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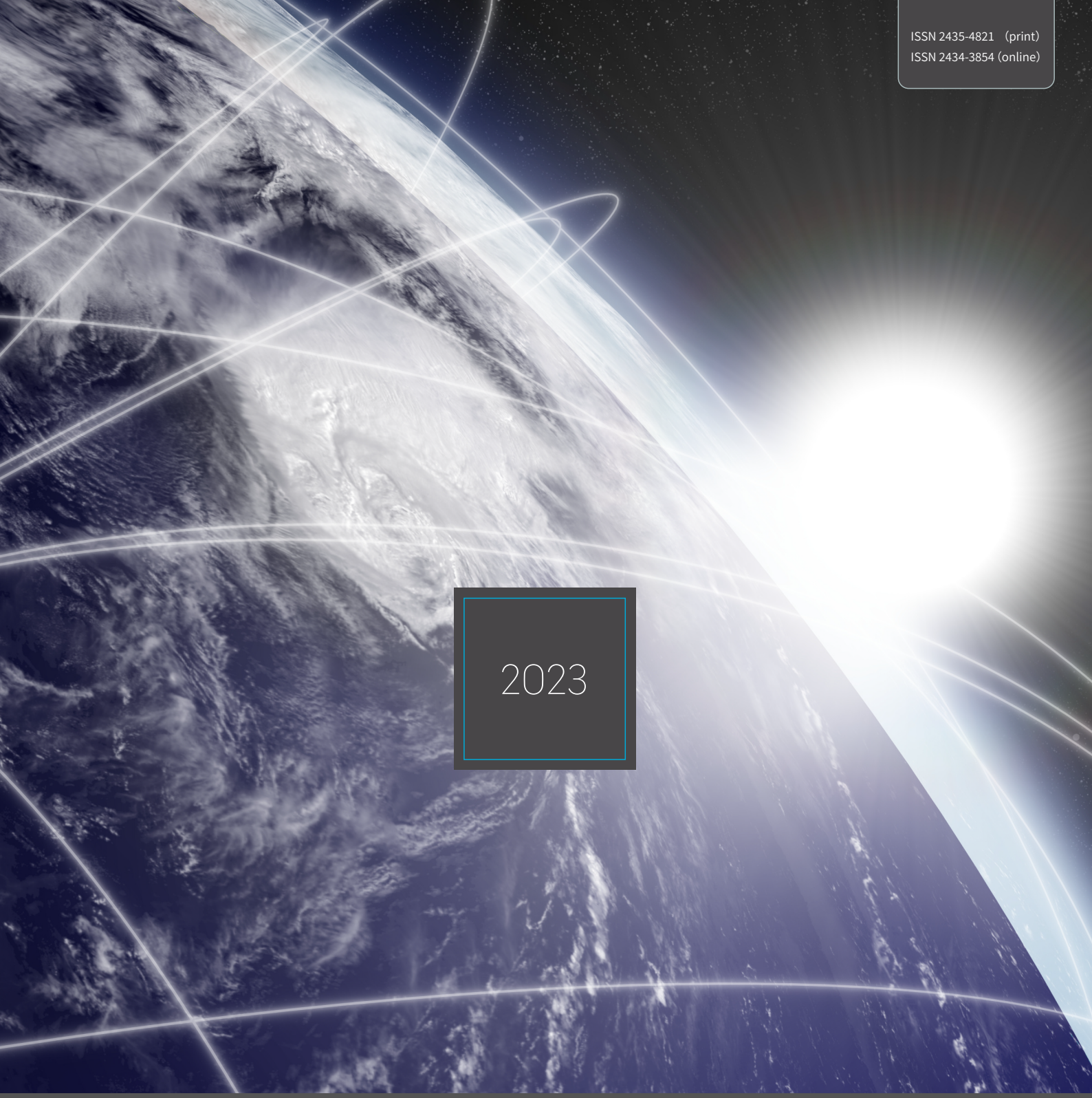
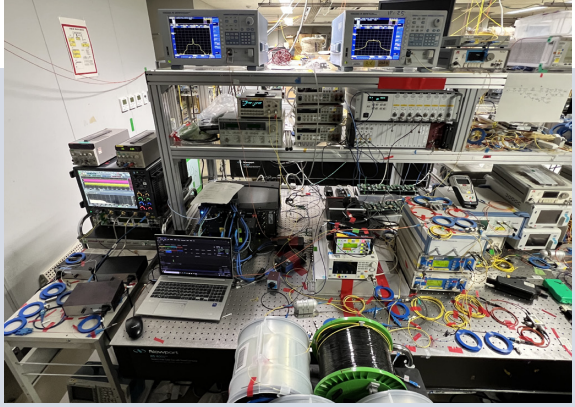


2023

NICT REPORT

New ICT technology strategy toward Society 5.0

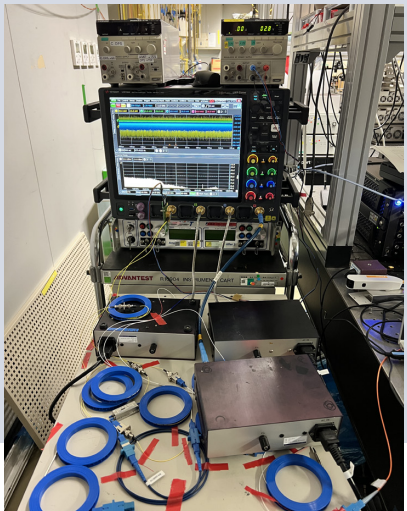
NICT National Institute of Information and Communications Technology



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

The pandemic of COVID-19 continues beyond 2020 with no end in sight, and last year Russia's invasion of Ukraine led to global food and energy shortages and soaring prices. Also, the Ukrainian mobile phone base stations were destroyed, but many people were able to continue information transmission and administrative services via Starlink satellites. If we imagine a world where information from Ukraine was cut off and only one-sided information (fake news, etc.) was sent from Russia, the world would have been misunderstood. It was a year in which we once again recognized, the importance of the robustness and resilience of our country's information infrastructure, non-terrestrial networks, and national security.

Thus, the importance of ICT is becoming increasingly significant. Telework and hybrid communication using web conferencing, accelerated by the COVID-19 pandemic, are expected to realize a richer communication environment by utilizing metaverse, cybernetic avatars and digital twins. In addition to the communication field, environmental sensing and forecasting techniques such as the prediction of torrential rain, space weather forecasting technology that observes and predicts environmental changes in space, and increasingly applicable and sophisticated machine learning and AI technologies, the evolution of new ICT will expand our living space.

It is important to realize a society in which everyone can play an active role freely, free from temporal, spatial, and physical constraints, and in which social issues can be solved and economic development can be sustained.

As Japan's sole national research and development institution specializing in the field of ICT, NICT aims to promote the research and development of ICT through an integrated approach ranging from fundamental to applied research. At the same time, we will pursue collaborations with universities, industry, local governments, and domestic and overseas research institutions to return R&D results throughout society and foster innovation.

NICT's 5th Mid-to-Long Term Plan, which is now in progress, calls for a system that deals flexibly with social problems on a global scale and merges cyberspace and physical space. Our aim here is to create a human-centered sustainable and inclusive society known as safe and secure Society 5.0.

To this end, we are making steady progress in the four strategic research fields of Beyond 5G, AI, quantum ICT, and cybersecurity. In Beyond 5G, we are taking the lead in international activities toward technology development and standardization in such areas as terahertz communications, non-terrestrial networks, and space-time synchronization technology. We are also supporting more than 60 R&D projects in our Beyond 5G R&D Promotion Project. In AI, we are advancing steadily in a variety of fields including AI simultaneous interpretation as targeted by the Japanese government's Global Communication Plan 2025 (GCP 2025), the use of big data, and the merging of AI with the research of brain information communication. In quantum ICT, we are making great strides from joint field experiments with domestic and overseas collaborating institutions to actual applications. Finally, in cybersecurity, Cybersecurity Nexus activities are gaining momentum as an industry-government-academia hub for improving cybersecurity abilities within Japan based on data accumulated over many years and knowledge of human resource development.

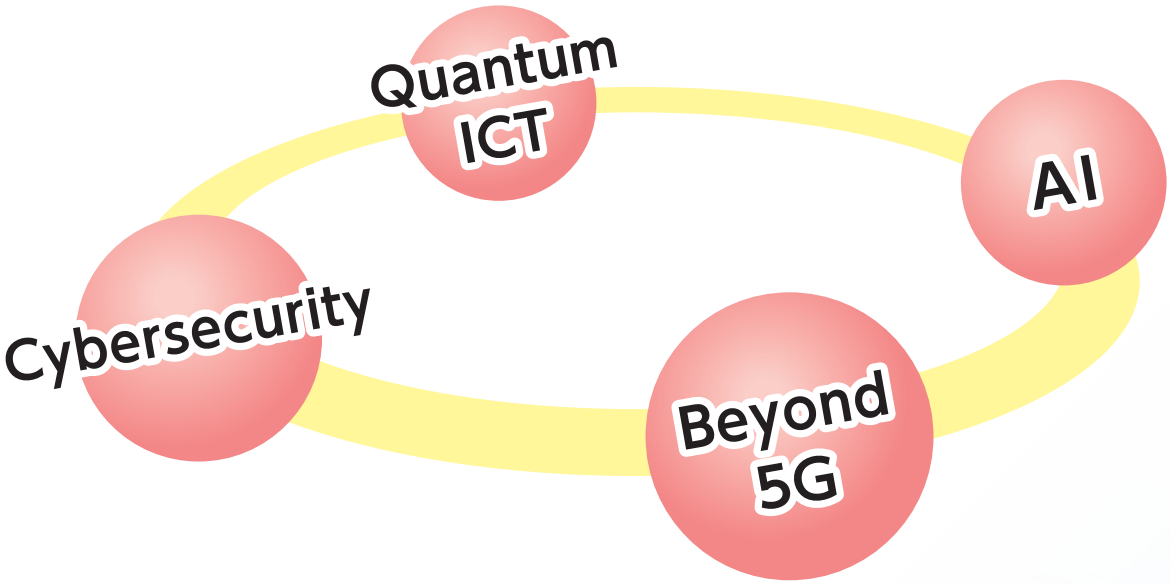
At NICT, we are committed to promoting industry-government-academia collaborative activities and continuously expanding ICT while listening to the opinions of a wide range of citizens and cooperating or even competing on a friendly basis with domestic and overseas stakeholders. In this endeavor, I look forward to your continued support and cooperation.

