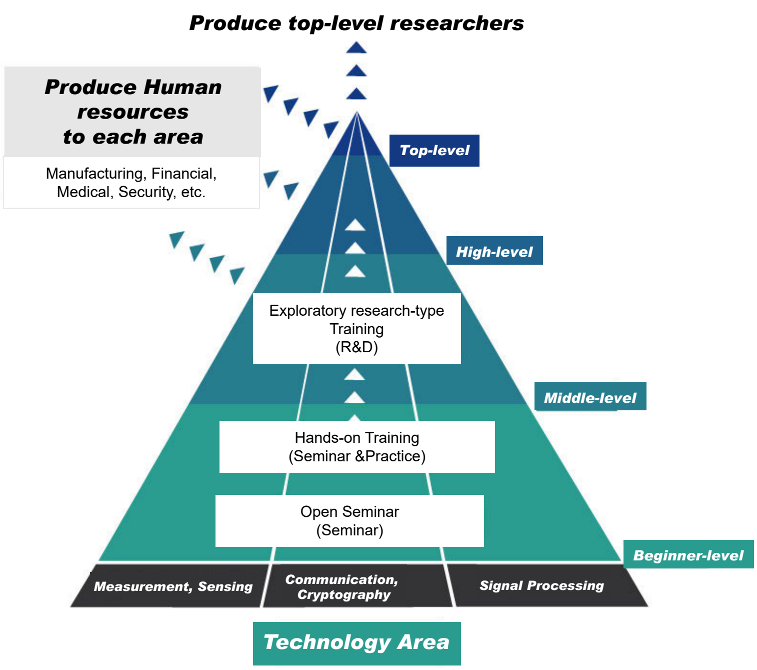


Fig.3 : Overview of NICT Quantum Camp

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General KOJIMA Fumihide

ICT Testbed Research and Development Promotion Center has integrated testbeds such as the High Speed R&D Network Testbed (JGN) and Large Scale Emulation Testbed (StarBED) to expand services as NICT's Integrated Testbed. This enables the Center to build and operate testbeds that support various types of IoT demonstrations and tests, from actual infrastructure to emulation (Fig. 1).

The Center is also conducting research and development for the basic technology needed for realizing testbeds. These include a large scale actual infrastructure testbed that is built based on the JGN and deploys leading edge ICT on actual infrastructure to perform technical verifications with high levels of feasibility, and StarBED that can perform various technical verifications by partially combining simulated infrastructure. Furthermore, the Center is conducting research and development on service infrastructure based on the emergence of new systems that apply synergies from cross-sectional integration and fusion across different fields and industries.

Construction and Operation of NICT's Integrated Testbed

NICT's Integrated Testbed is a testbed built to promote technical demonstrations and social demonstrations of the results of ICT research and development both inside and outside NICT. In the environment of NICT's Integrated Testbed Application Study Group that enables NICT's Integrated Testbed to be tested in an experimental and easy manner, the Center established a new system that enabled the members of the Utilization Research Group to provide devices, software, functions, and data or other services from their own companies to be tested by other Group members. The Center has also started to build and provide a multi-tenant testbed environment for P4, a next-generation SDN programming language.

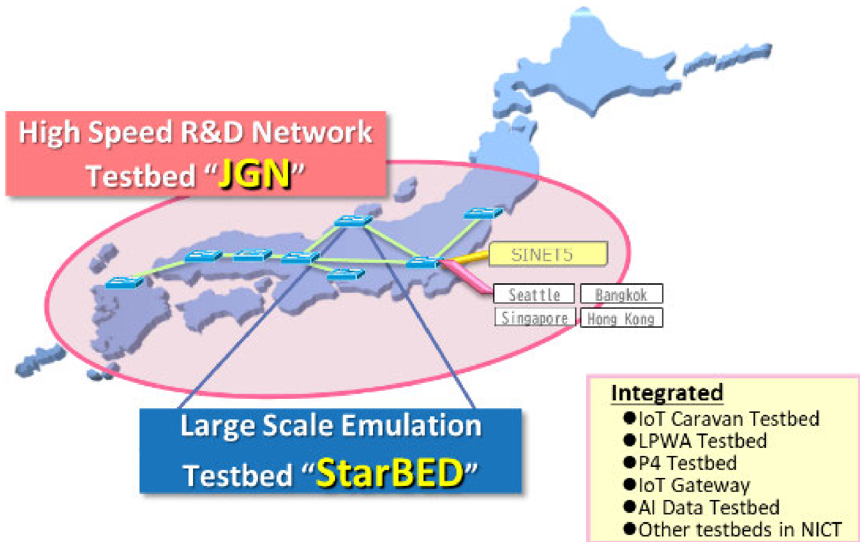


Fig.1 : NICT's Integrated Testbed

Activities for Advanced IoT Infrastructure Technologies

To realize connected cars in an environment where the public infrastructure is still under development, the Center enhanced the Vehicular Delay Tolerant Network (VDTN) method using a hybrid system of vehicle-to-vehicle communication and narrow-band mobile communication that were proposed up to last year. Based on this, the Center studied and implemented methods that greatly improved data collection performance (Fig. 2).

Development of Edge Computing Environments

The Center built an edge computing testbed on StarBED that operates an edge computing environment compatible with Kubernetes that is widely used on the existing cloud based on virtual regions (Fig. 3), and started to provide pilot services such as technical demonstrations of in-network video compositing applications.

Research and Development on Infrastructure Technology Provided by StarBED

The Center developed software that comprehensively manages the hardware wireless link emulator that can simulate Wi-Fi and LTE wireless devices and software wireless link emulator NETorium that can simulate more than 1,000 virtual wireless devices (Fig. 4). A radio propagation model created based on data acquired in actual environments was applied to enable realistic verifications even outside of locations where data is acquired, without transmitting radio waves. 802.11p and 802.11ac were added as supported wireless systems, and the bandwidths that can be simulated were expanded to more than 1 Gbps.

The Center performed emulation for verifying sprayer operation patterns at orchards using the Smithsonian infrastructure for linking multiple simulators and emulators, and BluMoon that simulates Bluetooth Low Energy (BLE) beacons. This is planned to be used as emulation to efficiently decide how to patrol the sprayer (Fig. 5).

Research and Development on Service Infrastructure Based on Emergence of New Systems

The Center is pursuing activities that prioritize social contribution, such as promoting demonstrations that link multiple diverse companies, based on the emergence of services that use IoT, which will be required in the post-Covid "new normal" era. As a pilot project for the utilization of testbeds that can promote technical demonstrations and social demonstrations in an integrated manner, the Center conducted activities such as support for collaboration between humans and robots based on IoT wireless technology (Fig. 6), which will result in the creation of open innovation.

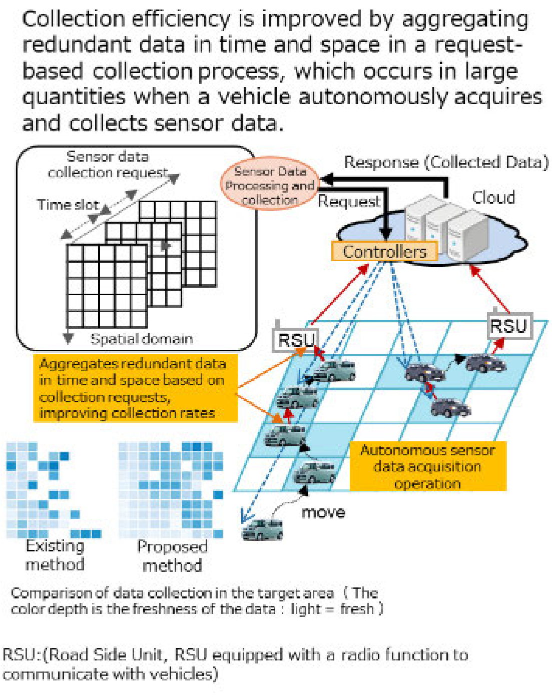


Fig.2 : Sensor network for drive automation

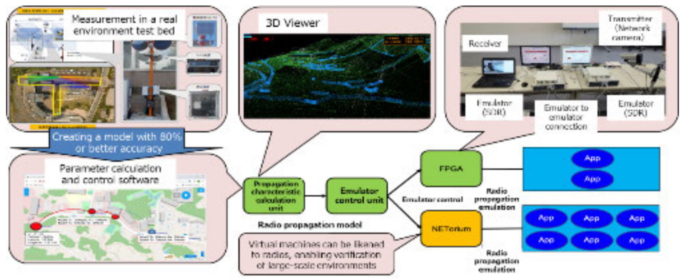


Fig.4 : Development of integrated management software for HW wireless link emulator and SW wireless link emulator "NETorium"

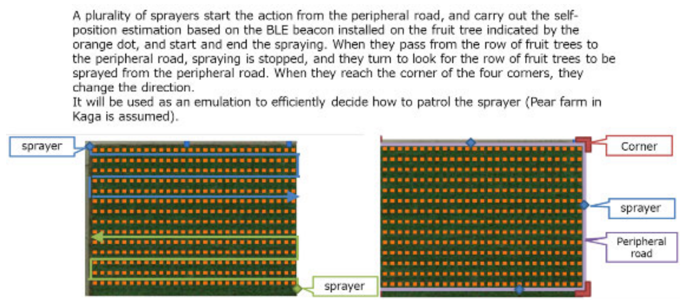


Fig.5 : Emulation of sprayers movement in orchard

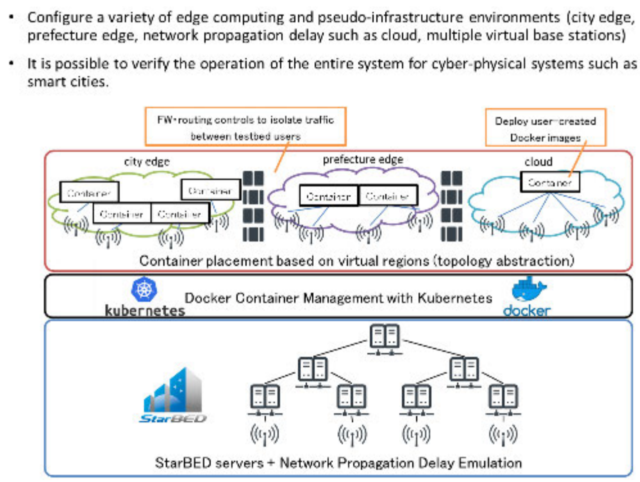


Fig.3 : Edge computing testbed

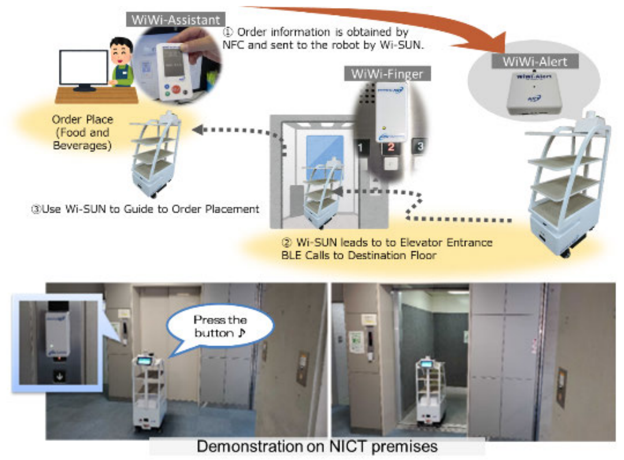


Fig.6 : A floor movement support system using short-range IoT radio that is effective in premises where humans and robots coexist and work together

Open Innovation

Innovation Promotion Department

Executive Director　YAMAGUCHI Shuji

The Innovation Promotion Department collaborates with others both inside and outside NICT on the following missions to maximize the benefits of research and development:

- ***To contribute to even stronger cooperation between industry, government, and academia by effectively using external research resources via various schemes such as joint research, commissioned research, and funded research to promote efficient and effective research and development.***
- ***To help create open innovation through the social implementation of research and development results by appropriately securing and effectively utilizing intellectual property, and performing effective standardization in cooperation with industry, government, and academia.***

Promotion of Joint Research with Companies, Universities, Public Research Institutes, and Others

In FY2020, the Department promoted 568 joint research projects (including projects continued from the previous year). Of these, agreements were made for a total of 98 new projects in FY2020; 91 in Japan and 7 overseas (Fig. 1).

Promotion of Capturing External Funds and Support for Appropriate Execution

To help capture more external funds, the Department surveyed the contents and rules of various research fund systems to provide information within NICT, and provided support such as checking application forms (more than 300), advising, and helping with clerical work (Fig. 2).

Promotion of Researcher Exchange with External Organizations, by Accepting or Dispatching Researchers, etc.

(1) Agreements for Mutual Cooperation with Universities and Others

In FY2020, the Department made a cooperation agreement with the University of Hyogo. This increased the number of agreements made between NICT and universities or other similar organizations to 18.

(2) Collaborative Graduate School System

In FY2020, NICT accepted 35 graduate students from 19 graduate schools and other bodies that NICT has made agreements with in the past to give them an opportunity to gain research experience, and NICT dispatched a total of 23 researchers as lecturers to graduate schools.

Promotion of Commissioned Research

(1) Promotion of Commissioned Research for Advanced Communications and Broadcasting Research and Develop-

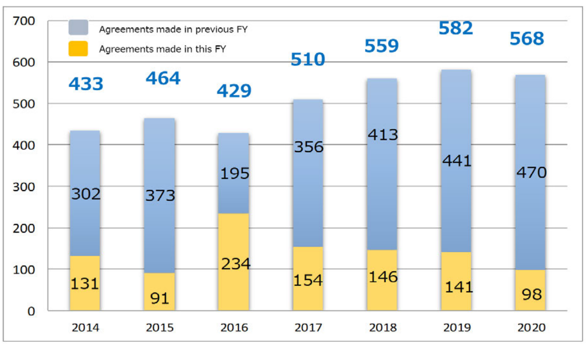


Fig.1 : Trends in number of joint research contracts

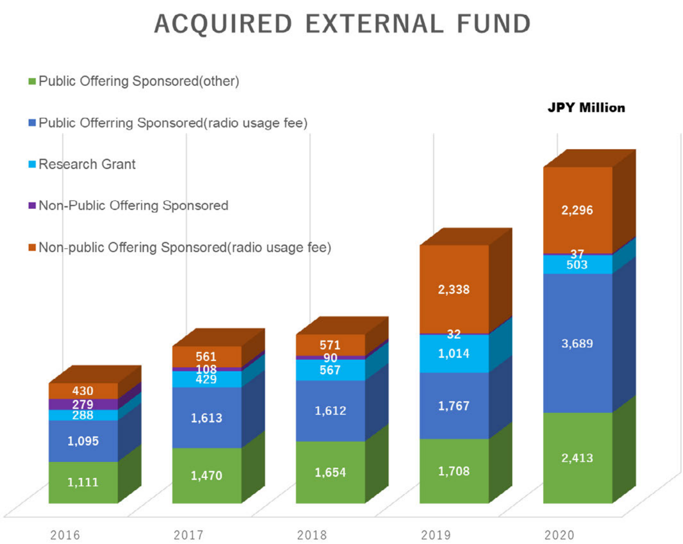


Fig.2 : Trends in captured income from competitive research funds

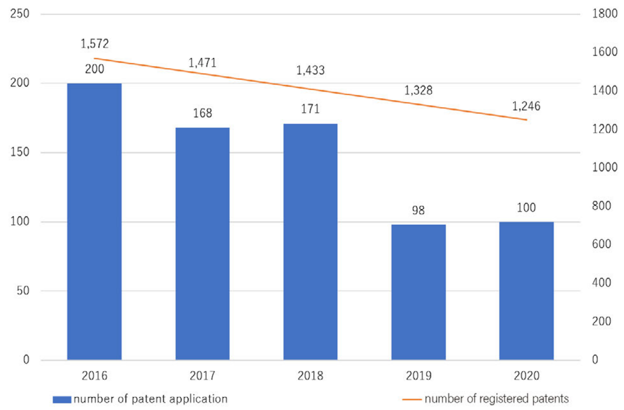


Fig.3 : Trend in patent application and registered patent

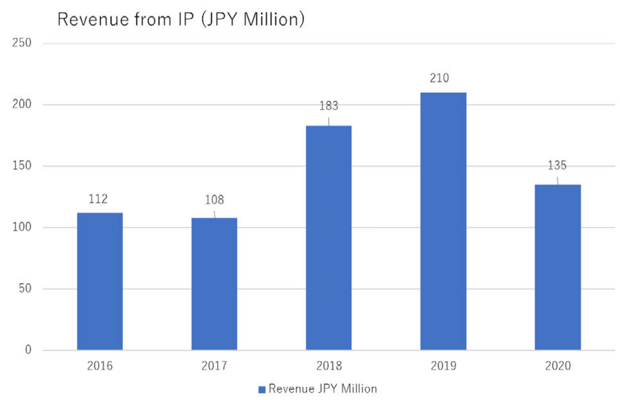


Fig.4 : Trend in revenue from IP

ment

In FY2020, NICT worked on 29 research projects continuing from the previous fiscal year and launched four new research projects. To maximize effectiveness, NICT researchers oversee commissioned research as project officers and carry out research and development in an integrated manner with NICT R&D with the aim of maximizing effects. In terms of research results , 226 paper presentations, 378 general oral presentations, 46 standardization proposals, and 81 industrial property rights applications (49 domestic and 32 overseas).

(2) Start of Commissioned Research for Innovative Information and Communications Technology Research and Development

In order to develop the elemental technologies needed to achieve Beyond 5G, the Department started operations of the Commissioned R&D for Innovative Information and Communications Technology, which was established in FY2020 to perform open research and development at organizations such as private-sector companies and universities. One research project has been started under this system.

Appropriate Management of Intellectual Property

In FY2020, 100 new patent applications were filed, with a cumulative total of 1,246 registered patents (Fig. 3).

(1) Revision of Patent Evaluations

The Department promoted operations for the appropriate determination of the necessity of foreign patent applications. The Department also systematically conducted re-evaluations of patents for which 10 years have passed since their application.

(2) Implementation of Patent Map Analysis

In cooperation with NICT's various research centers, the Department performed patent application trend research (patent map analysis) that can be utilized in research and development strategy and patent application strategy in technological fields such as voice recognition, dialog systems, secure computing, 5G/B5G, satellite communication, terahertz, and optical networks.

Effective Promotion of Technology Transfer

In FY2020, NICT won about 27 new paid-for implementation contracts (42 in FY2019), achieving intellectual property income of 135 million yen despite the declines due to the coronavirus pandemic (210 million yen in FY2019) (Fig. 4). As a result, the total amount in the current medium-to-long term target period increased to 748 million yen (average annual amount of 150 million yen), which is about twice the average annual amount of 78 million yen in the previous five-year period.