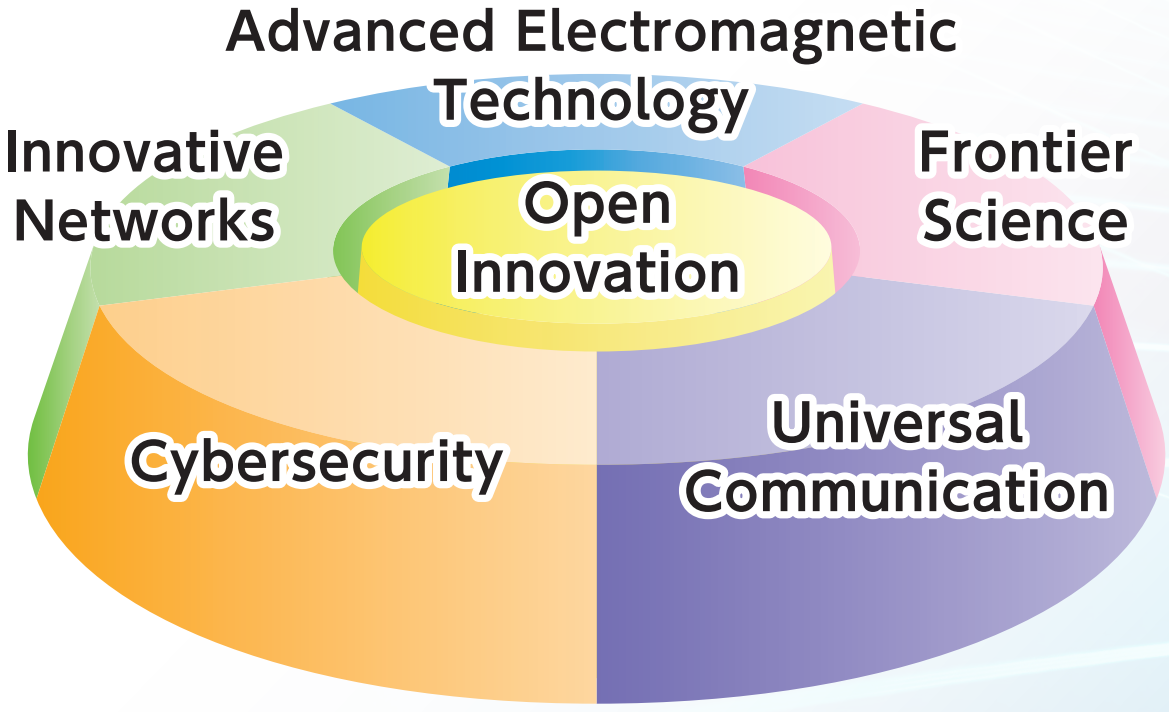
In closing, I pray that this year will be a wonderful and enriching time for everyone. Please accept my heartfelt New Year's greetings.

President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki

New ICT technology strategy toward Society 5.0





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

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

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

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

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

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

PR movie for NICT

A Future with N

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

https://youtu.be/YOenAWHhRIA

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Advanced Electromagnetic Technology Area
Radio Research Institute

Director General TAIRA Kazumasa

The Radio Research Institute is an organization that promotes research and development of various technologies related to electromagnetic waves and their use in society. The Institute aims to achieve Society 5.0 by utilizing radio waves.

Radio Propagation Research Center

The Radio Propagation Research Center is promoting research and development of monitoring and predicting technologies for the earth and space environment using radio waves. We observe real-space conditions using electromagnetic waves, and construct them in cyberspace to predict the future. We use simulation and other technologies to mitigate risks and disasters by feeding back the results of prediction to the real space.

Remote sensing technology

We pursued research and development on the airborne synthetic aperture radar "Pi-SAR X3." We carried out the first full-scale observation flight and technical trial in December 2021, demonstrating the world's highest resolution at 15 cm. The results were announced in the press (Fig.1).

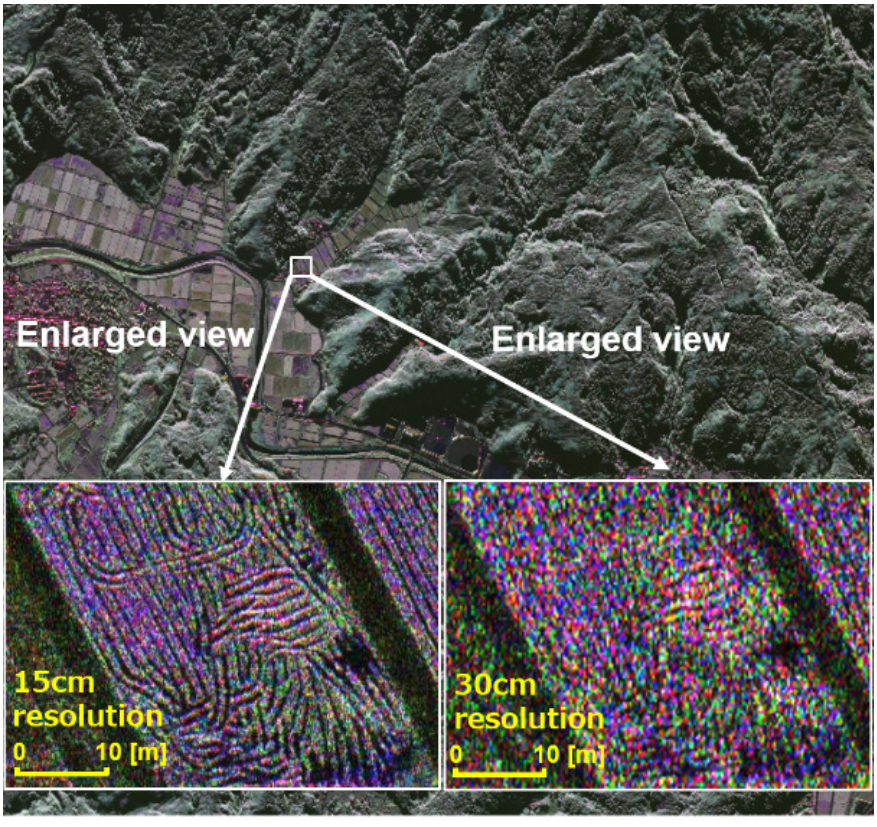


Fig.1 : Example of observation image by Pi-SAR X3

Using data from the "multi-parameter phased-array weather radar" operated by NICT, we conducted a demonstration experiment to provide real-time weather forecasts to the Tokyo Organizing Committee of the Olympic and Paralympic Games and the Bureau of Tokyo 2020 Olympic and Paralympic Games Preparation, in cooperation with the National Research Institute for Earth Science and Disaster Resilience, the Japan Weather Association, and other external organizations. Real-time demonstration experiments were also conducted using Fugaku during the Tokyo Olympic and Paralympic Games in cooperation with RIKEN and other organizations to predict ultra-high-speed high-performance precipitation forecast up to 30 minutes ahead and updated every 30 seconds.

In the framework of the second phase of the Strategic Innovation Promotion Program for the observation of water vapor using terrestrial digital broadcasting waves, the installation of observation instruments in the Kyushu region was carried out in cooperation with private companies, completing the observation network consisting of 15 locations.

We also conducted demonstration experiments to promote the adoption of the wind profiler equipped with adaptive clutter suppression function and demonstrated its usefulness. NICT also led the discus-

sions for the formulation of ISO international standards for the wind profiler.

We modified the active radar calibrators for ground calibration to be carried out after the launch of the Earth Observation Satellite "EarthCARE," which is being developed jointly by Japan and Europe. We also acquired data on cloud vertical distribution, etc. through the W-band high-sensitivity cloud radar for ground verification.

Space environment technology

We conducted ionospheric observations using ionosonde at four radio observation facilities in Japan and in Antarctica 24 hours a day, seven days a week, and issued space weather forecasts to carry out the "monitoring, forecasting and providing warning of anomalies regarding radio wave propagation, etc." stipulated in Article 14, Paragraph 1, Item 4 of the Act on the National Institute of Information and Communications Technology (hereinafter, the "NICT Act"),.