Promotion of International Standardization

To ensure that the results of NICT's research and development are reflected in international standards, the Department proactively participates in conferences and other events held by various international standardization organizations. In addition, in FY2020, a total of 154 contributions were submitted based on NICT's research and development results to such conferences (Fig. 5). A total of 50 NICT employees also worked in roles such as chair and editor at international standardization conferences in FY2020. This contributed to the establishment of 28 international standards based on NICT's research and development results. For example, in the field of quantum key distribution technology, the Department took the lead in standardizing six recommendations at ITU-T (Y.3801 (Requirements), Y3802 (Architecture), Y3803 (Key management), Y.3804 (Network control and management), X.1710 (Threat analysis, security requirements, etc.), and X1712 (Secure key supply, etc.)). They also participated in ETSI and ISO conferences and contributed to discussions on establishing standards.

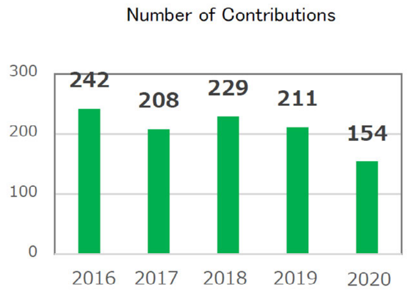


Fig.5 : Number of contributions for the international standardization conference

Open Innovation

Global Alliance Department

Executive Director FUKAHORI Michiko

In response to the continued globalization of the economy and society, international strategies are more important than ever, even from the perspective of research and development for information communication and the expansion of the corresponding research results.

The Global Alliance Department promotes international cooperation in NICT's research and development activities, and international expansion of the research and development results. By promoting open innovation from a global perspective, the Department contributes to strengthening international competitiveness of information communication technology fields in Japan.

Promotion of International Research Cooperation

To help ensure smooth international cooperation, the Department exchanges Memorandums of Understanding (MOU) with leading overseas research institutes and universities, and conducts joint research and personnel exchange. In FY2020, the Department exchanged 14 MOUs (4 new, 10 updates) with overseas universities and other research institutes, and promoted international research cooperation (93 projects with 89 organizations in 29 countries as of end of FY2020), encouraging the international expansion of NICT’s research results (Fig. 1).

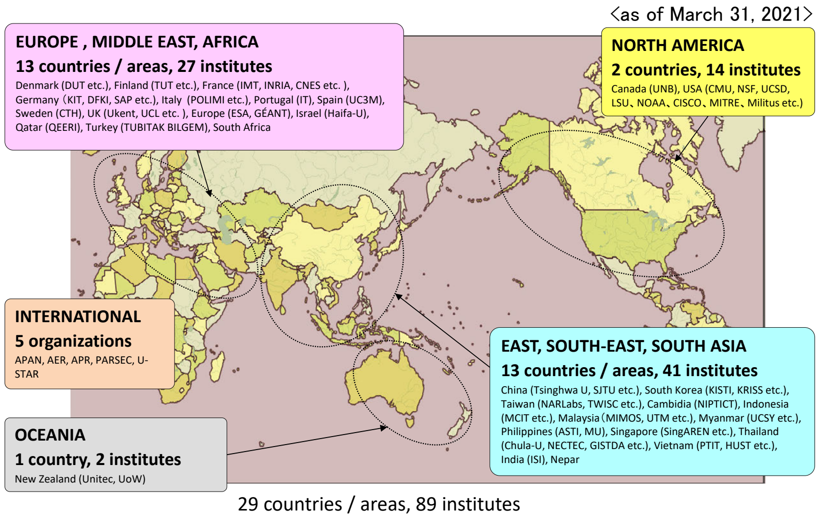


Fig.1 : Foreign institutes with MOU

Promotion of Cooperation with SouthEast Asia and Joint International Research Projects

the ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO) is a virtual research cooperation organization that NICT jointly established with universities and other research institutes in the ASEAN region in February 2015. ASEAN IVO has achieved high recognition in the ASEAN region, growing into a large joint research body with the participation of 68 organizations (+8 year-on-year) (Fig. 2). ASEAN IVO has promoted 17 joint research and development projects (started from FY2017 to FY2020) focused on ICT solutions for social issues shared by ASEAN countries. For example, in projects related to smart irrigation, peatland fire monitoring, and urban agriculture, sensors appropriate for each environment have been developed for installation and verification in locations such as paddy fields, peatland monitoring towers, and vertical plant cultivation shelves (Fig. 3). The ASEAN IVO Forum is held every year to organize the projects that will start the following year. In 2020, this forum was held online for the first time, and participants presented ideas for a total of 36 projects (+6 year-on-year) in such fields as food, environmental protection and disaster prevention, secure and smart communities, and health and welfare.

Promotion of Joint International Research with the United States

The Department manages Japan-US Network Opportunity 2 (JUNO2), a joint international research program in the field of networks, together with the National Science Foundation (NSF) of the United States. This program continued to conduct five joint research projects between Japan and the United States based on the theme of high-reliability networks. The Depart-

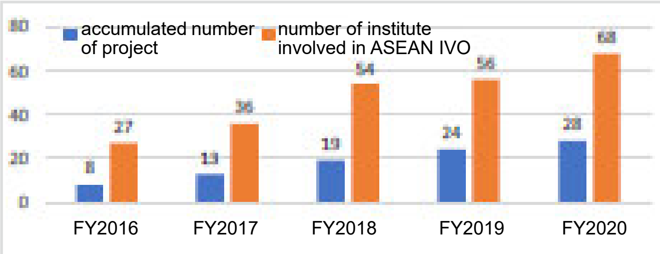


Fig.2 : Trend in number of projects and involved institutes in ASEAN IVO

Fig.3 : Three projects in field test in ASEAN IVO

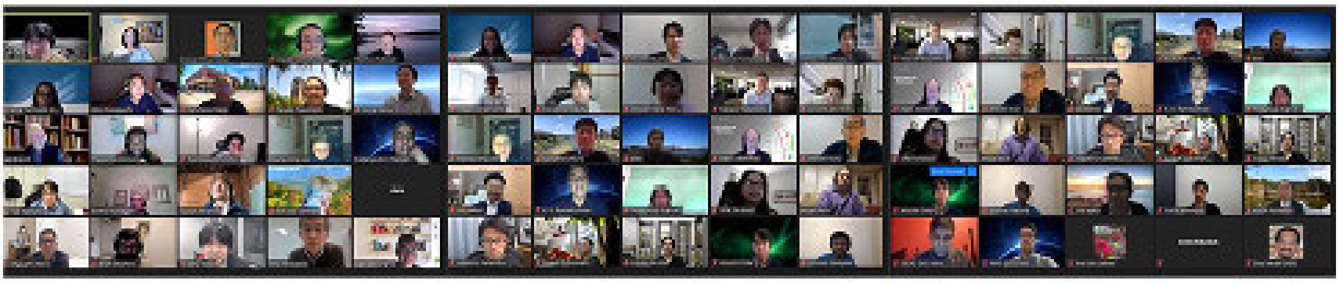


Fig.4 : US-Japan workshop on programmable networking (November 2020, jointly held with NSF)

ment also held a US-Japan Workshop on Programmable Networking (online) jointly with the NSF (Fig. 4). About 70 experts participated, and they discussed future issues for research and compiled their discussions in a report. The Department plans to start open recruitment for research in FY2021 based on this report.

Promotion of Joint International Research with Europe

Joint international research between Japan and Europe conducted by the European Commission and Japan's Ministry of Internal Affairs and Communications consisted of the Final Review for one joint research project that started in 2016 (ICT robotics field), and the 2nd Review of two joint research projects that started in 2018 (fields of IoT security and Beyond 5G). These were held online.

Participation in International Exhibitions

The Department has proactively participated in international exhibitions and various other events to help the international expansion of NICT's research and development results. These included online courses for the École Japonaise de Paris (May in Paris, France), KMITL's 60th Anniversary Ceremony (August at KMITL in Bangkok, Thailand), Chulalongkorn University 5G Seminar (August 2020 in Bangkok, Thailand, Fig. 5), and the Thailand National Science and Technology Fair 2020 (November in Thailand).

International Exchange of Personnel

In FY2020, three internship trainees continued their postings from the previous year at NICT research centers. The Department also supported foreign researchers by holding Japanese language training sessions and translating various documents into English.

Operations Related to Security Export Controls

The Department held a review meeting about security export controls to review the technologies that are scheduled to be provided under MOUs and other agreements, and the status of the organizations that are party to the agreements, and confirmed whether such agreements were allowed under export controls.

Fig.5 : 5G Seminar Opening Ceremony at Chulalongkorn University, Thailand

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director IBATA Kozo

Information communication provides the infrastructure for social and economic activity. We are currently engaged in many activities in this filed, such as providing support for startups that give rise to new services, enhancing our infrastructure to facilitate the use of diverse new forms of communication, promoting information barrier-free environments where information communication services can be used by anyone, promoting basic research in the private sector, and supporting international exchange in research and development. Through these activities, we are helping to stimulate industry and facilitate rich lifestyles that are both safe and secure, and to support the adoption of highly convenient information communication services in our society.

Support for Information Communication Ventures

From the policy perspective of strengthening Japan's industrial competitiveness over the medium to long term, the Department supports the startup of information communication ventures and transforming such ideas into businesses.

(1) Entrepreneurs' Championship and Entrepreneurs' Expo

The Entrepreneurs' Championship was held on March 1, 2021 and the Entrepreneurs' Expo on March 2, 2021 in Tokyo. On the day of the events, participants gave presentations online as a measure against the novel coronavirus, while the judges gathered in person to adjudicate. In the Entrepreneurs' Championship, five teams participated, while in the Entrepreneurs' Expo, 11 companies or organizations took part (Fig. 1) (Fig. 2).

(2) Silicon Valley Entrepreneur Training Program

The Silicon Valley Entrepreneur Boot Camp was held online in February 2021 as an opportunity for the future participants of the Entrepreneurs' Championship to develop a global mindset. The program included the chance to exchange views with ICT startups from Silicon Valley in the United States, as well as lectures from entrepreneurs and other businesspeople who are active locally.

Fig.1 : Entrepreneurs' Championship

Fig.2 : Entrepreneurs' Expo

(3) Participation in Large-scale Exhibitions

In FY2020, the Department provided an opportunity for 16 companies that participated in past Entrepreneurs' Expos (including three ventures originating from NICT) to exhibit as a part of CEATEC 2020 ONLINE in October 2020. Further, the Department provided recommendations for six participating companies of past Entrepreneurs' Expos (including two ventures originating from NICT) that wanted to exhibit at the ILS (Innovation Leaders Summit) in March 2021.

(4) Provided Information Related to ICT Startups

To provide information useful for startups, the Department used the ICT startup support center <https://www.nict.go.jp/venture/> to release information about events held in collaboration with local communities all over the country and distribute educational resources such as the video library for the Entrepreneurs' Championship and Entrepreneurs' Expo.

(5) Subsidies and Loan Guarantees to Support Information Communication Ventures and Other Businesses

The Department provides subsidies and loan guarantees for businesses that provide facilities for developing new technologies, and businesses that provide area-specific telecommunications facilities.

In FY2020, the Department decided to provide a subsidy to one regional data center project.

Support for Expansion of Information Communication Infrastructure

The Department provides interest compensation to banks and other financial institutions that provide loans to businesses that invest in enhancing telecommunications infrastructure in local areas outside the big cities (such as improving cable TV infrastructure or providing relay stations for terrestrial digital TV broadcasting).

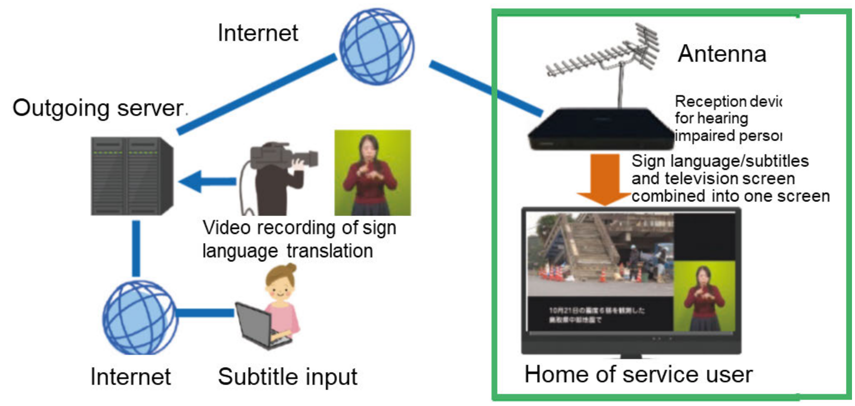


Fig.3 : Outline of Sign Language Interpretation System on TV

In FY2020, the Department provided interest compensation to three projects (three companies).

Promoting Information Barrier-free Environments

The Department aims to eliminate barriers to the use of ICT by the elderly and people with disabilities, and promote a society in which all people can use ICT.

(1) Subsidies for Promoting Television Programs with Subtitles, Commentary, and Sign Language

In FY2020, the Department provided subsidies to 49,527 programs by 118 broadcasters across the country.

(2) Subsidies for Promoting Sign Language Interpretation Video

In FY2020, the Department subsidized 148 programs that combined sign language interpretation video with the broadcast program. (Fig. 3).

(3) Subsidies for Providing and Developing Information Barrier-free Communication and Broadcasting Services

In FY2020, the Department subsidized five projects to improve convenience for disabled people in fields related to communication and broadcasting services.

(4) Providing Information Related to Information Barrier-free

The Website for Providing Information About Information Barrier-free <https://barrierfree.nict.go.jp/> is used to provide information useful for the disabled, elderly, and welfare related organizations, as well as other information such as the outline and results of information barrier-free projects conducted by NICT (subsidy system). In FY2020, the website was accessed about 710,000 times.

Support for Inviting Overseas Researchers and Holding International Research Meetings

Foreign researchers are invited to research institutes other than NICT by the Japan Trust International Research Cooperation Program, which is funded by private benefactors and NICT's own International Exchange Program. The International Exchange Program also supports the holding of international research meetings.

In FY2020, the Department invited two foreign researchers as part of the International Exchange Program, one to Hokkaido University and one to the Nagoya Institute of Technology. The Department also supported 10 international research meetings, including the Optics & Photonics International Congress 2020 and Software Methodology and Applied Technology International Conference.

Research Highlights

Researchers

Research Highlights

Researchers

Advanced Electromagnetic Technology Area

Assessment of social impact of solar flares and other space weather

How will space weather affect Japan?

NICT created and presented a report entitled "Assessment of the impact of space weather phenomena on society for scientific suggestions" in collaboration with related organizations in Japan under the Project for Solar-Terrestrial Environment Prediction (PSTEP) (2015 to 2019), which was supported with a Grant-in-Aid for Scientific Research on Innovative Areas from Japan's Ministry of Education, Culture, Sports, Science and Technology. This report assessed what kind of impact space weather that mainly originates in solar activity may have on Japan, based on information such as past literature and observation data. The report also described the frequency of phenomena that have a major social impact in fields such as satellite operations, communications, broadcasting, and positioning.

When space weather phenomena have a large-scale impact, they may affect not only the use of radio waves in communications, broadcasting, and positioning, but also social activities such as the use of satellites, electric power networks, and aviation operations. For example, a large-scale geomagnetic storm that occurred in October to November 2003 affected approximately 59 % of spacecraft, including Japanese

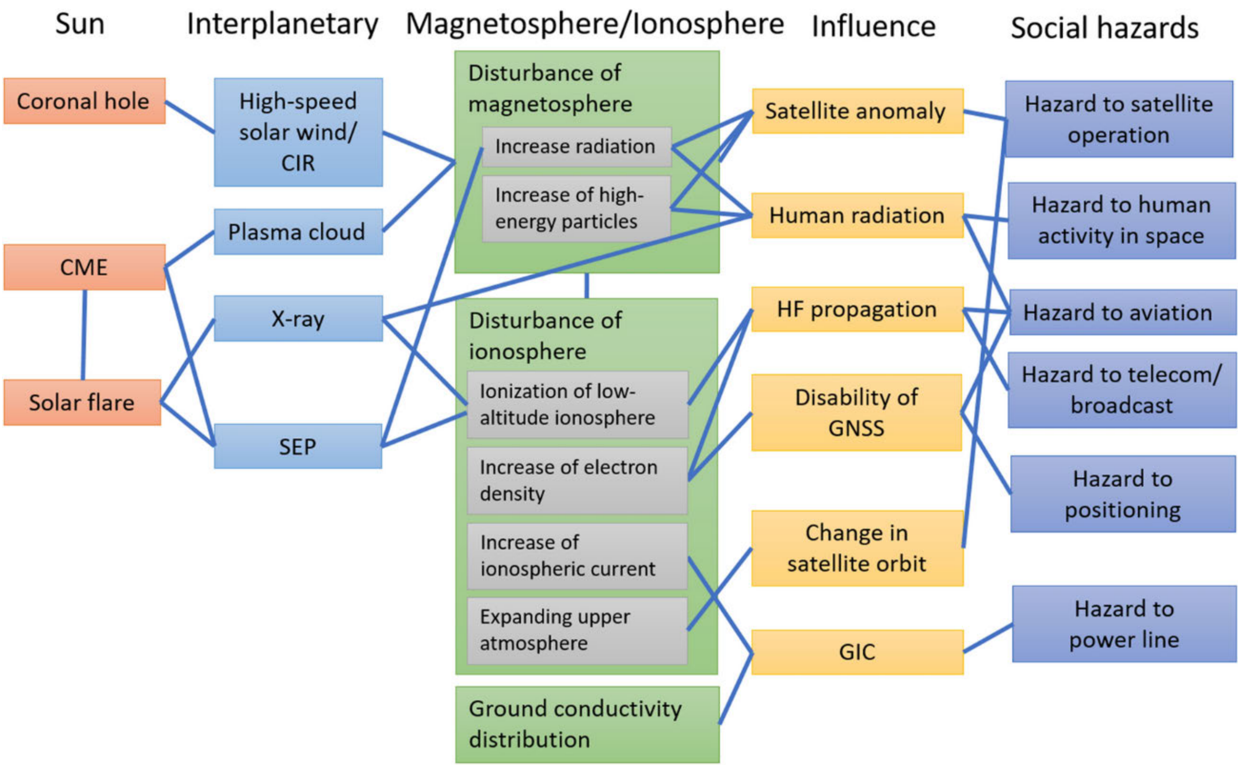


Fig. : Relationship among natural phenomena, social influence, and hazards (Ishii et al., EPS, 2021) scientific satellites, and 24 % of missions took safety measures.

Even though disasters caused by space weather are rare, any that occur will have a large and widespread impact. However, in the past there has been insufficient discussion about the quantifiable effects on society, such as the scale and frequency of phenomena that may occur, and there are no guidelines to prepare for hazards. As a result, users are either overly alarmed or not concerned at all.

Under the PSTEP activities, the editorial board composed of researchers in Japan fully utilized previously obtained knowledge to conduct multiple studies on the scale of space weather phenomena that may occur in the future and their impact on society, and compiled the results in a report. This was the first time for the social impact of space weather phenomena to be comprehensively studied and assessed in Japan. The contents also included new knowledge. For example, since Japan is at a mid-latitude position, the effects on electric power networks of telluric currents induced by geomagnetic activity have traditionally been ignored, but the results showed that this understanding should be reconsidered. Also, when large solar flares occurred in September 2017, concerns were raised about the effects of cosmic radiation on the ground, but the results showed minimal impact on health.

Enabling operators in various fields to take appropriate measures based on the report will disseminate correct knowledge about disaster-level space weather phenomena, resulting in increased social resilience. The Space Weather Users Conference established by NICT also communicates with users based on this report and proceeds with studies until users devise specific countermeasures, with the aim of providing good examples of incorporating leading-edge research results into social activities.

Reference

Ishii, M., Shiota, D., Tao, C. et al. “Space weather benchmarks on Japanese society,” Earth Planets and Space vol.73, article no.108, 2021.
https://doi.org/10.1186/s40623-021-01420-5

Frontier Science Area

Development of gallium oxide transistors for wireless communications in harsh environments

Achievement of the world's highest maximum oscillation frequency of 27 GHz with excellent high-frequency device characteristics

The Internet of Things (IoT) has spread rapidly in recent years, thus there is also a growing need to acquire sensing data and control devices even in specific environments known as “harsh environments,” which are exposed to high temperatures, high radiation, corrosive gas, etc. However, under harsh environments, conventional semiconductor devices cannot be used continuously for a long time due to significant performance degradation. Therefore, there is a strong demand for the realization of semiconductor devices for wireless communication that can be used in such severe environments.

Since NICT pioneered the Research & Development of gallium oxide (Ga_2O_3) devices in 2011, it has reported research results for numerous power device applications. At the same time, NICT focused on the new field of wireless communications in harsh environments and began research in 2018.

Ga_2O_3 is a thermally and chemically stable material, and is expected to be much more resistant to harsh environmental factors than conventional semiconductor materials. For this reason, Ga_2O_3 devices are considered to be very suitable for use in harsh environments.

NICT achieved the world's highest maximum oscillation frequency of 27 GHz for Ga_2O_3 transistors. This result was the first in the world to demonstrate that Ga_2O_3 transistors can be used with a frequency up to about 10 GHz since, in wireless communication, the maximum oscillation frequency needs to be at least two to three times higher than the practical frequency. 1 to 10 GHz is the most widely used frequency band, for applications such as satellite broadcasts, cellular phones, wireless LAN, and so on. Furthermore, since communication in this frequency band is possible with small antennas due to its short wavelengths of about 10 cm, it is suitable for communication in small devices, such as sensors.

The results of this research clarified the frequency targets in the development of high-frequency Ga_2O_3 transistors for wireless communication. In the future, in order to further enhance the performance of high-frequency Ga_2O_3 transistors, we will optimize device structures to maximize the output power characteristics in the used frequency bands, with the aim of achieving practical application.

Reference

Takafumi Kamimura, Yoshiaki Nakata, and Masataka Higashiwaki, “Delay-time analysis in radio-frequency β-Ga_2O_3 field effect transistors,” Applied Physics Letters, vol.117, 253501 2020.
DOI: 10.1063/5.0029530

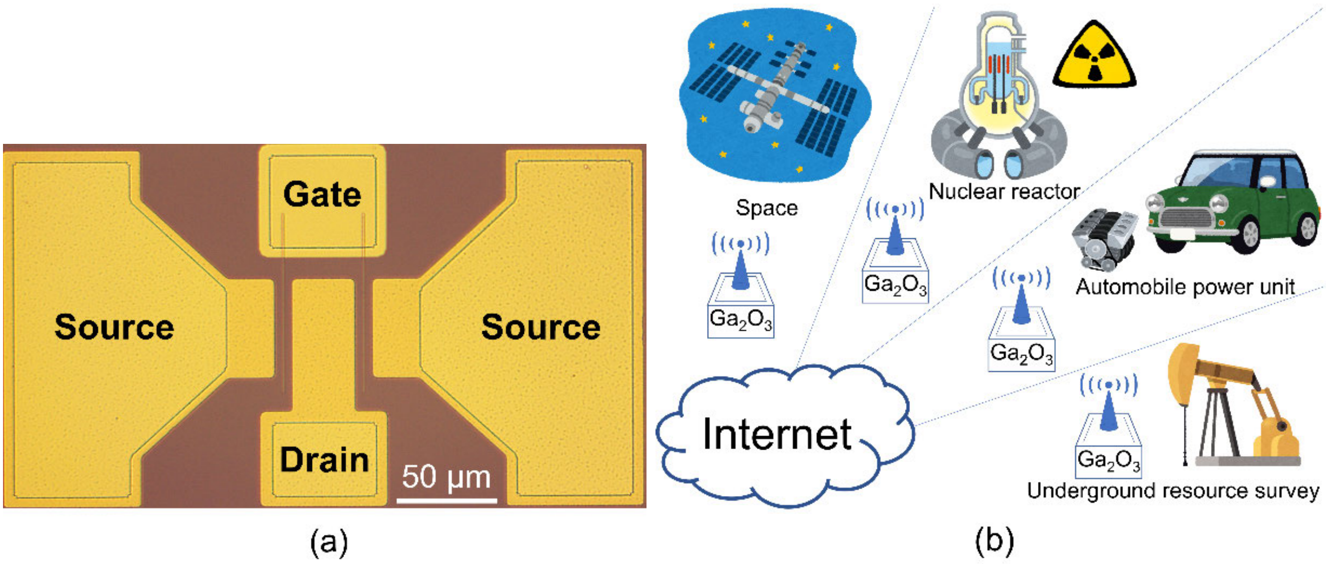


Fig. : (a) Optical micrograph of developed submicron-gate gallium oxide transistor, (b) Typical examples of harsh environments where IoT is expected to spread due to realization of high-frequency gallium oxide transistors for wireless communications.

Advanced Electromagnetic Technology Area

Development of high-speed holographic fluorescence microscopy system with submicron resolution

NICT, Tohoku University, Toin University of Yokohama, and Japan Science and Technology Agency (JST) have succeeded in developing a scanless high-speed holographic fluorescence microscopy system with submicron resolution for a 3D space. The system is based on digital holography. The developed microscopy system adopts an algorithm to acquire 3D information of fluorescent objects toward scanless 3D measurement in less than 1 millisecond. Scanless 3D sensing with submicron resolution and color-multiplexed holographic fluorescence imaging have been demonstrated using the algorithm. The microscopy system will be further developed to achieve holographic 3D motion-picture sensing of specimens with incoherent light.

The scanless high-speed holographic fluorescence microscopy system is shown in the Fig. The system is based on digital holography and is applicable

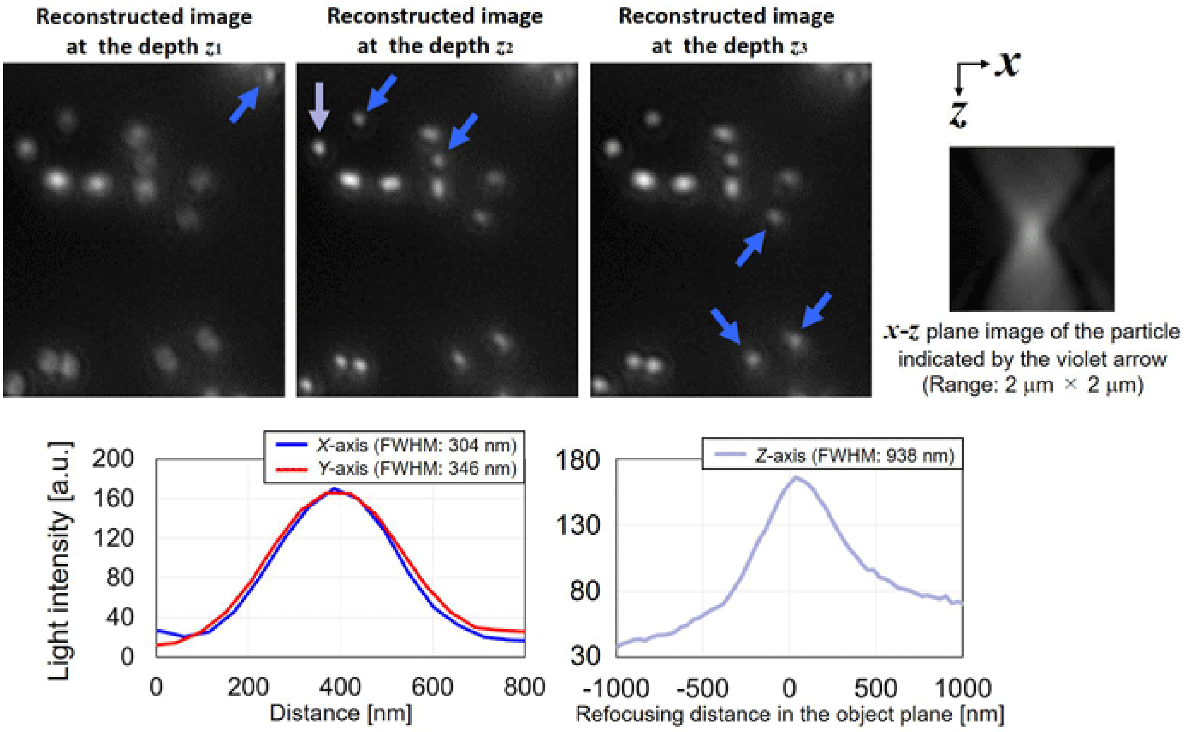


Fig. : Upper left: Experimental results of 3D sensing for fluorescent particles with a diameter of 0.2 μm.
Upper right: x-z image of the reconstructed particle marked by the violet arrow.
Bottom left: Plots of the particle marked by the violet arrow along the x- and y-axes.
Bottom right: Plots of the particle marked by the violet arrow along the z-axis.

to the sensing of incoherent light such as fluorescence light and natural light. The developed algorithm enables the adoption of a phase modulator to generate two phase values, which is expected to increase the measurement speed. Submicron resolution for a 3D space was successfully demonstrated using fluorescent objects with a diameter of 0.2 μm. The experimental results shown in the Fig. indicate that the developed microscopy system achieves 3D sensing of nanoparticles and has submicron resolution quantitatively for a 3D space. Scanless 3D measurement in less than 1 millisecond is achievable by using an algorithm with either a ferroelectric liquid crystal on silicon (FLCOS) or an electro-optic (EO) device. Color-multiplexed holographic fluorescence imaging with the algorithm and only four exposures has also been demonstrated by combining the proposed algorithm and computational coherent superposition (CCS) scheme. The number of exposures is reduced by the algorithm, and the number of photons per hologram is increased even for ultimately weak light.

Reference

Tatsuki Tahara, Yuichi Kozawa, Ayumi Ishii, Koki Wakunami, Yasuyuki Ichihashi, and Ryutaro Oi, "Two-step phase-shifting interferometry for self-interference digital holography," Optics Letters, vol.46, Issue 3, pp669-672, 2021.
DOI: 10.1364/OL.414083

Innovative Networks Area

Successful international joint experiment between Japan and Germany in the field of space optical communication using a small satellite

NICT is conducting research and development on space optical communications for the advancement of future satellite communication. Between 2014 and 2016, multiple experiments were performed between the Small Optical communication TrAnsponder (SOTA) and optical ground stations not only in Japan, but also in Europe (German Space Agency (DLR), French National Centre for Space Studies (CNES), and European Space Agency (ESA)) and Canada (Canadian Space Agency (CSA)). Currently, NICT is developing the High Speed Communication with Advanced Laser Instrument (HICALI) payload to be mounted on the ETS-9 to demonstrate 10 Gbps-class optical satellite communication between geostationary orbit and the ground. The HICALI experiments require an optical ground station with optical bench, which has a newly developed fine-pointing system.

NICT conducted an international joint experiment with the German Aerospace Center (DLR) between the optical terminal (OSIRISv1) onboard the University of Stuttgart's Flying Laptop satellite and NICT's optical ground, and in February 2021, the downlink light from OSIRISv1 station was successfully received at NICT's optical ground. During this experimental phase that took place between the end of January and the beginning of February 2021, NICT planned experiments to receive the laser light from OSIRISv1 at the optical ground station in Tokyo, which is equipped with a 1-meter telescope and the newly developed optical bench that has been developed for future HICALI experiments.

In addition, NICT succeeded in the initial test of a newly developed atmospheric-turbulence measuring device, which contributes to the estimation and mitigation of atmospheric-turbulence effects on space optical-communication links.

Furthermore, when aiming for the global dissemination of space optical communications, it is necessary to develop a small, low-cost ground station. A small 20-cm order-off-the-shelf telescope was installed in parallel to the 1-meter optical ground station and successful experiments in receiving the downlink light (first light) were performed. The OSIRISv1 optical terminal, mounted on the University of Stuttgart's Flying Laptop satellite uses body pointing for tracking, and this is the first time a successful experiment with such implementation has been performed in Japan.

The valuable data collected during these successful experiments is important for the modelling of the atmospheric turbulence and tracking errors. It is expected to contribute to the further development of space optical communication technology.

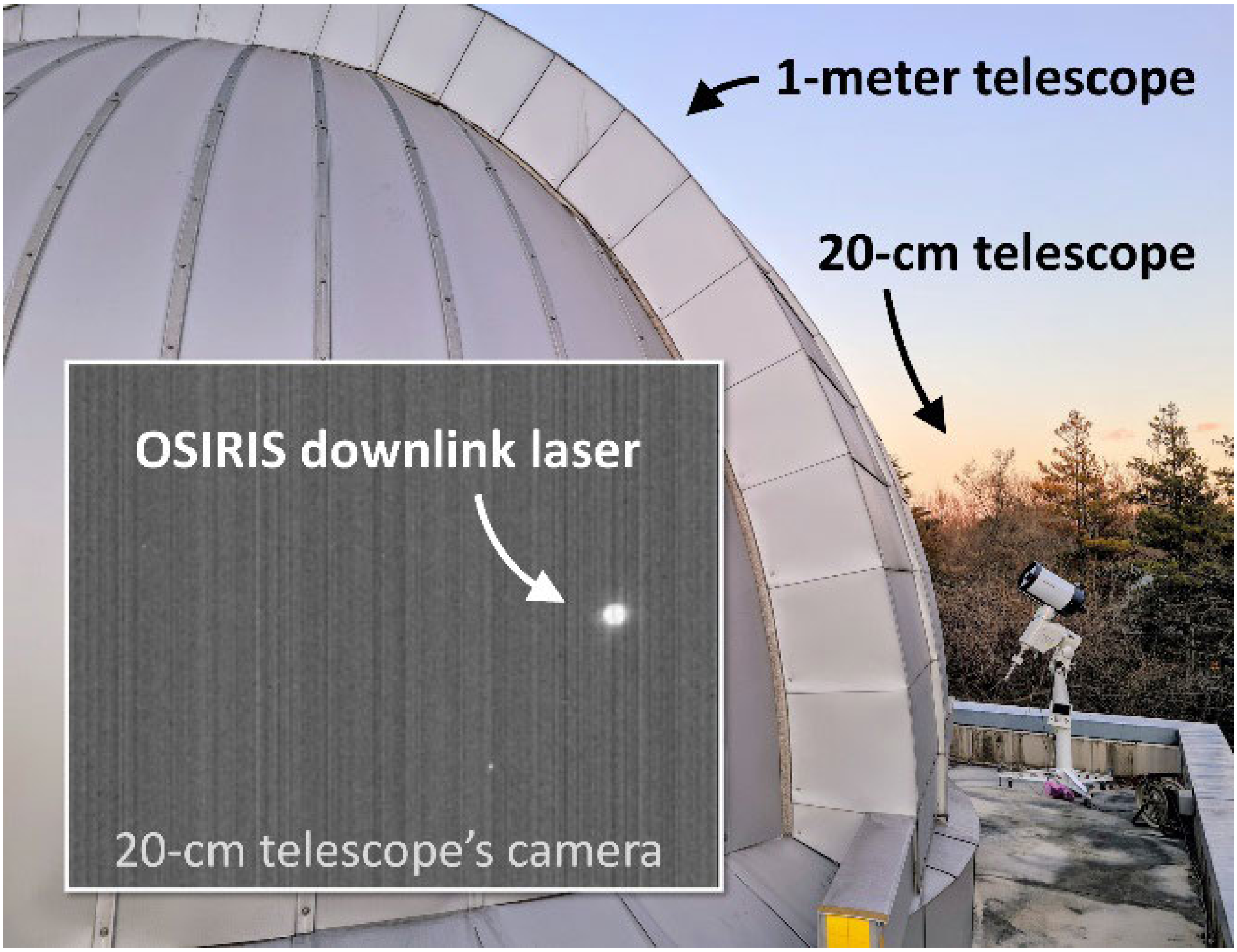


Fig. : NICT optical ground station with a 1-meter telescope, and small ground station based on a 20-centimeter telescope.

Innovative Networks Area

RaNNC, automatic parallelization deep learning middleware, released as open-source software

Drastically simplifies training of very large-scale neural networks

NICT and the University of Tokyo released RaNNC (Rapid Neural Net Connector), automatic parallelization deep learning middleware, on March 31, 2021. In recent deep learning research, neural networks have been rapidly increasing in size and they often no longer fit on a single GPU memory. Developers need to partition such large-scale networks and load them on multiple GPUs, which means rewriting complex network definitions and ensuring that each partition fits on the memory of each GPU.

RaNNC partitions neural networks automatically, drastically simplifying the training of very large neural networks. RaNNC takes definition files of a neural network written for PyTorch, a de facto standard deep learning framework, and automatically partitions the network to fit it into the memory of each available GPU while optimizing the training speed at the same time (Fig.).

Recent research reported the training of extremely large neural networks including GPT-3 (175 billion parameters), HyperCLOVA, a Korean language model trained by NAVER (204 billion parameters), and Wu Dao 2.0, which was trained using English and Chinese text as well as images (1.7 trillion parameters). However, training of such large networks must have required manual optimization by human experts. In contrast, we confirmed that RaNNC can automate parallelization of training of a neutral network with 100 billion parameters without any manual tuning, which is an unprecedented result in this research field.

Experiments using NICT's computational environment showed that RaNNC can train models approximately five times larger than Megatron-LM, a deep learning training framework for large-scale networks developed by NVIDIA. It also achieved almost the same training speed as Megatron-LM for models of a size that both frameworks could train. This research result was accepted at the IEEE International Parallel and Distributed Processing Symposium (IPDPS), a top international conference in the field of parallel and distributed computing.