We experimented with and evaluated methods for improving ionospheric echo tracing of ionosonde observation data using AI technology (Fig.2). We then constructed a system that can display temporal variations of the ionospheric vertical structure in real time to improve the ability to understand the current state of the ionosphere. We also constructed the prototype of the "Plasma Bubble Alert System" using data from the ionospheric observation network in the Southeast Asia.

We started the development of a high-energy-particle measurement device that can be mounted on satellites as well as an internal charge measurement device under the research project for the "Research and technology development for the enhanced functionality of Himawari" commissioned by the Ministry of Internal Affairs and Communications.

We developed a real-time version of the "Deep Flare Net-Reliable (DeFN-R)," an AI-based solar-flare forecasting model and made it available on the web for public use. We have started using it at space weather forecast briefing.

We held the Space Weather User's Forum and the Space Weather Users' Committee to promote exchanges with users of space weather information and to investigate user needs.

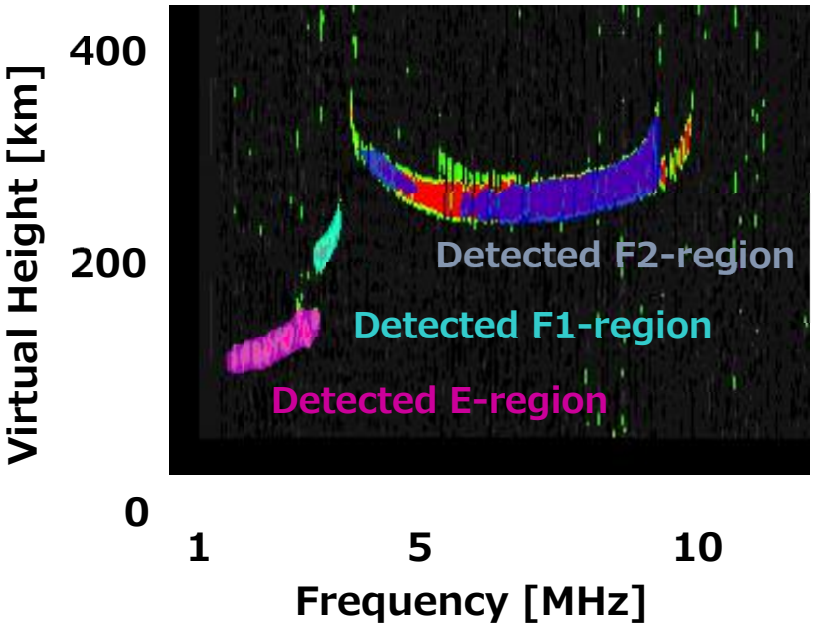


Fig.2 : Ionospheric echo tracing of ionosonde observation data using AI technology

Electromagnetic Standards Research Center

To contribute to the establishment of electromagnetic measurement standards, which are essential for science and technology and the foundation of modern society, the Electromagnetic Standards Research Center carries out two external roles; namely, as a public institute supporting the establishment of national and international measurement standards, and as a laboratory for cutting-edge measurement technologies.

Electromagnetic compatibility technology

We steadily carried out the work of "testing and calibration of radio equipment" as stipulated in Article 14, Paragraph 1, Item 5 of the NICT Act and contributed to the fair and efficient use of radio waves by maintaining the proper operational systems of domestic radio equipments and by maintaining Japan's measurement systems for frequency standards.

We developed a new calibration method for loop antennas used for measuring radiated interference below 30 MHz, which is important for the prevalence of wireless power transmission, LED lighting and so on, and contributed significantly to the establishment of the CISPR international standard issued in March 2022.

Using a model for uniform distribution of multiple broadband electromagnetic noise sources around a single wireless communication terminal, we derived the statistical distribution of received power for electromagnetic noise as a function of the household penetration rate of electromagnetic noise sources. We then clarified the effect of electromagnetic noise integration in the presence of multiple electromagnetic noise sources in comparison with the presence of only one noise source.

We obtained data on the maximum spatial average of the incident power density for the temporal region of the human head during calls using millimeter-wave band portable radio terminals, which will likely become widely used with the launch of 5G services. These data demonstrated the va-

lidity of the geometry of the model for the temporal region stipulated in international standards.

To comprehensively clarify the radio environment in daily life, for the past two years, we carried out measurements of the radio environment at places where such measurements were carried out in the past (about 10 years ago). This year, we statistically analyzed these measurement data, and for the first time in Japan, we were able to quantitatively show the long-term trend in radio exposure levels. (Fig.3).

Space-time standards technology

We steadily carried out the work of "setting standard frequency, emitting radio wave of standard frequency, and disseminating standard time" as stipulated in Article 14, Paragraph 1, Item 3 of the NICT Act. Standard time and frequency signal were broadcasted at 99.9% of the time throughout the year. Network Time Protocol (NTP) service responded to more than 8 billion inquiries per day.

We reported the results of the intermittent operation of the NICT strontium optical lattice clock to the International Bureau of Weights and Measures, and we calibrated the scale interval of Coordinated Universal Time (UTC) for eight consecutive months (Fig.4). In December, we calibrated the UTC rate at the smallest uncertainty for all frequency standards, including the cesium primary frequency standard, at 1.9 x 10^{-16}.

Using a two-way satellite communication modem developed by NICT, we started trial comparisons of frequencies using two-way satellite time and frequency transfer (TWSTFT) with time and frequency laboratories in Korea and Taiwan.

In the research and development of time synchronization using wireless two-way interferometry (Wi-Wi), we developed communication protocols, examined their applications to robot group control, and demonstrated an improvement in the efficiency of wireless power transfer.

We developed a frequency measurement system for terahertz waves using a semiconductor-superlattice harmonic mixer, enabling 16-digit-precision measurement in broadband ranging from 0.1 to 2.8 THz, resulting in a compact, broad-

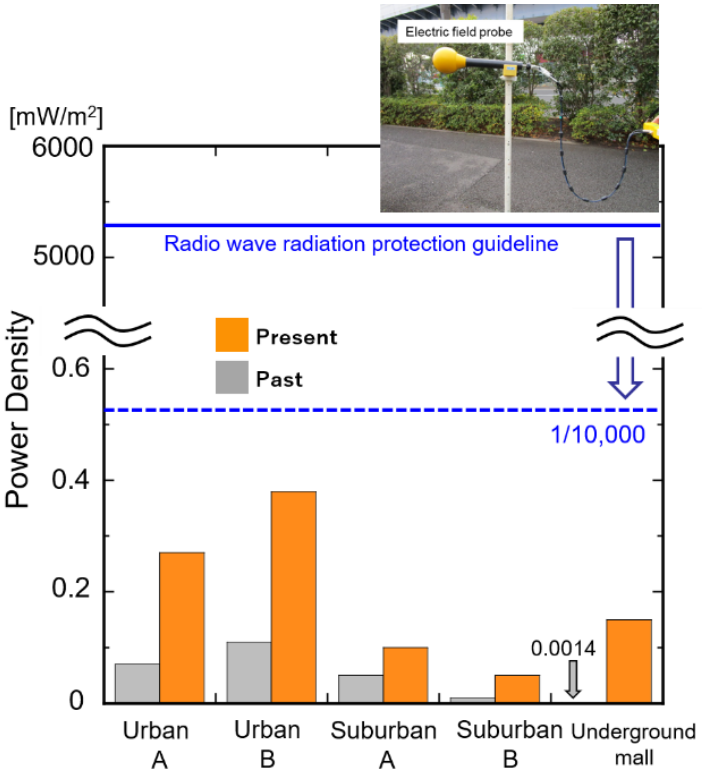


Fig.3 : Japan's first long-term trend measurement results comparing the radio wave strength around mobile phone base stations with the results measured about 10 years ago

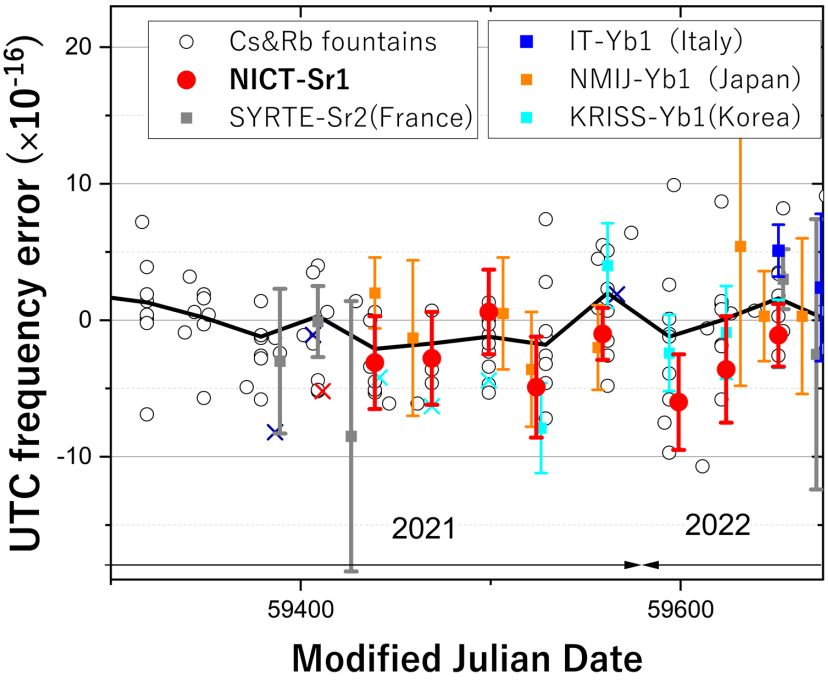


Fig.4 : Rate calibration in Coordinated Universal Time using an optical lattice clock

band, high-precision terahertz frequency counter that operates at room temperature.

Applied Electromagnetic Research Center

The Applied Electromagnetic Research Center mainly supports research and development activities related to industrial applications of digital optics technologies, as well as promotes exploratory and interdisciplinary research on electromagnetic waves and joint research with potential users from various fields.

Digital optics technology

To enable the production of highly accurate and stable holographic optical elements (HOEs), we developed a method for estimating and compensating the wavefront aberration generated in hologram cells, improving the accuracy of optical functions of the produced HOEs (Fig.5).

Aiming at the implementation of the HOE in optical communication modules, we worked on the basic design of hologram data in the wavelength band (850 nm) for communication and achieved a performance equivalent to +/- 0.06 degrees for quintuple-multiplex recording at an angle where the bit error rate of the spatial optical communication device tracking the signal using two driving mirrors is less than 10^{-12}.

Using natural-light digital holography as the core technology, we successfully fabricated a holographic quantitative phase video measurement optical system, a palm-sized hologram sensor, and a natural-light digital holographic optical system capable of recording full-color holograms of LEDs and sunlight in a single exposure. These achievements have been published in reputable international journals.

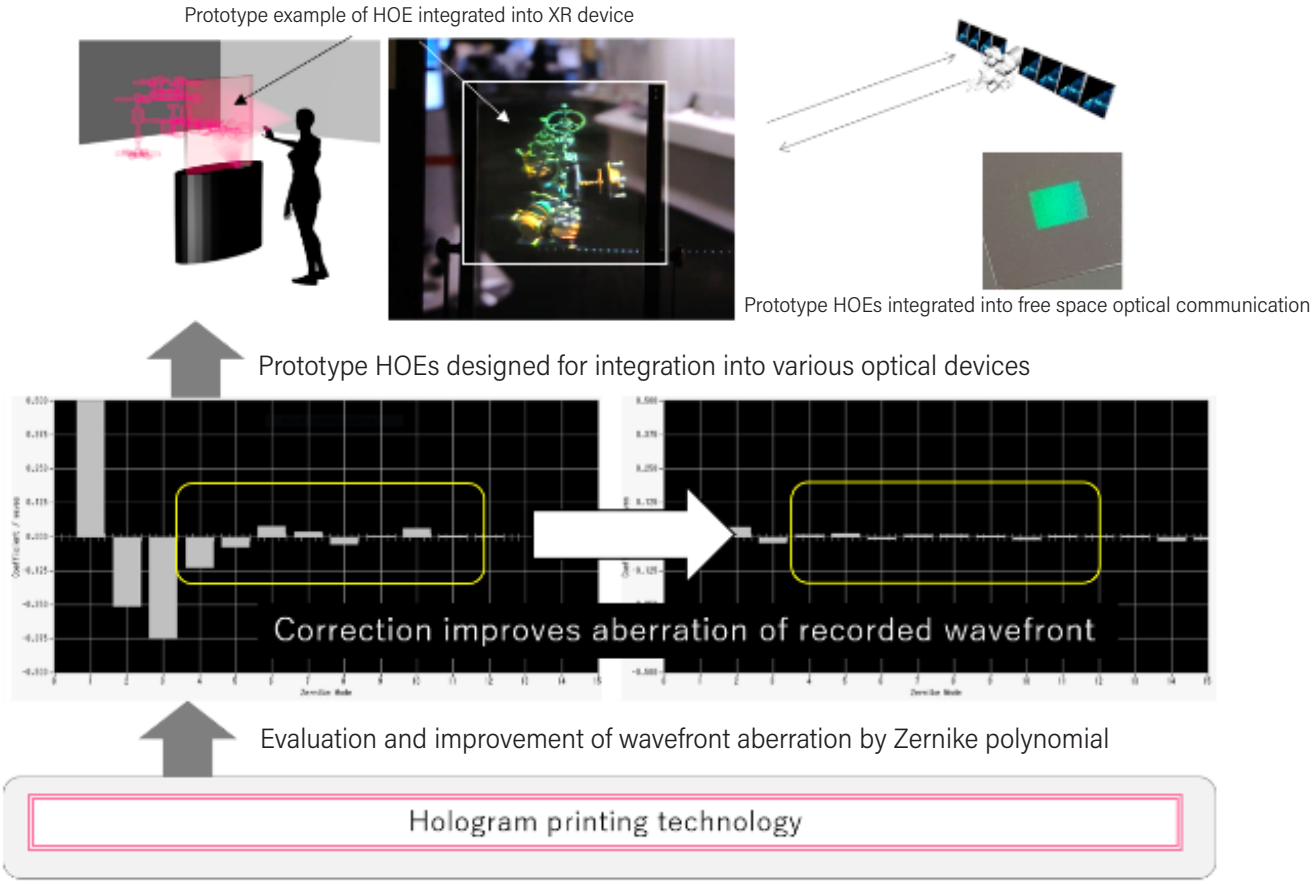


Fig.5 : Compensation and improvement of wavefront aberration caused by hologram printing technology and exposure equipment

Innovative Network Area
Network Research Institute

Director General HARAI Hiroaki

The Network Research Institute conducts R&D on building innovative networks for the Beyond 5G era to respond to the rapid increase in communication traffic, dynamic changes in communication quality, and various network services. In particular, we conduct R&D on computing and AI-enabled networking technology, photonic network technology, optical and radio convergence technology, next-generation wireless technology, space communications fundamental technology, and resilient ICT technology as key technologies for this purpose. We also aim to promote standardization activities, disseminate R&D results, and implement them in society.

Network Architecture Laboratory

To ensure high-quality communication for the reliable delivery of information required by network services in the Beyond 5G era and to dynamically control network resources in a sustainable and efficient manner, we are researching and developing federated computing network technology that integrates advanced data processing functions in the network.

To achieve scalable control technology for large-scale networks, we are researching scalable network telemetry methods for collecting dynamically changing network resource status information and automating control operations (automation level 4) in a specific environment based on that information. Specifically, we have proposed Intelligent Model Pipelining (IMP) technology that interconnects various types of analytical models including artificial intelligence (AI) models for automatically predicting CPU resource utilization of Virtual Network Functions (VNFs) as shown in Fig. 1. Preliminary results show that our technology can complete the training task in less than 6 seconds and reduce CPU utilization prediction errors by at least 24% compared with a conventional method that does not use AI. These results have been presented in an invited paper at a prominent international conference (IEEE CloudNet 2021).

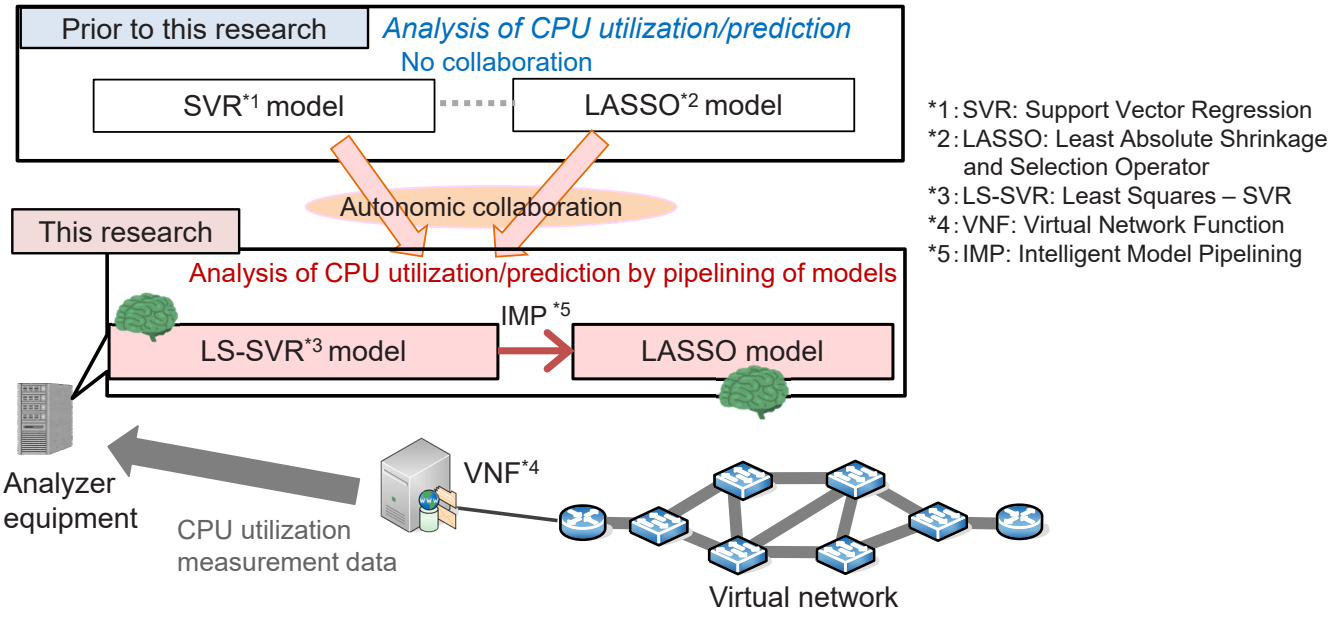


Fig.1 : Intelligent Model Pipelining (IMP) technology

Photonic ICT Research Center

The Photonic ICT Research Center conducts R&D on fundamental optical ICT technologies to support the communication network in the Beyond 5G era.