The source code of RaNNC is available on GitHub (https://github.com/nict-wisdom/rannc). It is licensed under MIT license, so users can use RaNNC for free, even for commercial purposes.

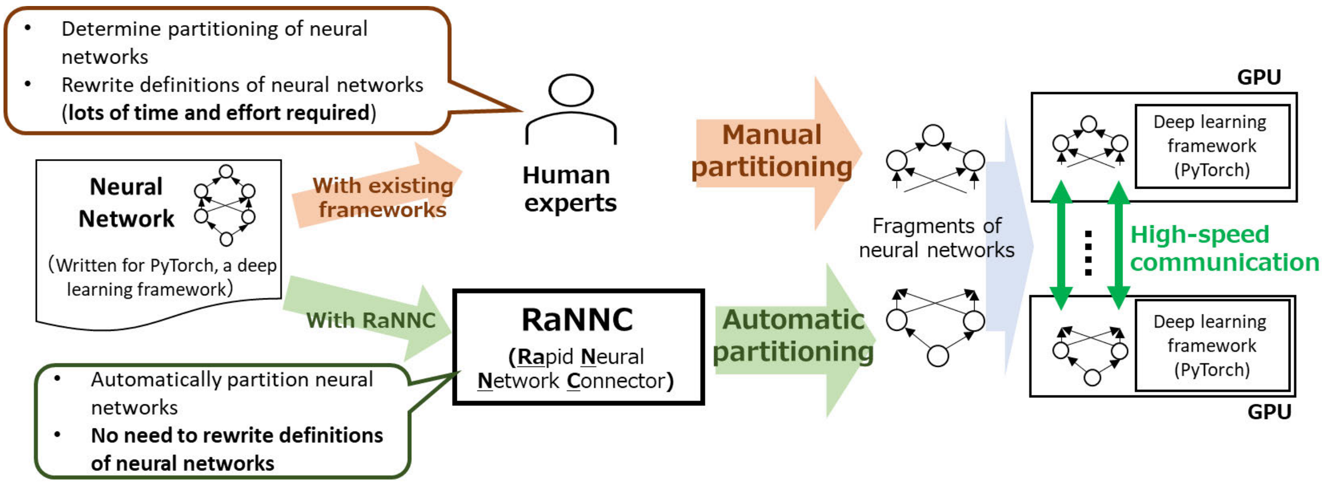


Fig. : Parallel training of large-scale neural networks

Open Innovation

A collaborative patrol system using service robots equipped with millimeter wave IoT devices

Short-time delivery of large-volume 4K resolution video without the need for broad-band communication infrastructure

NICT and Sony Semiconductor Solutions Corporation jointly developed a collaborative patrol system using autonomous mobile service robots equipped with next-generation, 60 GHz millimeter wave TransferJet communication technology (TransferJet X).

When multiple autonomous service robots equipped with a 4K camera are wirelessly requested to conduct a patrol, the robot closest to the patrol area moves there to record a video. Then, the robot itself carries the recorded data to the patrol requestor and wirelessly transfers it to the playback system via

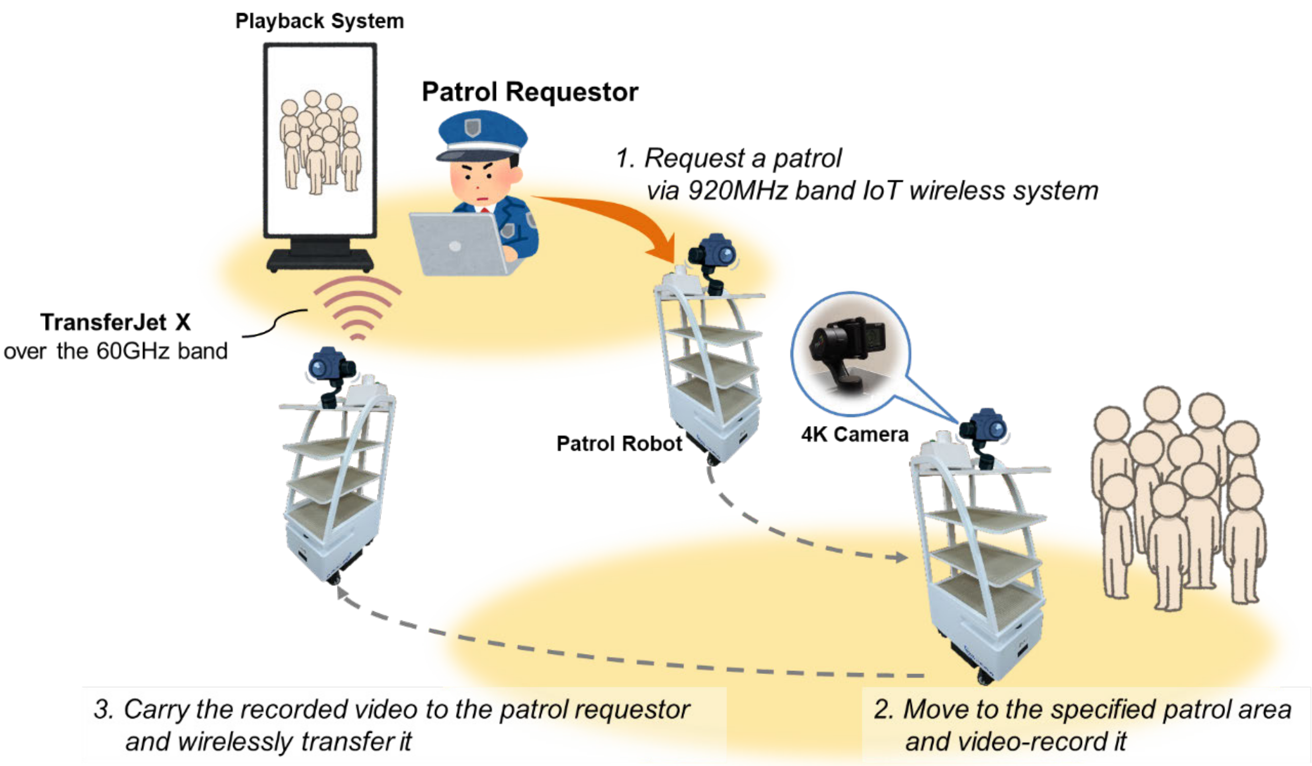


Fig. : An example of a demonstration flow of the patrol system using an autonomous mobile service robot

TransferJet X to be played back automatically. In the demonstrative trial conducted within the same office building, it took no more than 163 s (travel time 129 s + data-transmission time 34 s) for a robot with a maximum movement speed of 0.8 m/s to deliver the recorded video data (approximately 10 GB) from the patrol location to the client (located 86.8 m away), and to complete the data transfer using TransferJet X. Converted into data transfer speed, this is equivalent to 514 Mbps. This rivals the maximum device-to-device throughput of 480 Mbps under the technical standard for the 5th-generation mobile communication system (5G), which is available as a commercial service in Japan as of June 1, 2021. The Fig. shows an example of a demonstration flow of a patrol system using autonomous mobile service robots.

This system is expected to be used for collecting and disseminating large-volume data such as high-resolution video (4K) in areas where it is difficult for people to enter or where it is difficult to install new broadband communication infrastructure. Practical use can be expected in unmanned monitoring services for detecting cracks in structures due to disasters and aging. Also, the system can be applied to services that can provide automatic patrols and alerts in a contactless manner in dense office environments, by making use of commercial service robots in a diverse range of fields (security, cleaning, guidance, disinfection, serving, delivery, etc.) in the New Normal era post COVID-19.

In the future, we plan to verify the practicality of the system in real environments, such as in offices, hotels, hospitals, and other buildings, and in railway stations and commercial facilities, with the cooperation of anticipated service providers and building or railway station operators.

Innovative Networks Area

Demonstration of world record: 319 Tb/s transmission over 3,001 km with 4-core optical fiber

NICT successfully performed the first S-, C- + L-band transmission over long-haul distances in a 4-core optical fiber with standard outer diameter (0.125 mm). The researchers, led by Ben Puttnam, constructed a transmission system that makes full use of wavelength division multiplexing technology by combining different amplifier technologies, to achieve a transmission demonstration with date-rate of 319 terabits per second, over a distance of 3,001 km. Using a common comparison metric of optical fiber transmission, the data-rate and distance product of 957 petabits per second × km, is a world record for optical fibers with standard outer diameter.

In this demonstration, in addition to the C and L-bands, typically used for high-data-rate, long-haul transmission, we utilized the transmission bandwidth of the S-band, which has not yet been used over more than a few fiber spans. The combined >120 nm transmission bandwidth allowed 552 wavelength-division multiplexed channels by adopting two kinds of doped-fiber amplifier together with distributed Raman amplification, to enable recirculating transmission of the wideband signal. The standard cladding diameter, 4-core optical fiber can be cabled with existing equipment, and it is hoped that such fibers can enable practical high data-rate transmission in the near-term, contributing to the realization of a backbone communications system, necessary for the spread of new communication services Beyond 5G.

The results of this experiment were accepted as a post-deadline paper presentation at the International Conference on Optical Fiber Communications (OFC 2021).

NICT has built a long-distance transmission system around a 4-core optical fiber with a standard cladding diameter to exploit wider transmission bandwidth of >120 nm across S, C and L-bands. The system exploits wavelength division multiplexing (WDM) and a combination of optical amplification technology to enable long-haul transmission of 552 WDM channels from 1487.8 nm to 1608.33 nm. The system was used to measure achievable transmission throughput with each channel modulated with PDM-16QAM modulation at distances up to 3,001 km, where a data-rate of 319 terabits per second was achieved. This result may be compared to achievements in other SDM fibers and transmission regimes by calculating the product of transmission capacity and distance, often used as a comparison metric. The data-rate x distance product becomes 957 petabits per second x km, which is over 2.7 times larger than previous demonstrations in SDM fibers with standard outer diameter.

NICT will continue to develop wide-band, long-distance transmission systems and explore how to further increase transmission capacity of low-core-count multi-core fibers and other novel SDM fibers. Further, we will work to extend the transmission range to trans-oceanic distances.

Reference

Benjamin J. Puttnam, Ruben S. Luís, Georg Rademacher, Yoshinari Awaji, and Hideaki Furukawa , “319 Tb/s Transmission over 3001 km with S, C and L band signals over >120nm bandwidth in 125 μm wide 4-core fiber”, International Conference: International Conference on Optical Fiber Communications (OFC 2021) Post Deadline Paper

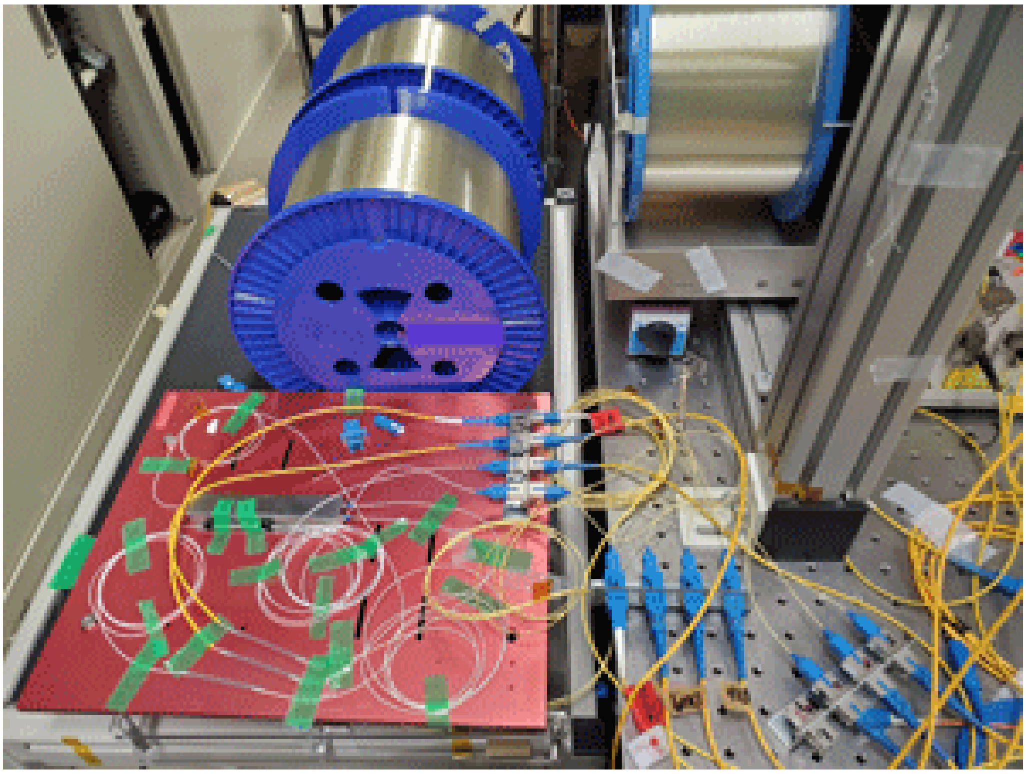


Fig. : Part of the transmission system in this demonstration (4-core fiber and Raman-pump multiplexer)

Advanced Electromagnetic Technology Area

Predicting torrential rain with the supercomputer FUGAKU

Started a real-time experiment that updates every 30 seconds in the Tokyo metropolitan area

A joint research group consisting of NICT, RIKEN, the National Institute of Informatics (NII), Osaka University, MTI Ltd., and others used the supercomputer Fugaku during two periods from July 20 to August 8 and from August 24 to September 5, 2021, to carry out real-time experiments in the Tokyo metropolitan area of ultra-high speed and high-performance rain predictions for up to 30 minutes in the future that were updated every 30 seconds.

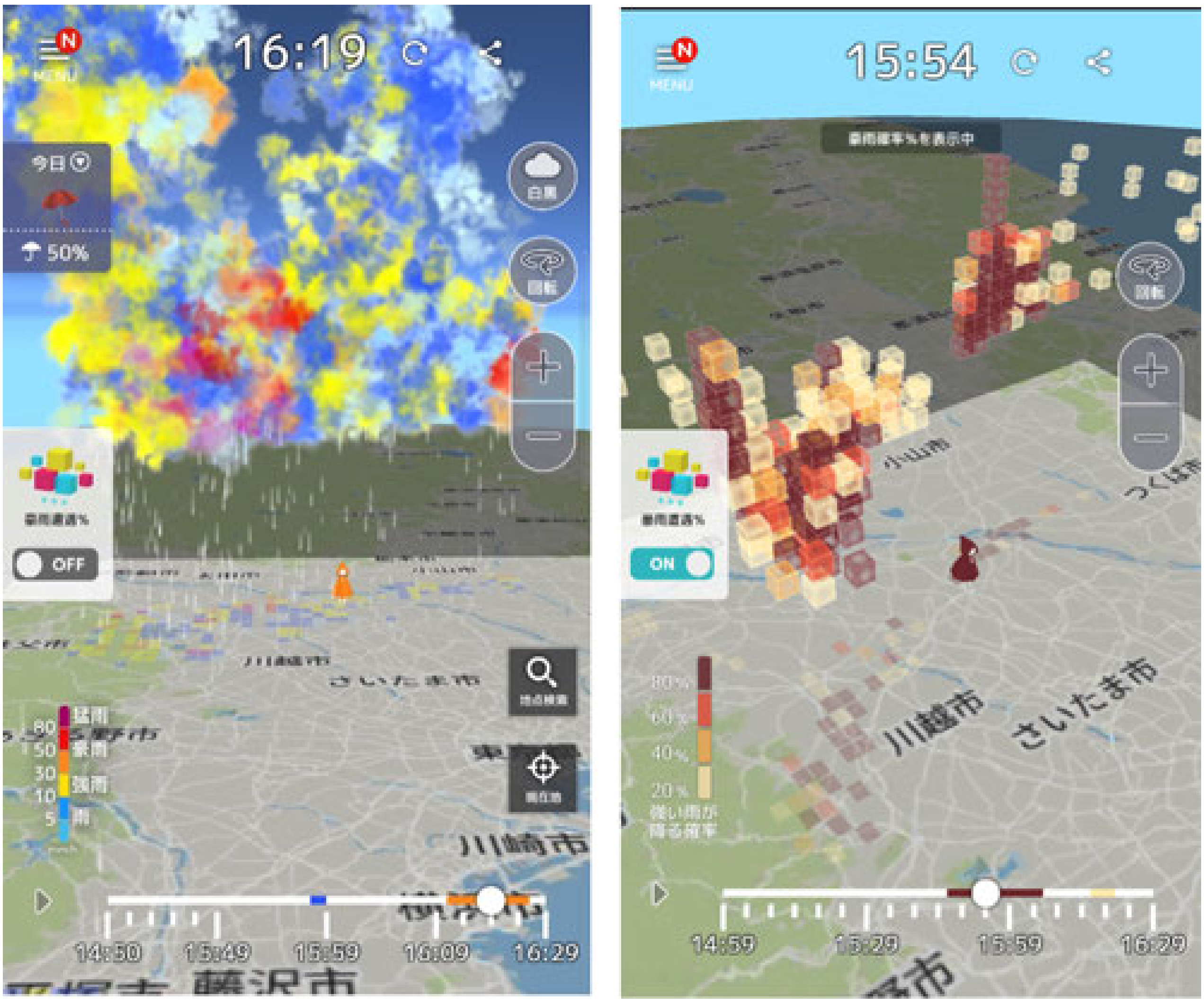


Fig. : Image of 3D Amagumo Weather app used in this experiment

By linking the virtual world on Fugaku to the real world in real time to help predict the risk of sudden torrential rainstorms, which have become more frequent in recent years, this research is expected to open up advanced uses for Fugaku and contribute to realizing the Japanese government's vision of an ultra-smart society dubbed Society 5.0.

In 2020, the joint research group used detailed observational data of rainclouds updated every 30 seconds by the state-of-the-art Multi-Parameter Phased Array Weather Radar (MP-PAWR) operated by NICT in Saitama City, and the supercomputer Oakforest-PACS of the Joint Center for Advanced High Performance Computing (JCAHPC) that is jointly operated by University of Tsukuba and the University of Tokyo, to conduct an experiment that collected and updated new data every 30 seconds in the Tokyo metropolitan area, and used this data to predict the weather up to 30 minutes in the future.

In the latest experiment, the group used Fugaku, the world's fastest supercomputer whose shared use was made available starting in March 2021, to perform as many as 1,000 ensemble calculations, a 20-fold increase from the previous year. The system as a whole has also been improved, enabling weather forecasts at a resolution of 500 meters in real time, which updates every 30 seconds. This real-time forecast is the first of its kind in the world and is the culmination of various achievements since the research began in October 2013. This was the first attempt to use Fugaku in real time, which is expected to open up new ways to utilizing Fugaku as a means of realizing the Society 5.0 ultra-smart society.