Photonic Network Laboratory

NICT aims to develop technologies for realizing ultra-high-capacity and flexible optical network systems. Researchers from the Photonic Network Laboratory recently reported the world's first demonstration of transmission capacities greater than 1 petabit per second in a multi-core fiber (MCF) with a standard diameter of 0.125 mm with a record 20 THz optical spectrum from S-band to L-band. The result was accepted as a post-deadline paper presentation at the International Conference on Laser and Electro-Optics (CLEO) 2022.

NICT also achieved world's first demonstration of optical transmission and switching of 15-mode multiplexed signals on a field-deployed multi-mode fiber network in the city of L'Aquila, Italy (Fig. 2). The optical switch prototype was constructed using conventional wavelength selective switches programmed to handle signals from multiple modes simultaneously. In addition, NICT also demonstrated the large-capacity transmission with large mode multiplexing technology using 55 modes. The demonstration reported a record data-rate of 1.53 petabit per second in standard cladding diameter (0.125 mm) optical fibers. A dramatic increase in spectral efficiency was achieved compared to conventional fibers and previous multi-mode transmission. These results were accepted as post-deadline paper presentations at the International Conference on European Conference on Optical Communications (ECOC) 2022.

Optical Access Technology Laboratory

In the Optical Access Technology Laboratory, a flexible access technology is investigated from the viewpoint of devices and sub-systems to realize a seamless access network between wired and wireless networks.

In the research of massively integrated hardware technology, dense two-dimensional integrated photodetector (PD) arrays were developed to achieve high-capacity data transmission and high tolerance of beam position fluctuation for a space division multiplexing and a free space optical communication. In this study, we achieved 240 Gbps optical data transmission in free space using 10 Gbaud 64 QAM signals with bundled fiber transmitter and two-dimensional PD array receiver (Fig. 3).

In the research of a harmonized seamless access system, we developed a phase retrieval technology for optical communication to simplify an optical coherent receiver. Using this technology, we succeeded in receiving and demodulating a 16 QAM polarized multiplexing signal at over 400 Gbps by single PD and phase retrieval signal processing.

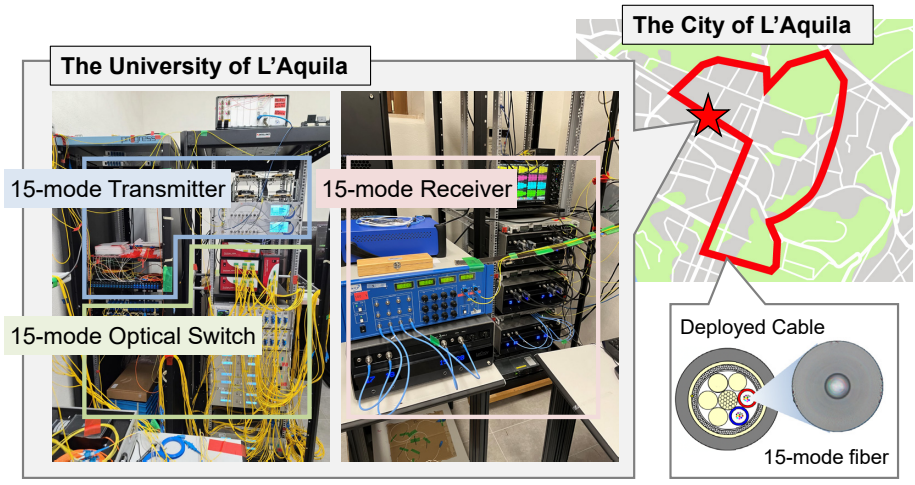


Fig.2 : 15-mode multiplexed network testbed constructed in the city of L'Aquila, Italy

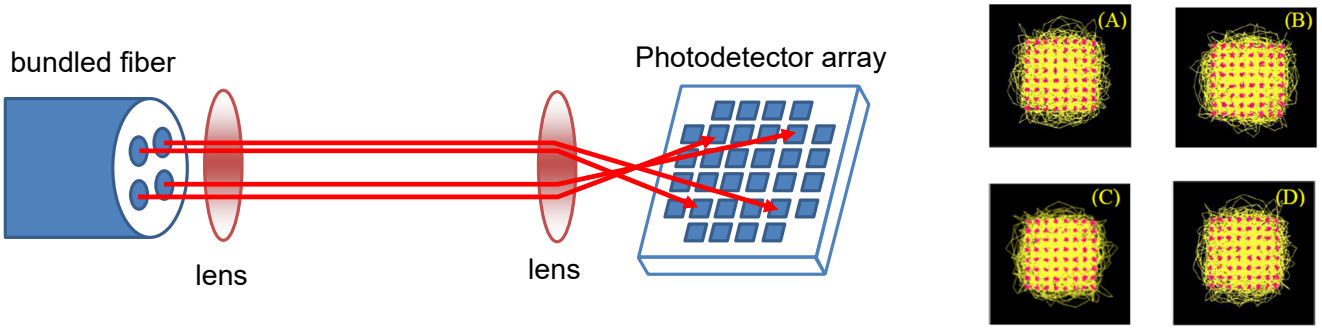


Fig.3 : Parallel optical signal detection using bundled fiber and PD array

Wireless Networks Research Center

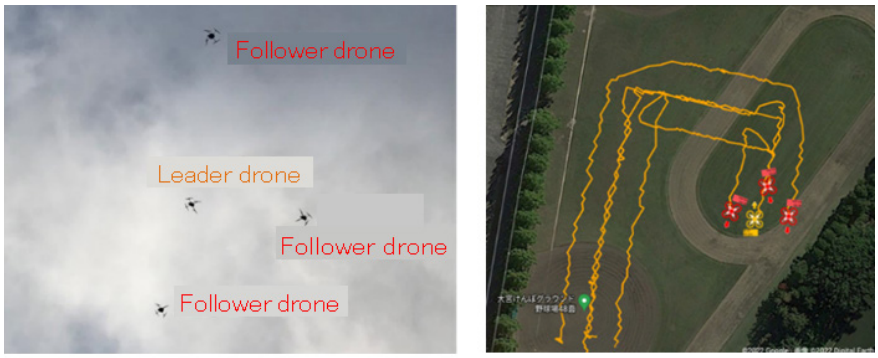
The Wireless Networks Research Center is conducting R&D on wireless network technology that can provide connectivity under any conditions and environment toward the Beyond 5G era. The research plan is to realize a three-dimensional seamless communications network across the globe that includes the seas and space by integrating the non-terrestrial network (NTN) and terrestrial system.

Wireless Systems Laboratory

Keeping in mind the role of NICT as the sole national R&D institute that makes effective proposals on the use of terrestrial frequency resources, the Wireless Systems Laboratory conducts cutting-edge R&D with the cooperation of domestic industries, aiming for social implementation of our outcomes through standardization and certification. Our R&D projects include cyber-physical-system-based evaluation technology for increasingly complex and sophisticated wireless communication systems, advanced wireless access system by effective cooperations between terminals and base stations, and mobility control and wireless area extension for applying wireless communication systems to the sky and sea. The Wireless Systems Laboratory has recently applied device-to-device communications technology to an autonomous drone flight system and demonstrated the world's first platooning flight that enables three follower drones to automatically keep a fixed distance from a leader drone, and also the world's first system in which four drones flying in the same airspace autonomously avoid avoid colliding (Fig. 4). These achievements are contributing to the expansion and enhancement of terrestrial wireless communications.

Space Communication Systems Laboratory

The Space Communication Systems Laboratory is researching and developing flexible satellite network platform technology and a compact, large-capacity, and high-security wireless communication system (Fig. 5). We aim to achieve an advanced information-communications network that can provide seamless connectivity from the ground to space in the NTN of the Beyond 5G era. When viewed in three dimensions, satellites, aircraft, and drones each have different altitudes and characteristics, so we have undertaken R&D to enable integrated and efficient data distribution based on their individual communication capacities, delay characteristics, etc. We are also conducting R&D of large-capacity optical satellite communications, flexible communications, and truly secure communications platform technology that apply digitalized and flexible communications technology. Our goal here is to enable connectivity among all sorts of locations and points on land, on the open seas, in the air, near the earth, and even on the moon. Furthermore, to establish a safe and truly secure wireless communications system, we are researching and developing platform technology for extremely sensitive quantum communications in space. Going forward, we plan to use these technologies to conduct trials of elemental technologies using satellites and other aircraft and to establish platform technologies toward practical use while promoting standardization and industry-academic collaboration.



Platooning flight following the leader drone　　Flight paths of four drones

Fig.4 : Autonomous platooning flight demonstration with a leader drone followed by three follower drones

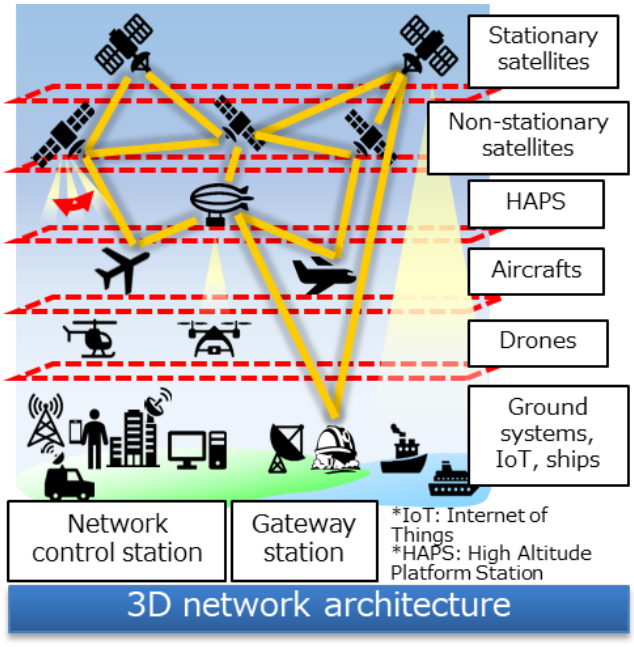


Fig.5 : Space-to-ground 3D connected network

Resilient ICT Research Center

With the slogan "Making the world more resilient through ICT," the Resilient ICT Research Center is engaged in the research and development of resilient ICT and the implementation of R&D results in society toward national resilience.

Planning and Collaboration Promotion Office

The Planning and Collaboration Promotion Office collaborates with the Sustainable ICT Systems Laboratory and the Robust Optical Network Laboratory in conducting technology demonstrations and deploying research results with the aim of implementing resilient ICT in society and achieving national resilience. To this end, we use research results in demonstration conducted in conjunction with disaster-prevention drills and at the time of actual disasters and hold symposiums and exhibitions of this technology. We are also engaged in collaborative research with universities and research institute based on a total of 23 joint research projects. These include six projects with Tohoku University targeting communications in severe environments such as swarm robot control, communications over the seas, the Greenest Area vision (Sendai city), and volcano monitoring by visual IoT and infrasound sensors.

Sustainable ICT Systems Laboratory

The Sustainable ICT Systems Laboratory conducts R&D towards achieving highly reliable wireless networks by optimally allocating limited radio resources (frequency channels, etc.) through machine learning and quantum computing, even in the case that radio propagation characteristics should dynamically change. We also develop distributed edge-cloud computing technologies that provide cloud services without disruption even if the link to the server is down. Furthermore, we conduct R&D on an efficient method for data collection from massively deployed sensors over a large area and on technologies for analyzing the collected data through machine learning to detect natural disasters such as volcanic activity, tsunami waves, and wildfires (Fig. 6).

Robust Optical Network Laboratory

The Robust Optical Network Laboratory conducts research of optical networks to establish telemetry technologies for detecting and predicting the causes of faults in large-scale failures and disasters and fundamental technologies for adaptive network control to prevent drops in performance. We establish fundamental technologies for achieving openness in network resources, balancing supply and demand, and coordinating communication and computing resources. Our goal here is to link communication and computing resources during normal times and times of disasters and large-scale failures toward flexible reconfiguration of the cloud ecosystem and rapid fault recovery.

Advanced ICT Device Laboratory

NICT promotes the research and development of innovative and attractive device technologies. The Advanced ICT Device Laboratory is an open innovation platform in the field of device fabrication and evaluation with an eye toward industry-academia-government collaboration as well as domestic and international collaborations. We also conduct research and development as a wide-ranging "device platform" that includes applications to the future ICT infrastructure, basic science, and implementation of research results in society using all types of waves including optical, radio, and quantum waves. That is, the Laboratory contributes to the creation of new knowledge as technology seeds for future industry. In FY2021, 41 external institutions and 207 researchers were registered users of the Advanced ICT Device Laboratory. We had counted a total number of over 5,900 researchers as the facilities user of the year until March in 2022.

The "R&D results from Advanced ICT Device Laboratory (in Japanese)" is issued to facilitate collaborative research among such a large number of researchers. Additionally, to deal with intense international competition in the device technology field, we steadily introduce various types of advanced device processing equipment capable of high-precision processing on the nanometer level.

Fig.6 : A field trial of a developed solar-powered sensor for monitoring volcanic activity

Cybersecurity Area
Cybersecurity Research Institute

Director General MORIAI Shiho

Countermeasures to increasingly sophisticated and complex cyberattacks are becoming an urgent national issue. The Cybersecurity Laboratory and Security Fundamentals Laboratory collaborate with industry and academia in the research and development of cybersecurity technologies and cryptographic technologies, respectively, and endeavor to disseminate and implement those R&D results in society. Additionally, in accordance with government policies, the newly established Cybersecurity Nexus has begun the formation of a cybersecurity base for industry-academia-government collaboration, while the National Cyber Training Center holds exercises in cybersecurity and the National Cyber Observation Center surveys IoT devices with weak password settings.

Cybersecurity Laboratory

The Cybersecurity Laboratory conducts R&D on data-driven cybersecurity technologies and emerging security technologies.

We have developed STARDUST, an infrastructure for luring cyber adversaries into a mimetic network and to monitor their whole behavior for long time. We enhanced the function for building parallel networks in STARDUST and achieved network virtualization and overlay networks based on the Generic Network Virtualization Encapsulation (Geneve) protocol, which enable us to build simulated environments that connect to any physical equipment. In this way, we can now simulate an even greater variety of environments including teleworking, control systems, and cloud infrastructures (Fig. 1).

We have developed Cybersecurity Universal Repository (CURE), a platform for gathering, analyzing, and connecting heterogeneous security big data. We have added six new types of data to CURE that, when combined with existing data, makes for a multifaceted analysis environment based on the fusion of 17 types of data. Furthermore, while CURE up to now has been based on a two-layer model that automatically assigns meaning with keywords based on natural language processing to the observed Indicator of Compromise

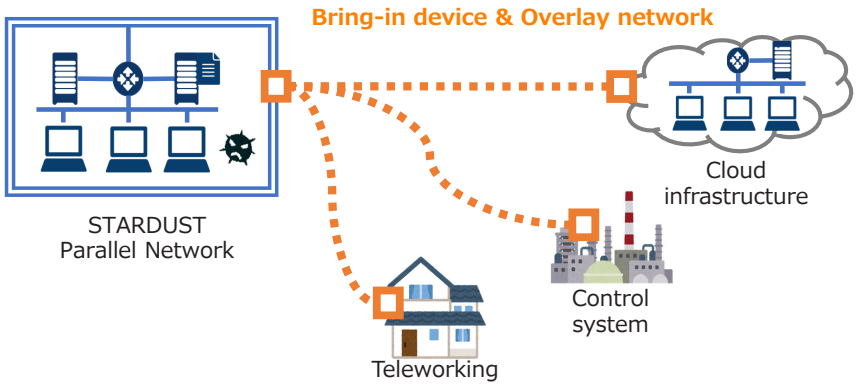


Fig.1 : Enhancement of STARDUST

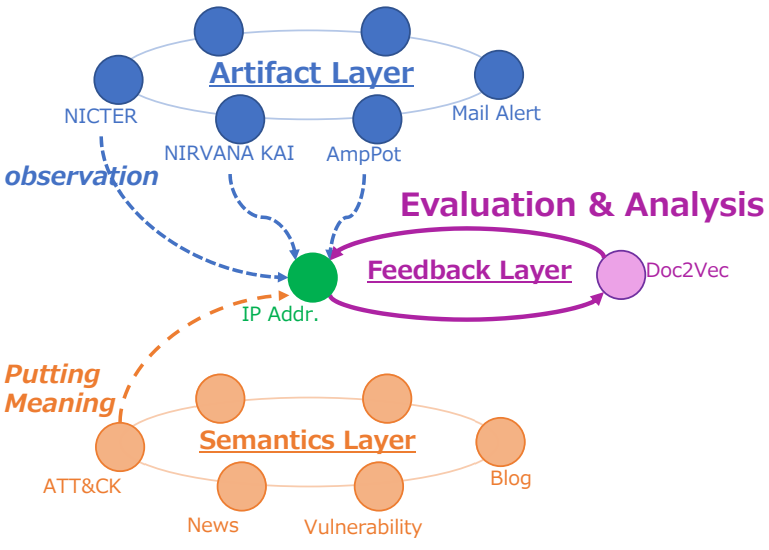


Fig.2 : Enhancement of CURE: Introducing 3 layer model

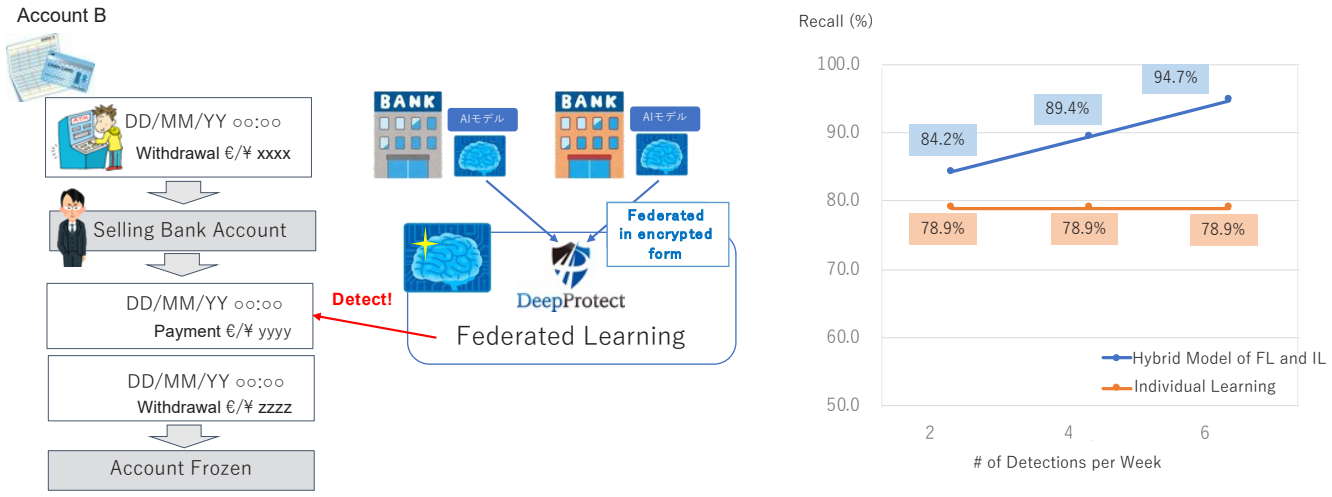


Fig.3 : Detecting fraudulent bank accounts using DeepProtect

(IoC: forensic evidence of a potential cyberattack), we have enhanced CURE functionality by adding a Feedback Layer that adds evaluation and analysis to the data stored in CURE resulting in a three-layer model (Fig. 2).