Frontier Science Area

Neural correlate of Pavlovian conditioning

The group led by Executive Researcher, Motojiro YOSHIHARA, and Senior Researcher, Akira SAKURAI at NICT unraveled a neural correlate of Pavlovian conditioning. The feeding command neurons, which were discovered by the same group in the brain of fruit flies (Nature, 2013)[1], were found to be hijacked by an originally-independent stimulus, leading to the conditioned response. Furthermore, the experimental system of Pavlovian conditioning made possible real-time observation of cell-cell connection for memory formation.

We unraveled a neural correlate in the brain during Pavlovian conditioning as one representative example of memory formation.

Although Pavlovian conditioning, where sound stimulus and food stimulus are associated, is widely known, its mechanism in the brain has been poorly understood. We used a fruit fly, *Drosophila melanogaster,* which allows us to monitor or manipulate the activity of specific cells through genetic techniques. We also used an experimental system, which we have developed for simultaneous observation of both brain and behavior[2], and tracked changes in the fly brain during Pavlovian conditioning.

The group discovered that change in information processing by the feeding neurons, a pair of command neurons[3] for feeding behavior, in the *Drosophila* brain, governs Pavlovian conditioning. The feeding neurons are originally activated in response to food signals. However, rod removal, akin to stimulating a dog with sound, activated the feeding neurons after repeatedly making the fly associate rod removal and feeding. They can speculate that putative feeding command neurons may be activated by sound stimulus through newly formed connections during Pavlovian conditioning of a dog (see Fig.). Furthermore, the experimental system of Pavlovian conditioning made possible real-time observation of cell-cell connection for memory formation.

The group is now observing formation of an engram, which is responsible for memory, as a newly formed cell-cell connection in real time. They will then try to test a general model of memory formation, the local feedback model that they have proposed (Science, 2005)[4], by taking advantage of this experimental system to elucidate the mechanism of memory.

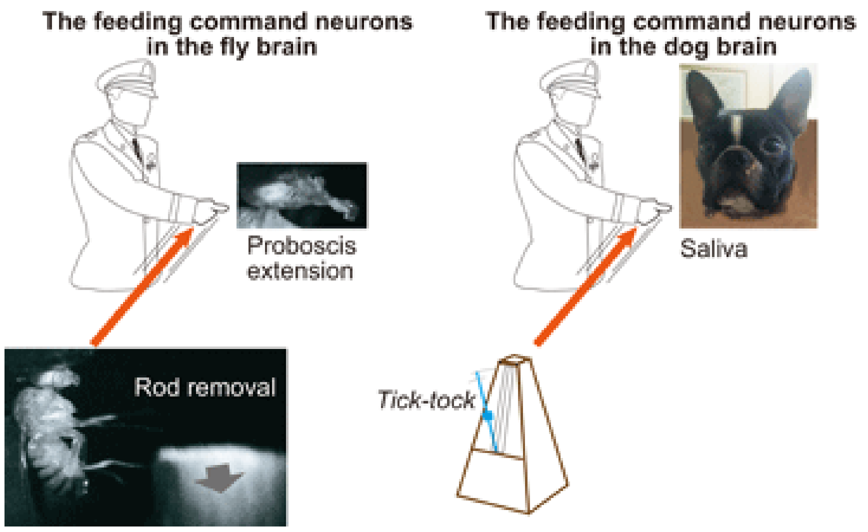


Fig. : Mechanism of Pavlovian conditioning

Reference

Akira Sakurai, J. Troy Littleton, Hiroaki Kojima, and Motojiro Yoshihara,
"Alteration in information flow through a pair of feeding command neurons underlies a form of Pavlovian conditioning in the Drosophila brain," Current Biology, vol.31, issue 18, pp.4163-4171, 2021
DOI: 10.1016/j.cub.2021.07.021

1. Flood, T., Iguchi, S., Gorczyca, M., White, B., Ito, K. and Yoshihara, M. *Nature* vol.499, pp83-87, 2013
2. Yoshihara, M. *Journal of Visualized Experiments* vol.62, e3625, 2012
3. Yoshihara, M. and Yoshihara, Motoyuki J. Neurogenet. vol.32, pp53-62, 2018 Introduced by *Nature* (*Nature*, vol.558, p162, 2018).
4. Yoshihara, M., * Adolfsen, B., Galle, K.T. and Littleton, J.T. *Science* vol.310, pp858-863, 2005

Frontier Science Area

Olfactory stimulation can modulate perception of speed

Lemon is slow, vanilla is fast

Senior Researcher Yoshiaki TSUSHIMA and his colleagues at NICT CiNet conducted psychophysical and fMRI experiments which revealed new crossmodal phenomena in which the perception of speed in a video was modulated by different scents. They discovered that in the presence of a lemon scent, people perceived video to be slower, and in the presence of a vanilla scent, people perceived video to be faster. These results are the first time that scent has been shown to modulate low-level perceptions (such as that of video speed), rather than just high-level cognitive functions like emotion and memory.

Humans receive information about the outside world through their five senses, which include vision, hearing, and smell, and employ multiple senses at the same time. For instance, they use vision and hearing when watching a movie, or smell and taste when cooking. These senses influence one another as the person processes information from the outside world (crossmodal phenomena). The effects of crossmodal phenomena due to olfactory stimulation are well-known. The smell of perfume can change our mood and aromas are used for aromatherapy and other methods of relaxation and enjoyment in our everyday lives. However, scientific research into crossmodal phenomena using olfactory stimulation is still underway, and many issues remain poorly understood. Researchers face major challenges, chief among them the difficulty in controlling olfactory stimuli and evaluating perceptions relative to the stimuli.

In this research, NICT took full advantage of psychophysical experiment methodology and fMRI experiments to successfully demonstrate, in a scientific manner and based on psychological and physiological data, that the perception of speed when watching a video is modulated by scent.

In the experiment, the researchers used Aromajoin Corporation's Aroma Shooter to control olfactory stimulation (Fig. top left). Then, following the methodology of psychophysical experiments, they asked participants to describe the speed of moving dots (Fig. bottom left). The results showed that even when these dots were moving at the same speed, the presence of a lemon smell made them seem to move slower compared to when no smell was present. In contrast, a vanilla scent made them seem to move faster (Fig. center). The participants were asked to perform almost the same psychophysical experiments while inside an fMRI device in order to examine their brain activity. This confirmed that brain activity in the visual cortices (hMT, V1) changed significantly based on the type of olfactory stimulation (Fig. right), thus demonstrating the presence of crossmodal phenomena between the visual and olfactory senses based on psychological and physiological data.

These results are scientifically significant in that they reveal a new crossmodal phenomenon between the senses of vision and smell. They are also expected to have various industrial applications in fields which utilize crossmodal phenomena, such as VR and entertainment.

Reference

Yoshiaki Tsushima, Yurie Nishino, and Hiroshi Ando, "Olfactory stimulation modulates visual perception without training," Frontiers in Neuroscience,vol.15, 642584, Aug. 2021.
DOI: 10.3389/fnins.2021.642584

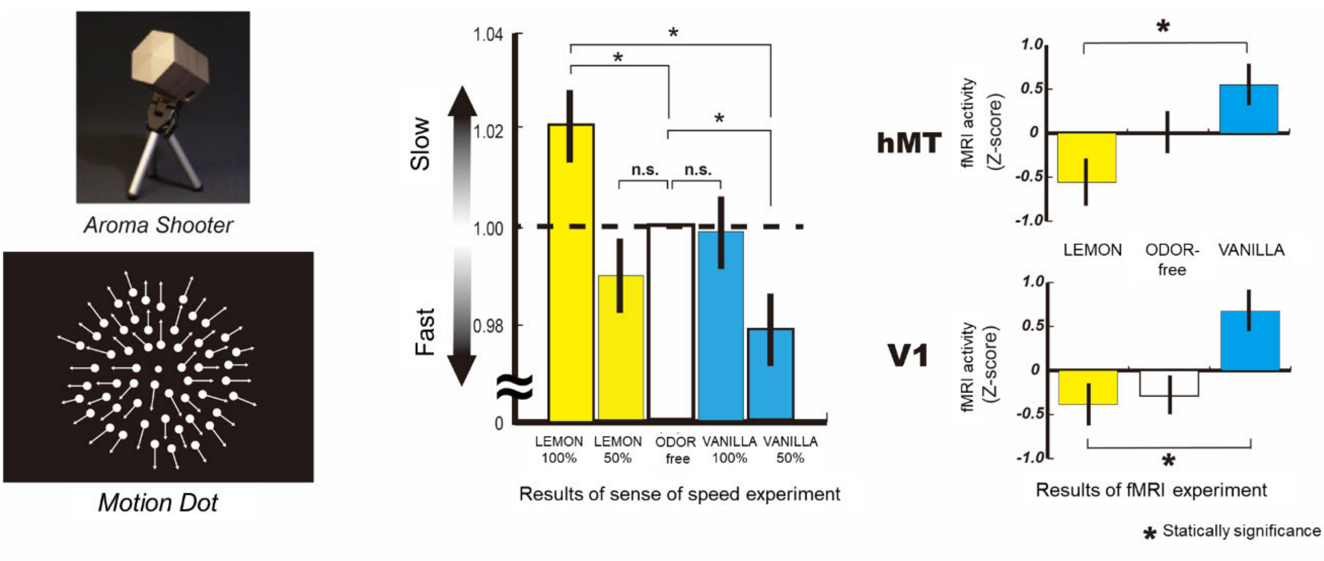
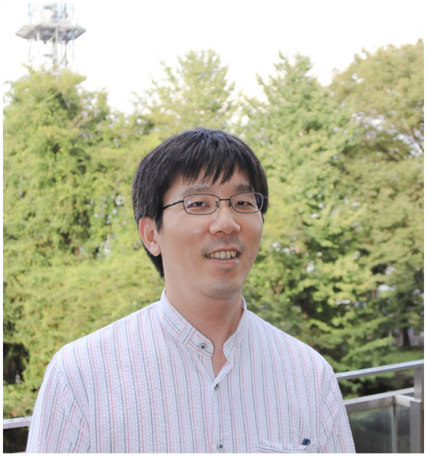


Fig. : Devices and visual stimuli used in this experiment, and experimental results
Top left: Aroma Shooter olfactory controller used in experiment, Bottom left: Screen viewed by participants in psychophysical experiment,
Center: Results of speed perception in psychophysical experiment, Right: Results of brain activity in hMT and V1 brain regions in fMRI experiment

Researchers

Person 1



AONO Yoshinori
Tenure-track researcher, Security Fundamentals Laboratory, Cybersecurity Research Institute

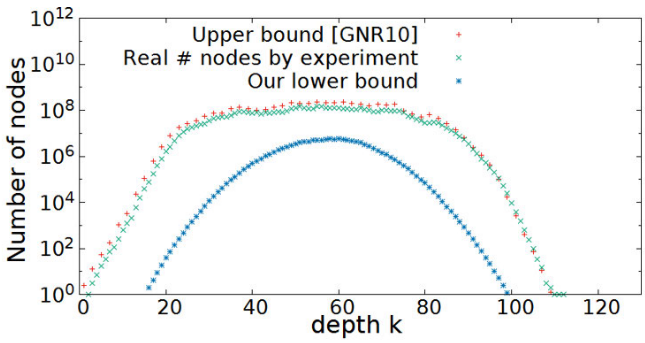
He was born in Tokyo, Japan in 1982. After earning a doctorate degree, he joined NICT in 2011. He has been involved in the research and development of security analysis of public-key cryptography, especially lattice-based cryptography. Ph.D. (Science).

The limit of cryptanalysis

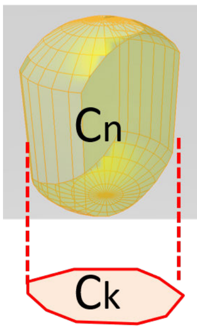
Since cryptographic encryption/decryption are computing processes, cryptanalysis focuses on the classical problem: How we can reduce the resources required for them? Proving upper or lower bounds is a central topic in complexity theory. There is an old rule of thumb that it is easy to show one boundary side but tremendously difficult to show the other side. The easy side is typically satisfied by showing the existence of a single example (∃), while the other side needs to consider all (∀) instances.

Resource estimation in cryptanalysis is no exception. (To my best knowledge,) there is no useful theorem to guarantee that breaking a cryptosystem must take an extremely long time. As a next best thing, the design of the cryptographic system will be based on the cryptanalytic results of researchers around the world and a little bit of future prediction. Fortunately, I was able to show a lower bound on the attacking time of lattice-based cryptosystems albeit under limited conditions. That is somewhat close to the known upper bound.

During research to develop this work, I found that the energy efficiency of state-of-the-art electric circuit-based computation is close to the physical (Landauer's) limit. Such physical limitation-based parameter selection has been discussed for a long time. Calculating cryptographic parameters by referring to old textbooks provides a pretty good result. So, these types of approaches will increase in the future. I tried to see if something similar is possible within the quantum field, but the theoretical hurdles seemed to be quite high.



a)



b)

Fig. : a) Comparison among the known upper bound, experiment, and our lower bound of attacking time of lattice-based cryptosystems
b) Isoperimetry: our key tool from mathematics

Yoshinori Aono, Phong Q. Nguyen, Takenobu Seito, Junji Shikata, "Lower Bounds on Lattice Enumeration with Extreme Pruning," CRYPTO 2018

Q&A

What is the most interesting point in your research?

My research subject is lattices, which have a very simple structure and appear in cryptography, wireless communication, quantum computation, and everywhere else. I feel it is interesting when I discover unexpected connections between them.

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

In the research of cryptography, it is necessary to consider the long-term protection of data. For this purpose, it is also necessary to research emerging/future technologies (including science fiction-like ones) to see how society will develop in the future. It is interesting to learn about the cutting edge of various fields.

What are you aiming at as a researcher?

I want to do a job where I can leave a theorem with my name on it in a textbook. To do so, I want to continue working in one field.

Researchers

Person 2

NAWA Norberto Eiji
Senior Researcher, Brain Function Analysis and Imaging Laboratory, Center for Information and Neural Networks, Advanced ICT Research Institute

Norberto Eiji Nawa joined NICT in 2006, after completing his Ph.D. studies and working as a researcher at ATR Labs. His main areas of interest are in the intersection of emotion processes with episodic memory, attention, and well-being, with a focus on the role played by positive emotions.
Ph.D. (Informatics)

Understanding how to harness the power of positive emotions to enhance well-being

Our lives are filled with emotions; we may feel frustrated when plans do not work out as expected in one moment, but we can feel truly grateful when people come to our help in another. Emotions color our memories from the past, influence our decisions and even our attention. Not surprisingly, the emotions, or *affective states,* we experience in everyday life are strongly related to our sense of *well-being*. People high in well-being typically experience more positive affective states as they go about their activities. They also tend to be more *optimistic* and *grateful.* But what if you are not naturally inclined to have such positive dispositions? Luckily, a growing body of evidence has shown that cognitive-behavioral interventions can help people enjoy some of the positive outcomes associated with such dispositions. In a recent study [1], we showed that university students who engaged with a *gratitude journal* activity for 2 weeks displayed dramatic enhancements in academic motivation. Remarkably, such effects did not recede even

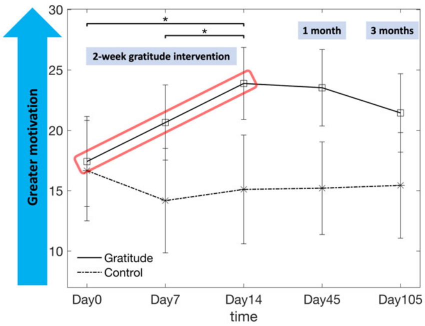


Fig.1 : Academic motivation improved during the 2-week intervention only among students in the Gratitude group (red rectangle); interestingly, such effects were still present 1 and 3 months after the end of the gratitude journal intervention.

3 months after the end of the intervention (Fig. 1). We also found that the improvements were driven by decreases in scores of "amotivation", a facet of motivation that is linked to feelings of helplessness, incompetence, and lack of purpose. Though it most certainly is not a solution for all problems, writing a few words every day about the individuals and things one is thankful for can go a long way in helping people find and appreciate the little but bright gems life has to offer.

[1] NICT press release (in English)
https://www.nict.go.jp/en/press/2021/05/13-1.html
[2] N.E. Nawa & N. Yamagishi, "Enhanced academic motivation in university students following a 2-week online gratitude journal intervention", BMC Psychology, 9, 71, May 2021.
https://doi.org/10.1186/s40359-021-00559-w

Q&A

What is the most interesting point in your research?

Emotions have belonged to the realm of the intangible since the beginning of human history, but we may be reaching a turning point with recent advances in neuroimaging and AI technology. The possibility that one day we might have a comprehensive and mechanistic understanding of human emotions is a very exciting and interesting part of my research.

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

A typical day in the life of a researcher involves many tasks, but the highlight is always to have the chance to discuss new ideas and possibilities with a collective of very creative and sharp-minded people. Though the ***hedonic treadmill*** *makes it easy to forget, that is a privilege for which I feel tremendously happy and grateful.*

What are the social meaning, importance and future prospects of your research?

In recent years, people have gained access to an incredible amount of material goods and information but there are no signs that well-being has advanced in tandem with such progress. By producing a solid evidence base through rigorous science, I believe emotion research can make important contributions in that respect.

Researchers

Person 3

Sunmi Kim
Senior Researcher,
Quantum ICT Laboratory, Advanced ICT Research Institute

After earning a Ph.D. degree in physics from Sogang University (Korea) in 2003, she worked at NIMS, Osaka University (as a post-doctoral fellow) and Tokyo University (as a project assistant professor). Then she joined the NICT in 2018. She has been involved in research for the development of superconducting quantum circuits, especially with nitride superconductors and pi-junction materials.
Ph.D. (Physics)

Exploring quantum technologies based on the NbN-based superconducting qubit for future quantum information processing

Since superconducting qubits are solid-state elements, they have excellent design flexibility, integration, and scalability, but they are easily affected by various disturbances in their surrounding environment. The challenge is how to extend the coherence time, which is the lifetime of quantum superposition states. The remarkable progress of superconducting qubits has to a large extent resulted from the innovative five-order increase in their coherence times by improving mainly circuit designs. And a breakthrough in the further improvement of superconducting qubits can be expected by exploring alternative materials for superconductor/insulator/superconductor junctions.

It has been pointed out that superconducting circuits made from aluminum and aluminum oxide are fundamentally limited by losses due to microscopic two-level systems (TLS) within the amorphous oxide layers encasing them. NICT had been developing an all-nitride superconducting qubit using NbN/AlN/NbN epitaxial junctions grown on an MgO substrate, but its coherence time was around 0.5 microseconds due to a dominant dielectric loss from the MgO substrate. Since I joined NICT in 2018, I have been involved in developing a superconducting flux qubit with π-phase shifter where NbN-based Josephson junctions are used [1]. By utilizing the NbN-based fabrication technique on a silicon substrate with a TiN buffer to decrease dielectric loss from the MgO substrate, we have successfully observed the enhanced coherence time of all-nitride superconducting qubit in the order of tens of microseconds [2]. These results are an important step towards constructing a new platform for superconducting quantum information devices.

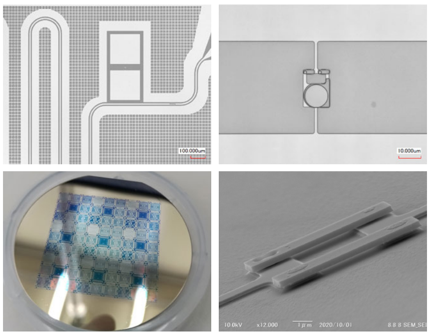


Fig.1 : NbN-based superconducting quantum circuits

[1] T. Yamashita, S. Kim, H. Kato, W. Qiu, K. Semba, A. Fujimaki, and H. Terai, "π phase shifter based on NbN-based ferromagnetic Josephson junction on a silicon substrate," Scientific report, vol.10, 13687, 2020.
[2] S. Kim, H. Terai, T. Yamashita, W. Qiu, T. Fuse, F. Yoshihara, S. Ashhab, K. Inomata and K. Semba, "Enhanced coherence of all-nitride superconducting qubit epitaxially grown on silicon substrate," Communication Materials, vol.2, 98 ,2021.

Q&A

What is the most interesting point in your research?

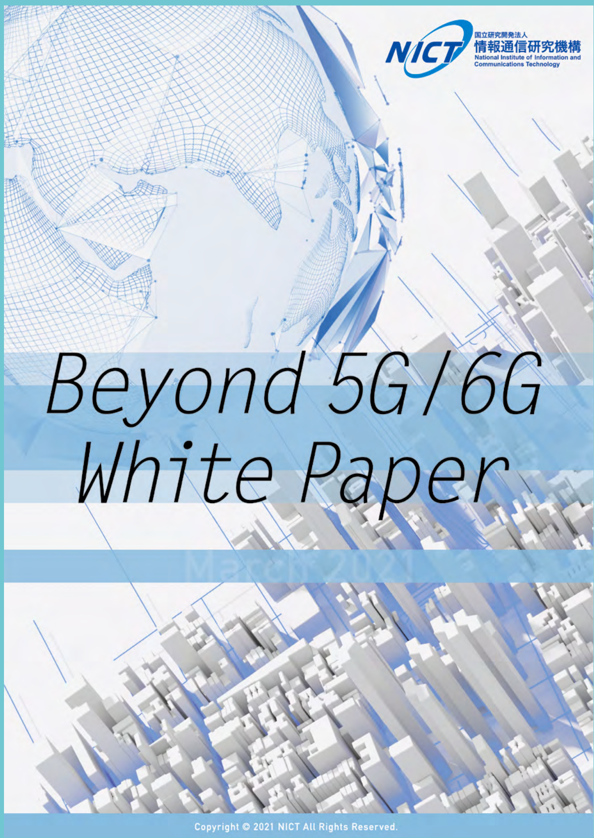
By combining circuit elements like capacitors and inductors with non-linear quantum elements such as the superconducting tunnel junction, I create a quantum bit (qubit) functioning as an artificial atom and study its coherent quantum state using the microwave technique at extremely low temperature. The most interesting point in my research is that I can explore the world of quantum physics by designing and controlling this physical system.

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

During this research, I am very pleased to learn more deeply about many experimental techniques such as nanofabrication with nitride superconductors, dilution refrigeration, and ultra-low noise microwave measurements, through collaboration with my colleagues and collaborators from NICT, Nagoya University, and AIST. The happiest moment in my current research subject was when we observed relatively long Rabi oscillations from a sample improved based on feedback from many failures.

What are the social meaning, importance and future prospects of your research?

Using this new material platform based on nitride superconducting materials, we will accelerate the research and development of quantum information processing, which will contribute to the realization of more power-saving information processing and the realization of quantum nodes necessary for the construction of safe and secure quantum networks.



Beyond 5G / 6G

White Paper Summary

Beyond 5G / 6G(B5G / 6G), the next-generation information and communications infrastructure, is essential for achieving the SDGs and realizing Society 5.0, and it is important to define its functional structure. In physical space, a flexible and scalable communication environment is provided by combining not only conventional terrestrial mobile networks, but also satellite networks and multi-core optical networks. In cyberspace, a variety of spaces coexist depending on the application, and information processing is carried out based on accumulated past data and future forecasts (Fig. 1).

In the Beyond 5G / 6G era, time and space will be highly controlled in both physical space and cyberspace, and the integration of the two spaces will make it possible to do things that have not been possible in the physical space alone. The combination of enablers (Platform services / Basic functions) that can be implemented across the integrated physical space and cyberspace is expected to provide new applications and help solve various social issues.

Chapter 3 of this White Paper introduces three scenarios and several use cases that illustrate social life around 2030 to 2035. "Cybernetic Avatar Society," which depicts a society in which avatars are highly utilized; "City on the Moon," which depicts a society in which human activities spread to the Moon; and "Transcending Space and Time," which depicts a society in which the limitation of space and time is transcended. The second half of the White Paper summarizes the elemental technologies and requirements to realize the use cases, the R&D roadmaps (Chapter 4), and the deployment strategy (Chapter 6).

This document is the first initiative that NICT, a group of experts in information and communication technologies, has studied for realization of the Beyond 5G / 6G world. We will continue discussions with many people based on this document and revise this White Paper as needed according to the progress of the discussions.

Background

1. Evolution of Mobile Communication Systems

Mobile communication systems have evolved from communication infrastructure (1G-3G) to living infrastructure (4G), and have become an indispensable element in the lives of individuals. 5G has become social infrastructure that connects not only people but also things, such as in the Internet of Things (IoT). Cyber physical systems (CPSs), in which people interact with each other, people with things, and things with things through cyberspace, have become significant in various aspects of social life. In next-generation mobile communication systems (Beyond 5G / 6G), communication networks supporting the CPSs will serve as the nerve network of society itself.

2. COVID-19 Pandemic

In response to the global pandemic of the novel coronavirus, governments around the world have responded by enforcing lockdowns and other measures to minimize direct human-to-human contact and reduce infections. Many people are being encouraged or compelled to work from home. Telecommuting enables individuals to connect through cyberspace, enabling them to continue their economic activities to some extent. However, the inadequacy of current information and communication technology has become clear.

3. R&D Competition for Next-Generation Mobile Communication Systems

There is an accelerating trend towards the dominance of next-generation mobile communication systems, both economically and in terms of security. Against this background, interest in Beyond 5G / 6G has increased significantly compared to previous generation changes, and there is much discussion about how to proceed with research and development.

B5G/6G Era: Scenarios and Use Cases

Chapter 3 of the White Paper describes three future use cases of Beyond 5G / 6G in 2030 to 2035.

1. Cybernetic Avatar Society

In this scenario, we forecast a day of a technical manager in 2035 (Fig. 2). He plays multiple roles in different places for different people using his own cybernetic avatars.

To realize this scenario, we think three systems will be implemented: a mutual understanding promotion system; mind and body support avatars; and a working style revolution using a telepresence.

2. City on the Moon

In this scenario, we forecast that people

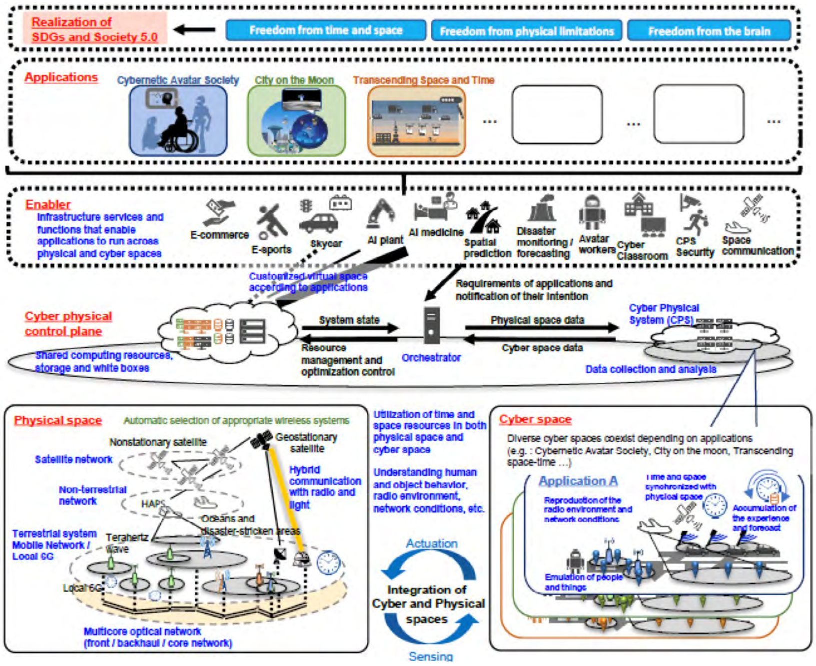


Fig.1： B5G / 6G Era

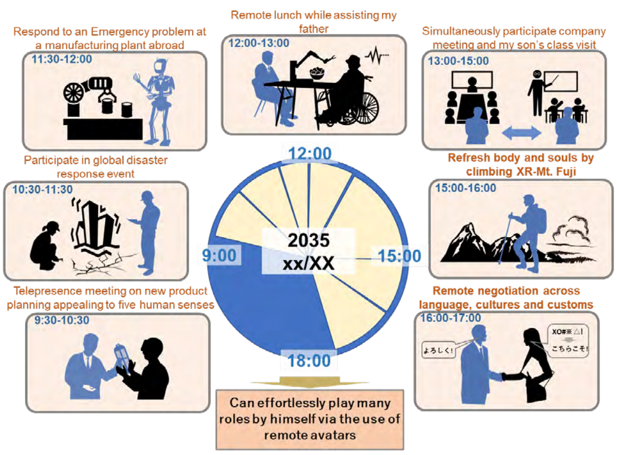


Fig.2： Cybernetic Avatar Society

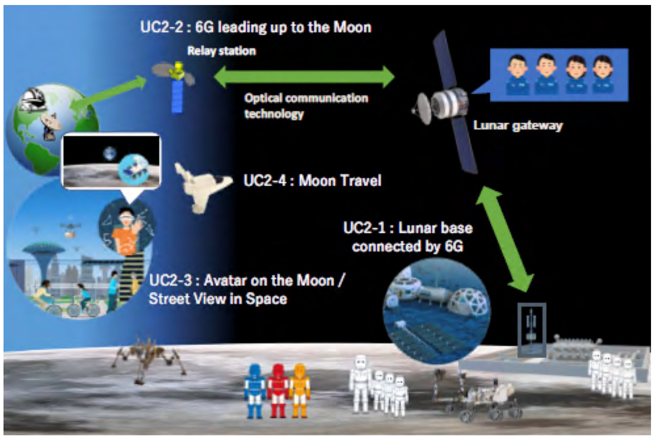


Fig.3： Moon City

will cultivate the Moon (Fig.3). A group of astronauts manipulates their own avatars working on the Moon from a Lunar Gateway orbiting the moon, and also from the Earth.

To realize this scenario, three systems will be required: a Lunar Base connected by 6G, enabling positioning and location in the harsh lunar environment with high reliability and security; 6G leading up to the Moon, used for communication between lunar avatars and users on the Earth; and an Avatar on the Moon/Street View in Space and Moon travel system, enabling real-time work to be performed at lunar plants, construction sites, and lunar laboratories while on the ground.

3. Transcending Time and Space

In the third scenario, people from small children to elders lead creative and active lives with the help of Beyond 5G technologies. Autonomous AI and drones above the Earth watch and maintain natural environments and physical infrastructure, and provide alerts. We assume three use cases: a vertical flow of people(Fig.4), things and information; a resilient village forest; and an omni-cloud gateway(Fig.5).

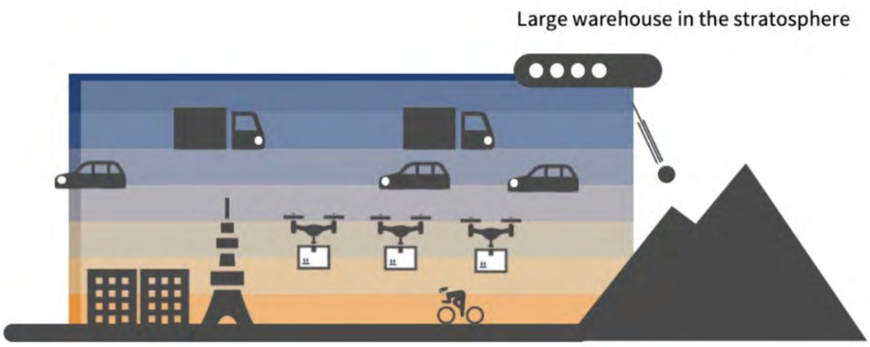


Fig.4 : Vertical Flow of People, Things and Information

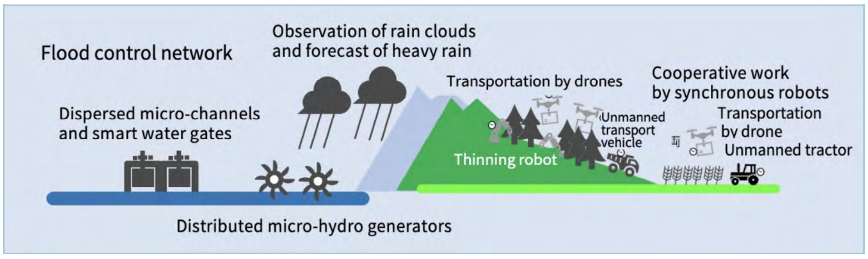


Fig.5 : Resilient Village ForestInformation

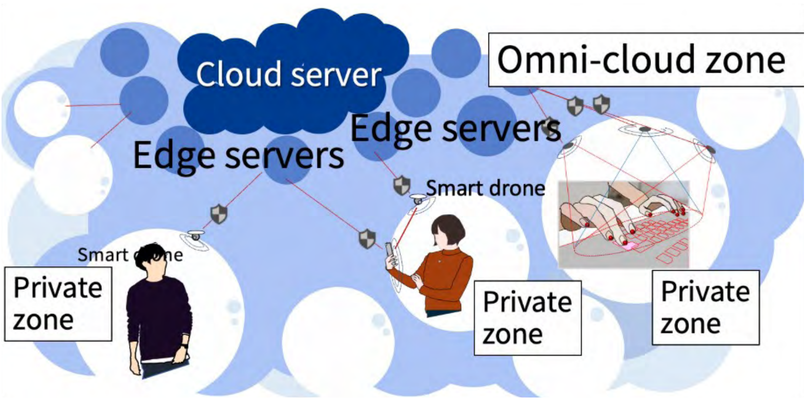


Fig.6 : Omni-cloud Gateway

Key Technologies

Chapter 4 of the White Paper describes key technologies that support the use cases in Chapter 3.

Fig. 7 summarizes the key technologies that are considered necessary for Beyond 5G/6G.

Fig. 8 summarizes the roadmaps, focusing on the most representative of each field. It also shows the estimated timing of the scenarios in Chapter 3.

Deployment Strategy

Chapter 6 of the White Paper describes the deployment strategies. We focus on both international standardization and the National Project for Beyond 5G/6G Research and Development.

・Standardization for Beyond 5G/6G

After 3G, ITU-R has made recommendations on specifications established by private standardization bodies, and one of the major trends is to make them international standards. The international allocation of frequencies will be decided at the World Radiocommunication Conference (WRC), which is held approximately every four or five years. The standardization of mobile communications at ITU-R has been conducted at WP5D (IMT systems) under SG5 (terrestrial services). In October 2020, WP5D began compiling the survey results and future technology trends, and it is scheduled to be completed in June 2022. First, it is necessary to incorporate the elements of NICT and Japanese technologies into future technology trend surveys and to reflect them in the recommended vision, and then to have them adopted in the next step of standardization, while improving the specificity of technologies and building partnerships.

・National Project for Beyond 5G / 6G Research and Development

In the "Beyond 5G Promotion Strategy – Roadmap to 6G" announced by the Ministry of Internal Affairs and Communications in June 2020, activities up to the introduction of Beyond 5G/6G around 2030 are described in two phases: the "Proactive Action Phase" and the "Acceleration Phase." As a part of the Proactive Action Phase, the Beyond 5G R&D Program is strongly supported by the government. Under the program, the following three sub-programs will be implemented in accordance with the three basic policies of "Global First," "Creation of Ecosystems that Generate Innovation," and "Intensive Allocation of Resources."

1. Beyond 5G Function Realization Program
2. Beyond 5G International Joint R&D Program
3. Beyond 5G Seeds Creation Program

In the Beyond 5G Function Realization Program, we plan to gradually establish key technologies from around 2025 and reflect them in international standards for 3GPP, etc.

Conclusion

In the Beyond 5G/6G White Paper, we assumed three scenarios based on the views of social life around 2030 to 2035. By backcasting from the future society scenarios, we summarized Beyond 5G/6G concepts, use cases, and essential technologies. We also presented roadmaps for R&D. In order to develop, implement, and utilize the necessary future technologies to realize the depicted social life and world view, it is necessary to take into account technological evolution not only in the information and communication fields, but also in a wide variety of other areas, and discuss them with various stakeholders. We will continue to discuss and revise the White Paper.