Additionally, as an information security related agency, NICT used the threat information obtained from the DAEDALUS darknet-based alert system, the AmpMon DRDoS observations system, etc. to cooperate with the Cyber Security Incident Response Coordination Center during the Tokyo 2020 Olympic and Paralympic Games. For a 59-day period, we monitored the IP addresses and URLs of organizations related to the Games and provided much information on detected threats to the Cyber Security Incident Response Coordination Center.

Security Fundamentals Laboratory

The Security Fundamentals Laboratory conducts R&D on cryptographic and privacy-preserving techniques for secure data utilization and on evaluating the security of cryptographic technologies toward the quantum computer era.

As a privacy-preserving data analysis technology using AI, we performed joint demonstration experiments with financial institutions and other parties of a privacy-preserving federated learning system (DeepProtect) that performs deep learning while mutually concealing the data sets possessed by multiple participants. Through these experiments, we presented a case study of improving the accuracy of detecting fraudulent accounts through a federated learning model (Fig. 3). Additionally, with a view to implementing this technology in society, we compiled a list of legal issues (in relation to the Act on the Protection of Personal Information in Japan), worked on creating a platform to facilitate technology transfer, and enhanced this privacy-preserving federated learning technology by improving its communication efficiency.

We also evaluated the security of end-to-end encryption schemes used by video conferencing systems such as Zoom and Webex and discovered a number of vulnerabilities. We then proposed multiple attack techniques exploiting these vulnerabilities and countermeasures against them.

At CRYPTREC, for which we work in collaboration with the Digital Agency, Ministry of Internal Affairs and Communication (MIC), Ministry of Economy, Trade and Industry (METI), and Information-technology Promotion Agency, Japan (IPA), we began the drafting of three sets of guidelines on post-quantum cryptography, cryptography with advanced functionality, and lightweight cryptography with the plan of releasing them at the end of FY2022.

Cybersecurity Nexus

Cybersecurity Nexus was established in FY2021 to create a nexus for industry, academia, and government to collaborate in information analysis and personal development in relation to cybersecurity with the aim of improving Japan's cybersecurity capabilities on an ongoing basis and continuously developing cybersecurity personnel throughout society. To this end, we plan to consolidate a wide range of cybersecurity-related information on a large scale and build a platform for performing cross-cutting and multifaceted analysis of this information and generating practical and explainable threat information. We will provide this threat information to concerned institutions on an ongoing basis. Additionally, we will use this platform to create environments in which domestically developed cybersecurity technologies can be tested by equipment manufacturers and system operators.

Furthermore, to facilitate smooth collaboration among industry, academia, and government in anticipation of an alliance system scheduled for launch in FY2023, we have defined a CYNEX secretariat for overall management support and Co-Nexus A/S/E/C as four subprojects centered about the tasks and objectives of this future community and the information distributed and shared within it, and we have begun to build the system (Fig. 4). As of

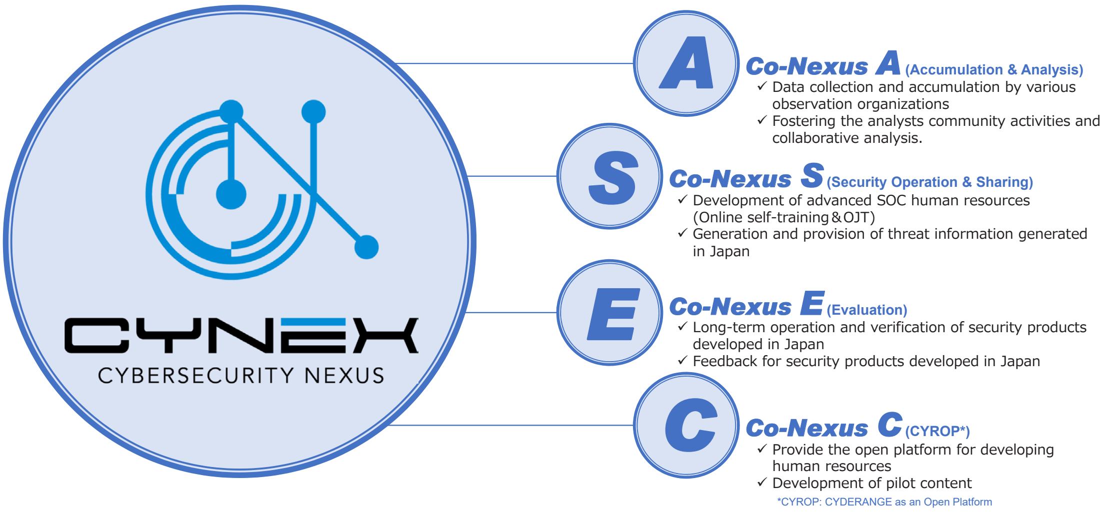


Fig.4 : Four Co-Nexus subprojects

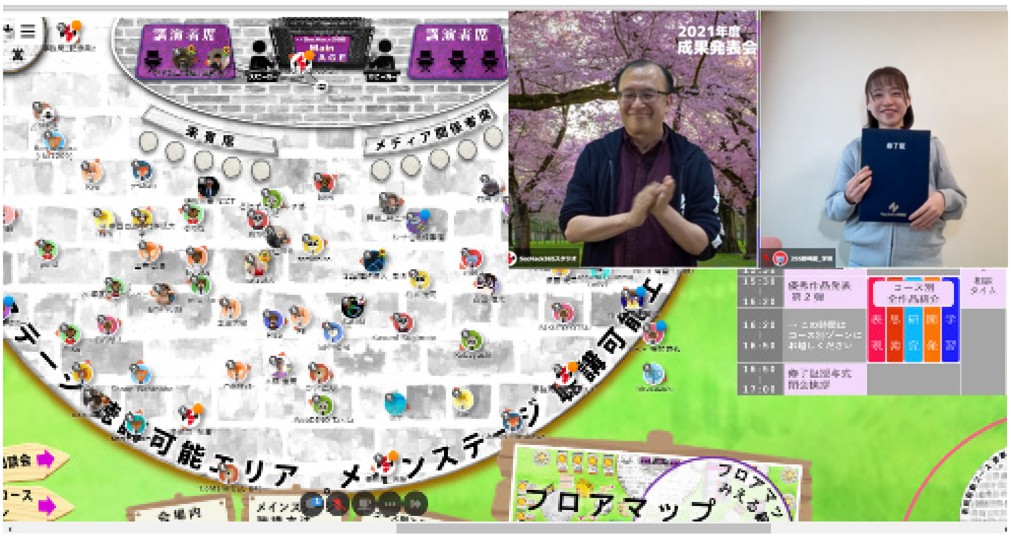


Fig.5 : Scenes of the SecHack365 Achievement Presentation held online

the end of FY2021, 37 organizations from industry, academia, and government have agreed to participate.

National Cyber Training Center

The National Cyber Training Center provides training programs for security operators and security innovators.

In training for security operators, we target security operators within government agencies and private sectors and hold two types of practical cyber defense exercises using actual equipment—CYber Defense Exercise with Recurrence (CYDER) and Response Practice for Cyber Incident (RPCI)—with the aim of developing an ability to respond quickly to incidents when faced with a serious cyberattack within one's organization.

Since FY2016, we have been providing CYDER exercises with different scenarios in each course based on the latest examples of actual cyberattacks. We have also strived to ensure many opportunities for attending these training exercises by giving due consideration to the format of exercise venues. As a result, the total number of CYDER exercise attendees as of FY2021 exceeded 16,000 reflecting its growth into the largest training exercise in Japan. Meanwhile, we started providing RPCI program in FY2021 as a specific exercise for qualification update for registered information security specialists firstly as the public institute. A total of ten exercises were held in FY2021.

In training for security innovators, we have been holding SecHack365 (Security and Hackathon 365 Days) events that aim to develop top-notch talents who can perform "research and development" of innovative security software on their own. Due to the effects of the COVID-19 pandemic, the series of events was held online in FY2021, but it was still able to hold a total of six "Event Weeks" within a one-year period with the same content as past in-person events while targeting 45 trainees selected from 203 applicants. In March of FY2021, "SecHack365 Achievement Presentation"

was held online to present trainee achievements to the general public (Fig. 5).