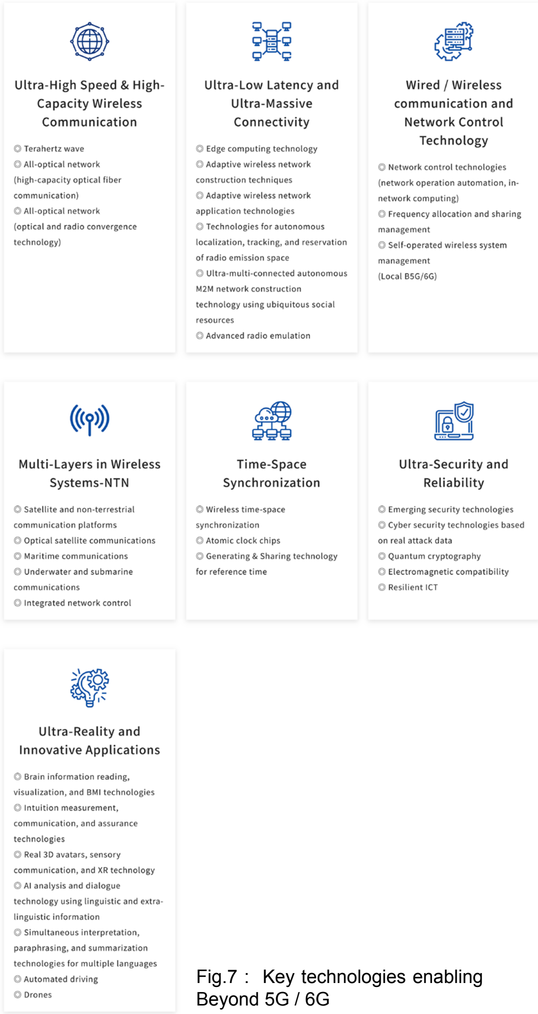


Fig.7 : Key technologies enabling Beyond 5G / 6G

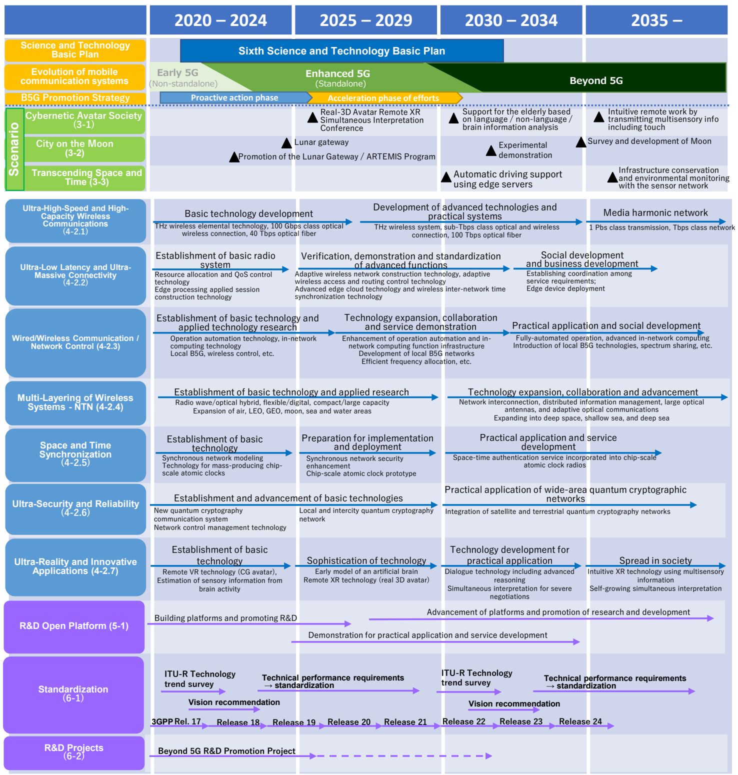
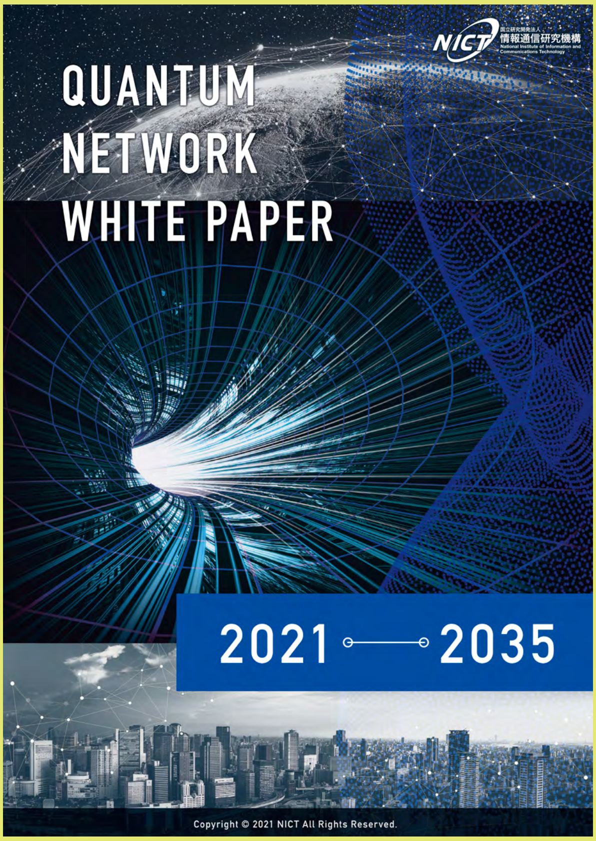


Fig.8 : R&D roadmaps



Quantum Network

White Paper Summary

Information and communication technologies, such as the internet and cellular phone networks, have become indispensable infrastructure for the global economy and our daily lives.

However, cyber-attacks on information and communication networks continue to increase, and it is also feared that the latest cryptography used in modern networks will be broken by high performance quantum computers being developed by major IT companies.

For this reason, quantum cryptography is required to realize "information-theoretic security" that cannot be broken by any computer in principle.

Efforts are underway in Japan and overseas to develop quantum cryptography and quantum networks with the ultimate goal of achieving the "Quantum Internet," a new-generation social infrastructure.

In January 2020, the Japanese government released the "Quantum Technology Innovation Strategy." NICT has been promoting cutting-edge R&D related to quantum networks as a "Quantum Security Hub" in the government strategy.

The Quantum Network White Paper describes the direction of NICT's Research and Development as the hub of quantum security, and the issues to be tackled in the future. In order to attract international researchers, the White Paper promotes cooperation with international research institutes, and accelerates research and development of quantum networks.

Key Technologies

Quantum Cryptography

Quantum cryptography is a technology that uses the properties of quantum mechanics to make cryptographic communication unbreakable by any computer, including quantum computers. It consists of two steps: quantum key distribution (QKD) and one-time pad encryption. QKD is a method of sharing symmetric cryptographic keys between two remote locations without revealing any information to a third party (eavesdropper) that has any theoretical ability. In one-time pad encryption, a cryptographic key of the same size as the data (plain text) is prepared, and a ciphertext is generated by XOR of the plain text and the cryptographic key. The cryptographic key is discarded each time and is never reused. This realizes cryptographic communications with "information-theoretic security" that cannot be deciphered in principle by any computer (Fig. 1).

Quantum Network

A quantum network is communication infrastructure for distributing quantum information (quantum bits used in quantum computers, quantum entanglement state with quantum correlation, etc.) over a network in a manner that is different from classical digital (0s and 1s) networks. Distribution of quantum information thorough a quantum network is expected to enable quantum cryptography over longer distances than is currently possible. Furthermore, by connecting multiple quantum computers to a quantum network, it would be possible to build a large-scale quantum computer with high computing power (distributed quantum computing) to perform secret quantum computing without anyone knowing the contents of computation (Fig. 2).

The Quantum Internet is a global quantum network that connects quantum information devices such as quantum computers and quantum sensors. Given that the current Internet is a network in which multiple networks are are interconnected and digital information (bits) is distributed, the Quantum Internet is a network in which multiple quantum networks are interconnected and and quantum information (qubits) is distributed.

Image of Society with Quantum Networks

Fig. 3 shows examples of use cases that are expected to be realized by quantum technology in the future.

•In the 2020s, QKD networks are expected to enable the secure exchange of critical information in the medical, manufacturing, and financial fields.

•In the 2030s and beyond, the spread of QKD networks is expected to enable safe and secure distribution of information in a wider variety of fields. In addition,

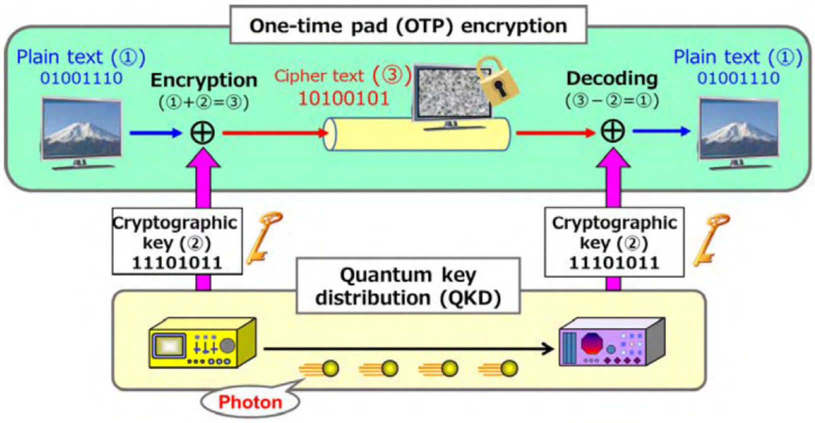


Fig. 1 : Mechanism of quantum cryptography

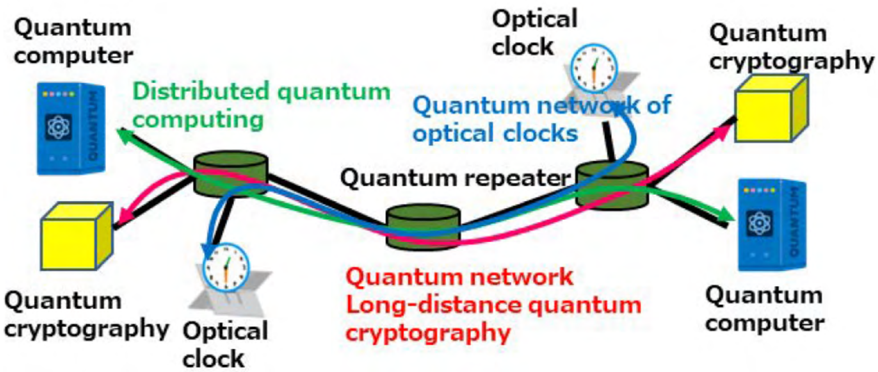


Fig. 2 : Overview of quantum network

	Example of use cases	Progress in quantum network technology	Quantum computing and sensing technology
2020s	● Medical care : Exchange of biological information, such as electronic medical records of genome information, that would have a lifetime impact if leaked ● Manufacturing : Exchange od information that would have a significant impact on corporate activities due to leakage of trade secrets, knowhow, important technologies, etc. ● Finance : Exchange of information on financial systems, transactions, etc.	• QKD (Kanto region → nationwide)	• NISQ Quantum Computer IBM 2020 : 65qubit 2021 : 127qubit 2022 : 433qubit 2023 : 1121qubit
2030s	● Administration/Diplomacy/Security : Exchange of personal information in admiration, communication of confidential in diplomacy, national security etc. ● Life : Ultra-secure Internet at the home level through cryptography vending machines for mobile terminals to exchange of personal medical and financial information	• QKD (nationwide → global) • Satellite QKD/physical layer encryption • Quantum networks	• NISQ Quantum Computer • Small-scale fault-torelant quantum computers • Quantum sensors
2040s	★ Chemicals, materials, drug discovery, etc. :Discovery of new materials and new drugs, etc. using quantum computers connected to quantum networks ▲ Disaster prevention and disaster response: Direction of weak gravity fluctuation by quantum sensors connected to quantum networks ● Resource development : High-precision image transmission of drilling robots on the Moon and Mars(Quantum coding beyond the Shannon limit)	• QKD (global scale) • Satellite quantum communication • Quantum networks (global scale)	• Fault-torelant quantum computers • Distributed quantum computing • Quantum sensors

●: QKD, ★ : Quantum computer, ▲ : E quantum sensing

Fig.3 : Examples of use cases of quantum networks

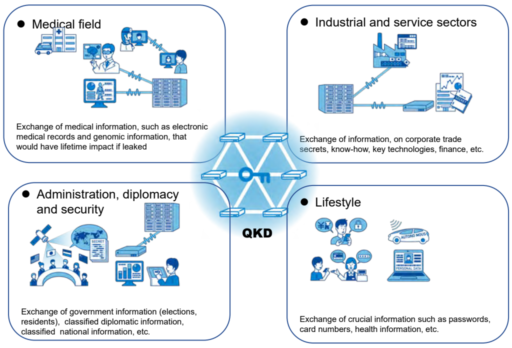


Fig. 4 : QKD use cases

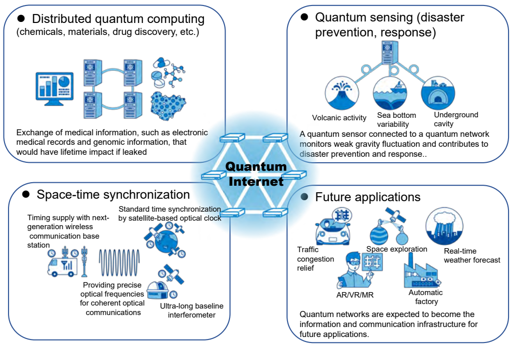


Fig. 5 : Quantum network use cases

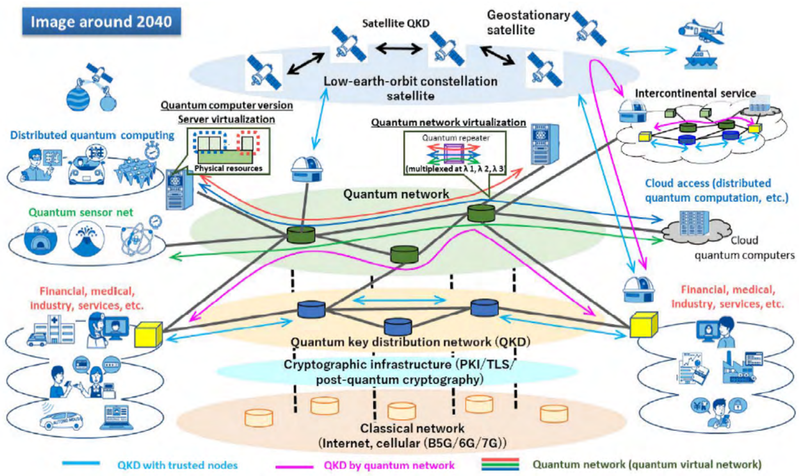


Fig. 6 : Evolution of quantum networks around 2040

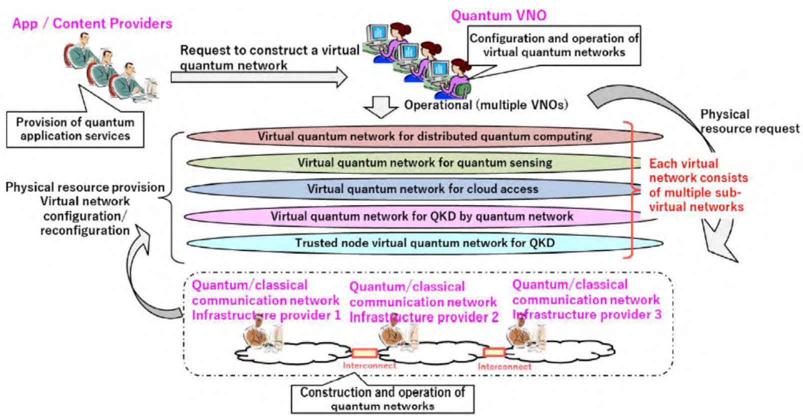


Fig. 7 : Image of quantum network services around 2040

quantum networks that interconnect with quantum computers and quantum sensors will begin to be deployed in society.

・In the 2040s, the Quantum Internet, in which multiple quantum networks are connected to each other around the globe, will be established, and entirely new applications and services will emerge. The Quantum Internet is expected to provide the foundation for affluent lifestyles and socioeconomic activities.

QKD Use Cases(Fig.4)

IInformation that must be protected for a long time includes government information related to diplomacy, defense, security, geographics (infrastructure, underground space), family registers, and voting; private company information like customer lists, sales information, new technologies, and design drawings; and individual information like health data, genome information, and personal information numbers. It is expected that QKD, which guarantees information theoretic security, will be used for such data.

Quantum Network Use Cases(Fig.5)

The realization of quantum networks is expected to lead to safe, secure, and convenient lifestyles and advanced socioeconomic activities.

Around 2040, a global quantum network of satellites and terrestrial networks will be established(Fig.6), and virtual quantum network services will be realized, accommodating a wide variety of quantum networks and protocols(Fig.7).

Overview of Quantum Network Technology

Fig. 8 to 10 show the key technologies of quantum networks in the "Quantum Technology Innovation Strategy" (January 2020). Of these, NICT is conducting R&D on the technologies shown in red.

NICT is conducting R&D on QKD networks, satellite and space communications, and quantum networks.

For more details on each technology, please visit the NICT Whitepaper download site.
https://www2.nict.go.jp/idi/en/index.html#whitepaper

Roadmap to Quantum Network

For the key technologies in the previous section, NICT has compiled a roadmap for the period from 2020 to 2035. The roadmap for R&D of terrestrial and satellite QKD networks is shown in Fig. 12.

The roadmap for R&D of quantum networks is shown in Fig. 13.

Promotion Strategy

A promotion strategy will be important for NICT to develop QKD networks and quantum networks in society in cooperation with external stakeholders.

In order to deploy quantum networks in society, it is necessary to promote five initiatives in an integrated manner:

① Research and development
② Social implementation
③ International cooperation
④ System design
⑤ Human resource development

Conclusion and Next Step

With regard to quantum networks, work on the social implementation of QKD and research and development for the Quantum Internet are underway internationally. NICT will collaborate with experts, companies, universities, and research institutions in Japan and overseas to promote the use of quantum networks in society.

NICT will update the Quantum Network White Paper based on future international trends and the latest R&D.

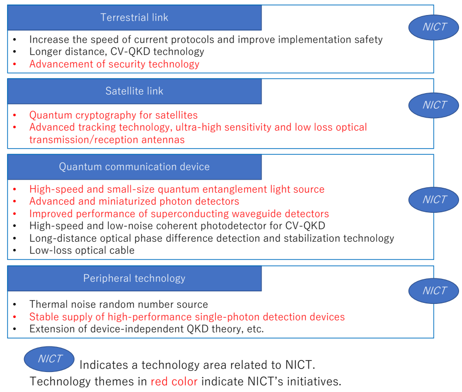


Fig. 8 : Quantum communication and cryptographic link technologies

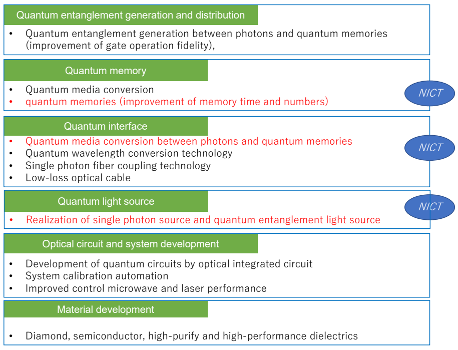


Fig. 9 : Quantum network technologies

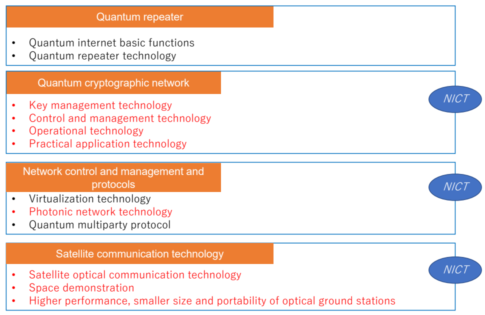


Fig. 10 : Networking technologies

(1) Quantum key distribution (QKD) technology	
	① Quantum key distribution (QKD) ② Key management and key relay technology ③ QKD network control and management technology ④ Quantum secure cloud technology
(2) Satellite and spatial communications	
	① Satellite quantum key distribution (QKD) technology ② Physical layer encryption technology ③ Satellite/ground network coordination technology
(2) Quantum network	
	① Quantum interface ② Quantum repeater ③ Multi-quantum network control and management ④ Quantum sensor network (Quantum network of optical clocks) ⑤ Quantum computing (Ion trap quantum computer) ⑥ Quantum computing (Superconducting quantum computer)

Fig. 11 : R&D Initiatives at NICT

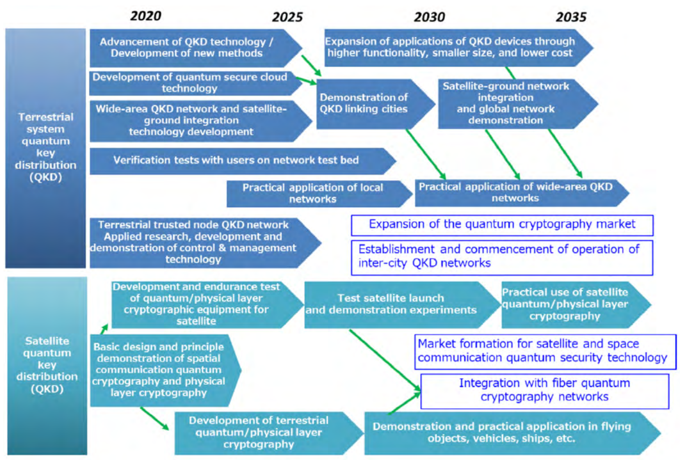


Fig. 12 : R&D roadmap for QKD networks

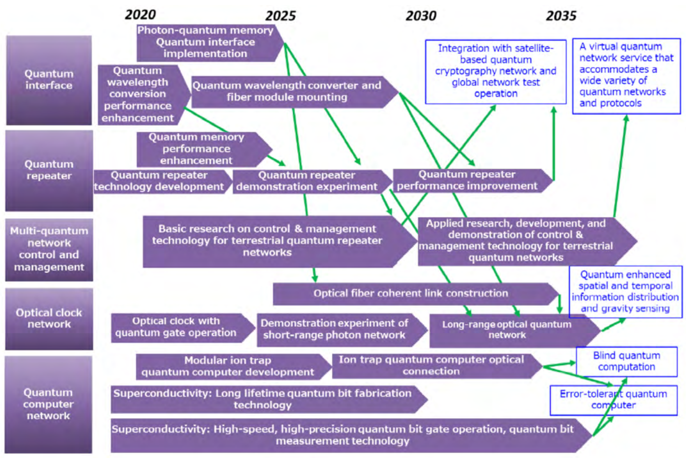
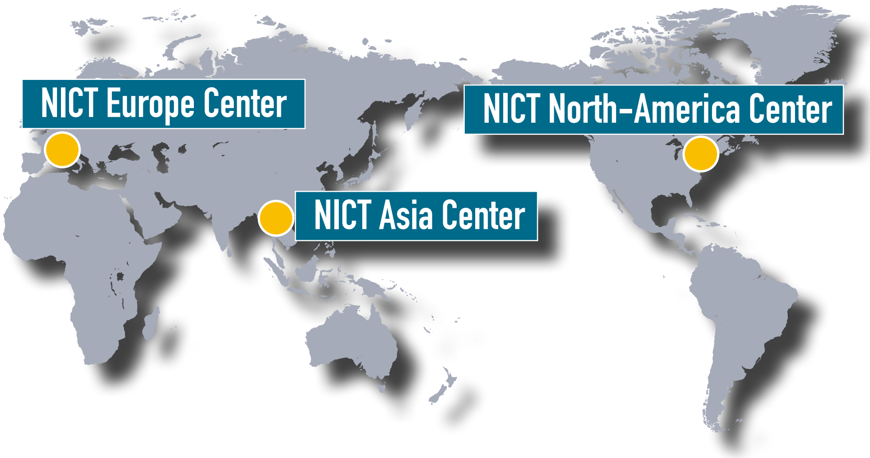


Fig. 13 : R&D roadmap for quantum networks

① Research and Development	● Promotion of continuous R&D at NICT ● Promotion of technology transfer of research result ● Promotion od R&D through national projects
② Social implementation	● Establishment of testbed ● Provision of application development infrastructure (establishment of business ecosystem) ● Fostering of industry
③ International corporation	● Collaboration with universities and research institutions ● Formation of research communities ● Formation and support for consortiums ● Organization of global partner network ● Launch of collaboration program with foreign institutions
④ System Design	● Promotion of international standardization ● Development of evaluation, certification and its framework ● Application of cyber insurance
⑤ Human resource development	● Development and securing of quantum natives ● Development and securing diverse quantum human ● Utilization of NICT quantum security hub

Fig. 14 : Promotion strategy

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
NISHINO Hisanori

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

It is now 19 years since the predecessor of the Asia Center, the CRL Asia Research Center, was established in Bangkok, Thailand in 2002. The Center has been gathering information, promoting and supporting research collaboration mainly in South-East Asia, as well as building relationships with relevant organizations as needed for collaboration.

One of these activities is to conduct an exhibition related to NICT's joint research with Thai research institutes every year at the National Science and Technology Fair (NSTF), which is organized by the Thai government. The NSTF is held in Bangkok every year in August and is one of the largest fairs focused on science and technology. There are various exhibitions and activities arranged through extensive cooperation from public and private, and local and international sectors to deepen understanding and spark inspiration about science and technology.

In 2020, NSTF was postponed to November due to COVID-19. The NICT booth received Thai VIP observers in addition to visitors (most of whom were Thai) who were able to receive explanations in Thai with the support of graduate students from our partner research organizations in Thailand. This contributed to their deeper interest and understanding of NICT activities. This year, NSTF has been postponed to November again, and we are currently making various preparations for our exhibition in collaboration with related organizations. (As of October 20)

COVID-19 continues to have an impact, but the Asia Center is striving to fulfill our role as an overseas base in the New Normal era to support R&D activities from Bangkok, Thailand.

Fig.1 : NICT booth staff

Fig.2 : Japan pavilion staff and Thai VIPs

NICT ASIA Center
100th Year Engineering Building,Room 703.
Floor 7th,Chulalongkorn University
254 Phayathai Road, Wang Mai,Pathumwan,
Bangkok 10330, Thailand
Tel & Fax: +66-2-252-1512
E-mail: int_asia@ml.nict.go.jp

Peace in Bangkok

The Asia Center office is located at Chulalongkorn University. The luscious green campus stretches across about one million m² in a lively central neighborhood of Bangkok. Currently, the campus is unusually quiet as the University is closed due to COVID-19 (as of October 20). Birdsong can be heard more than usual, creating a tranquil atmosphere that seems more like a secluded Thai resort.

Fig.3 : Rare peace and quiet in central Bangkok (inside Chulalongkorn University campus)

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. The current office is located near central Washington DC in walking distance of the White House and federal government organizations. The area became quieter for a time due to the coronavirus pandemic, but the streets are now returning to normal.

The work of NICT North-America Center is centered on the following activities:
(1) Promote joint research with research institutions and other organizations in the United States
(2) Collect, analyze, and report information on R&D trends at research institutions, universities, and corporations, as well as U.S. government policies such as budgets and regulations related to R&D in the ICT field
(3) Conduct public relations activities and promote deployment of NICT R&D achievements by holding exhibits and participating in conferences

Specifically, we are focusing on fields such as Beyond 5G/6G and quantum information technology, which were identified as areas requiring deeper cooperation in the Joint Leader's Statement issued after the Japan-U.S. Summit Meeting held on April 16, 2021. For instance, we summarized and explained white papers of these themes published by NICT in April 2021 to various related U.S. organizations. It encouraged the promotion of an exchange of opinions that will strengthen research collaboration between Japan and the United States and enabled us to participate in relevant meetings held in the United States.

In the U.S. as elsewhere, the coronavirus pandemic has accelerated digitalization trends both in industry and everyday life. The increasingly complex status of international relations is also having a major impact on governmental and R&D policies within the United States. Amid such a complicated environment, the role of the North-America Center is to accurately assess conditions in the United States and leverage our cultivated knowledge to bridge the research scenes of Japan and the United States, thus contributing to R&D activities in the ICT field at NICT and across Japan.

NICT North-America Center
Office:1020 19th Street NW Suite 880,
Washington DC 20036
Tel.:202-857-0070
email:nac@ml.nict.go.jp

A Day at Smithsonian Museum

Prices rise year by year in the United States. Housing costs in particular have risen considerably in recent years, leading to an increase in the number of children living with their parents. Regardless of the current situation, the Smithsonian Museum, located at the heart of Washington, D.C., provides an opportunity for people to learn about and enjoy large-scale exhibitions free of charge! The area around the museum is a popular spot for residents and tourists of all ages, with street vendors selling ice cream, light snacks, and T-shirts.

Fig. : A Day at Smithsonian Museum

NICT Overseas Centers

Europe Center

Director of Europe Center
ISHINITANI Yasuki

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

Avenue des Champs-Élysées is known as the most beautiful street in the world. Just one street over, in an office district, is our Europe Center. The Europe Center forms and deepens networks with European research institutes, government agencies, and industry groups, shares information about NICT's research and development within Europe, and gathers information on policy and technological development trends related to ICT within Europe.

Many European countries continued lockdowns and other restrictions for a long time in 2020 and 2021, due to the rapid spread of COVID-19, but this did not mean that research and development for making the world a better place came to a stop.

The Horizon Europe framework program for research, development, and innovation has begun throughout Europe and will run from 2021 to 2027. The 2030 Digital Compass for achieving digital transformation in Europe by 2030 and the Path to the Digital Decade that sets out the specific plan to do this were also proposed, which included research in four areas that should be promoted strategically by NICT, such as Beyond 5G / 6G and quantum information communication.

During the course of the COVID-19 pandemic, many events, such as exhibitions and exchanges with European research institutes and government agencies have taken place online. Even in such conditions, the Europe Center has acted in accordance with the new trends in Europe and participated proactively in discussions with European research institutes, government agencies, and other stakeholders, as well as in other related events, in order to promote objectives like research and development for Beyond 5G, the adoption of wireless processes for manufacturing at factories, and the international application of quantum information communication. In this way, we act as a bridge between overseas organizations and our home institution.

Deep Tech has grown in Europe as well, with many ventures and startups attracting attention. We visited and exchanged opinions with Station F, the world's largest startup campus, and Inria (a national research institute for digital science and technology) in France. By building such networks with stakeholders, we are working hard to collect and publicize information in Europe.

The Europe Center will continue in the future to proactively build mutually beneficial relationships between NICT and research institutes and other organizations in Europe.

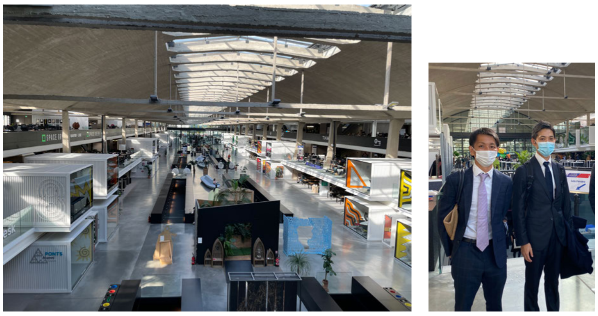


Fig.1 : Visiting the Station F startup campus in Paris

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Beyond Tokyo Olympics and Paralympics

People all over Japan enthusiastically welcomed the Tokyo Olympics and Paralympics. Before the excitement cooled down, the promotional video for the next Paris Olympics was shown at the closing ceremony, attracting interest from many. Various preparations are already underway here in Paris as the host city for the 2024 Olympics and Paralympics.

The Paris Olympics and Paralympics are fully utilizing existing infrastructure, such as holding large bicycle events on the Avenue des Champs-Élysées, equestrian events in the grounds of the Palace of Versailles, and street sports on the Place de la Concorde. The aim is to be an Olympic Games based on the philosophies of sharing and sustainability.

A wide range of information communication technologies were developed for the Tokyo Olympics and Paralympics, and we are eagerly anticipating the technologies that will be developed for the Paris Games.

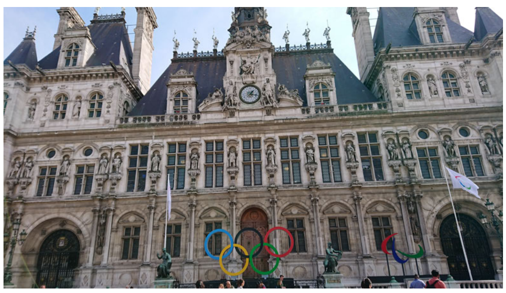
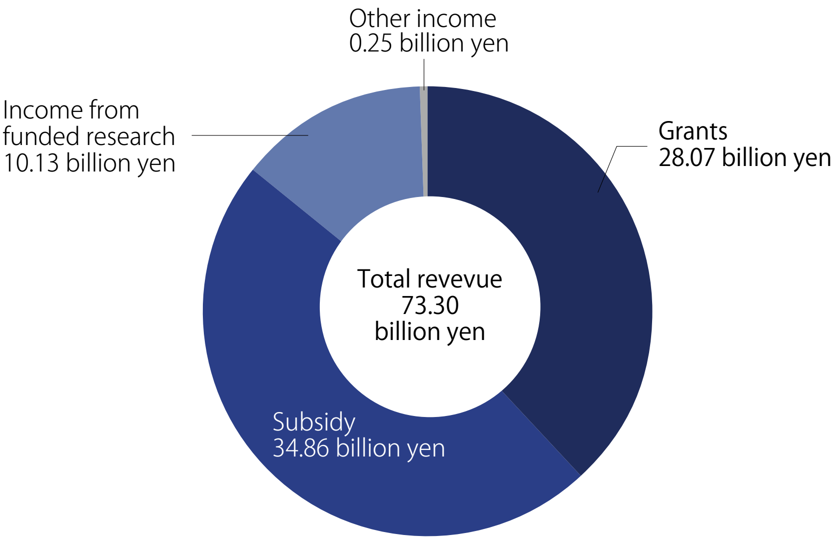


Fig.2 : Paris City Hall adorned with Olympic and Paralympic symbols

Budget

The original budget for FY2021

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



Total expenditure for FY2020 was 102.82 billion yen in a reported basis.

Yen-dollar conversion ratio: 110.84yen/dollar (Aplil 2021)

Work Force

1204 (as of April 1, 2021)
(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
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 is established
April 2015		Renamed as National Institute of Information and Communications Technology, National Research and Development Agency

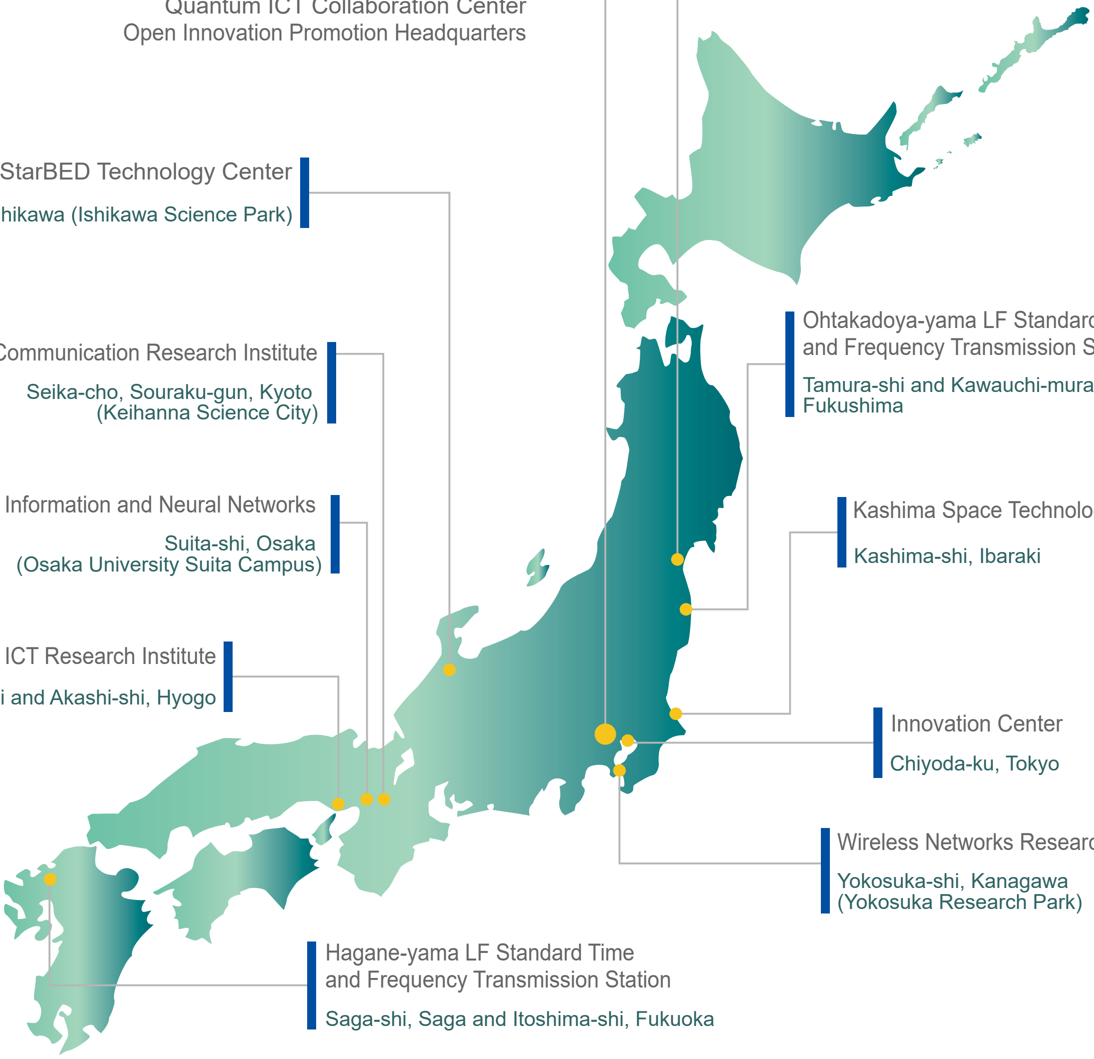
NICT Primary Facilities

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)



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

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

Kashima Space Technology Center
Kashima-shi, Ibaraki

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

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

Innovation Center
Chiyoda-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

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

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