We continue to build up a SecHack365 graduate community by holding "SecHack365 Returns" events targeting graduates, and we have created a "Graduate Portal Site" to introduce communication tools to these graduates.

National Cyber Observation Center

Against the background of increasingly serious cyberattacks exploiting IoT devices, the Act on the National Institute of Information and Communications Technology was amended to add the survey of IoT devices with weak password settings and other vulnerabilities to the work of NICT (as a limited measure for five years). This development led to the establishment of the National Cyber Observation Center. In February 2019, MIC and NICT in collaboration with Internet service providers (ISPs) initiated the National Operation Towards IoT Clean Environment (NOTICE) project to survey IoT devices vulnerable to cyberattacks and alert users of those devices. As of August 2022, 73 ISPs in Japan had completed procedures for participating in NOTICE. Targeting approximately 112,000,000 IP addresses of those ISPs, we conducted surveys using approximately 600 types of IDs and passwords, and in FY2021, gave those ISPs information on a total of 21,024 cases deserving an alert (Fig. 6). Survey status is publicly released every month on the NOTICE website (https://notice.go.jp/en/status). Each ISP receiving such information alerts the users of those devices, and as of March 2022, the number of alerts had decreased by approximately 17% compared with the peak period (December 2020).

Additionally, as special-access protocols targeted for surveying, we developed special access functions targeting not only Telnet and SSH but also HTTP/HTTPS ID/password authentication (Basic and Digest authentication schemes) and started a preliminary survey in March 2022. By alerting users of those IoT devices discovered in this preliminary survey from FY2022 on, we hope to contribute to enhanced security measures for IoT devices within Japan.

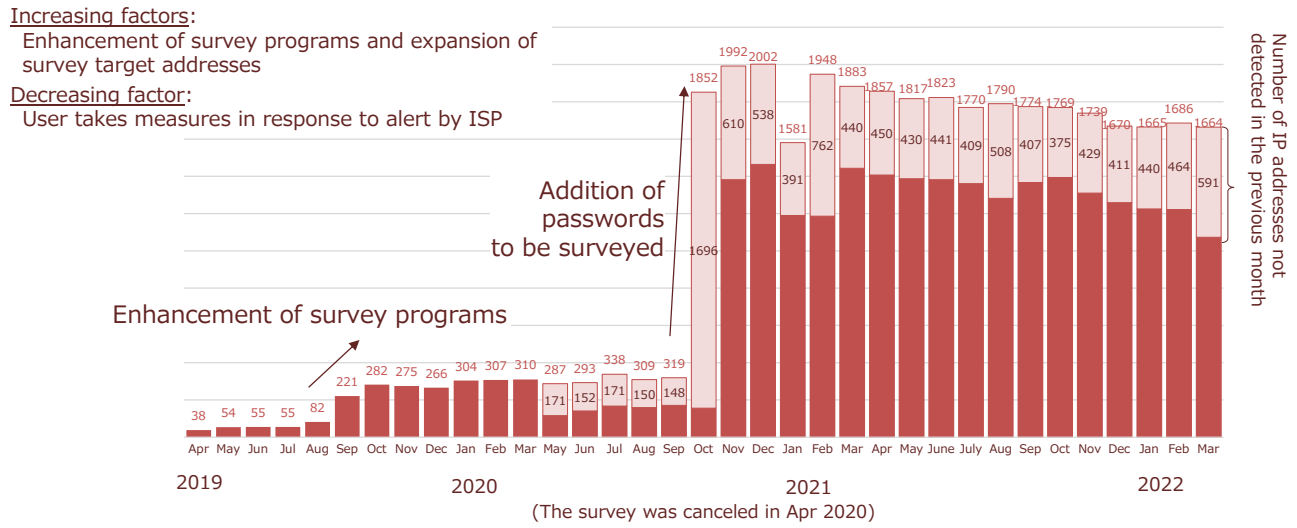


Fig.6 : Progress of NOTICE project

Universal Communication Area

Universal Communication Research Institute

Director General UCHIMOTO Kiyotaka

The Universal Communication Research Institute (UCRI) aims to achieve universal communication that anyone can understand. By leveraging advanced technologies such as deep learning using massive amounts of data including speech, text, and sensor data, we are researching and developing multilingual communication technology, data-driven intelligent communication technology, and smart data analytics technology. We are also promoting the social implementation of systems that support diverse user interfaces. Through these initiatives, UCRI seeks to help solve a variety of social problems using ICT and create new value in society toward the Beyond 5G era.

ASTREC

The Advanced Speech Translation Research and Development Center (ASTREC) has been promoting research and development (R&D) of multilingual speech translation technologies and their social implementation based on the Global Communication Plan[*1] with the aim of eliminating language barriers and enabling people around the world to communicate freely among each other. In March 2020, the Ministry of Internal Affairs and Communications announced the Global Communication Plan 2025[*2] (GCP2025) with the aim of promoting the further advancement of multilingual translation technologies such as simultaneous interpretation through artificial intelligence (AI) by the year 2025. ASTREC has been conducting R&D on simultaneous interpretation technologies based on GCP2025 and has come to develop an algorithm for translating chunks (translation units shorter than a sentence) according to a partitioning model derived from deep learning (Fig.1).

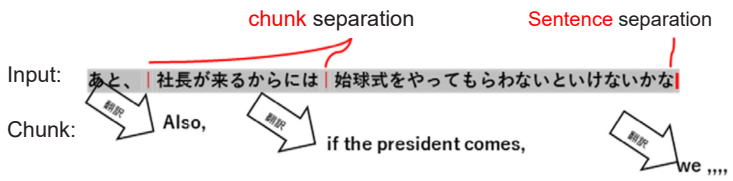


Fig.1 : Two types of delimiting: chunk and sentence

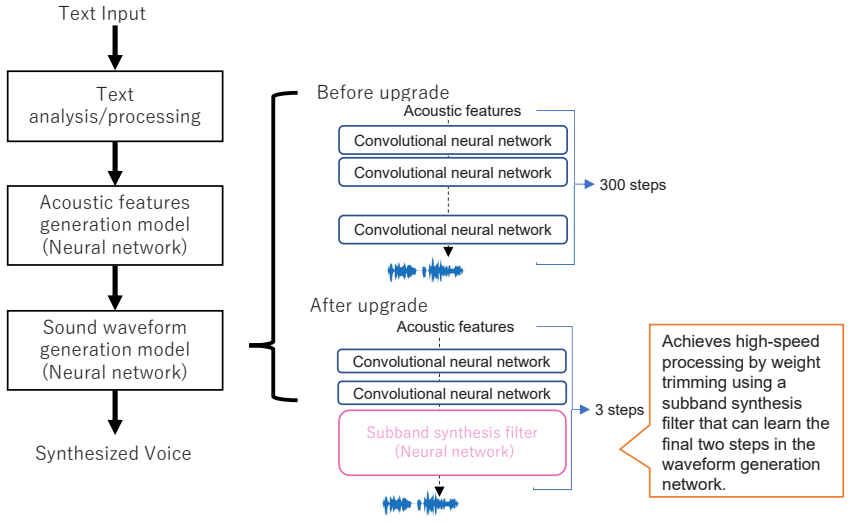
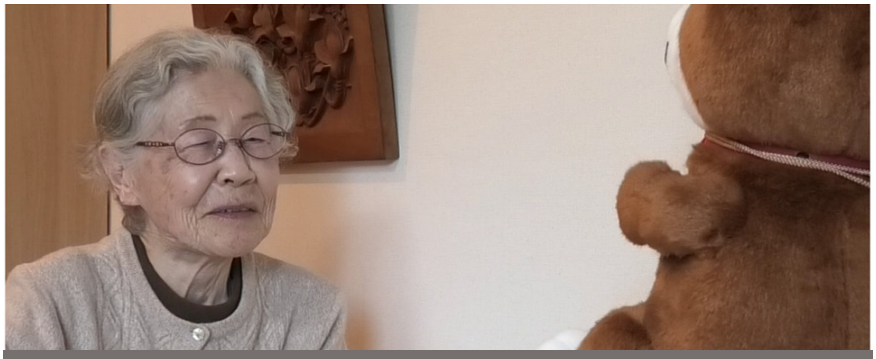


Fig.2 : Development of high-speed, high-quality neural speech synthesis operable on a general-purpose CPU

In the field of speech synthesis, ASTREC has developed a CPU version of a high-quality speech synthesis model approaching a method using general-purpose computing on graphics processing units (GPGPU). By devising a configuration for a waveform generation model (Fig.2), we were able to synthesize speech with a calculation time 0.15 times the speech time length on a CPU. We applied this method to Japanese text and performed a 5-grade subjective evaluation experiment on the naturalness of the resulting sound quality and obtained a mean opinion score (MOS) of 4.3 for both male and female voices. This is equivalent to a method using GPGPU and close to the MOS for actual human voices (about 4.5). The developed method has been applied to English, Chinese, Korean, and Vietnamese for which there is high demand in Japan, and after making

some improvements such as enhanced robustness to the input of various types of text, it has been released to the general public as a field experiment application called VoiceTra and commercial licensing of the technology has begun.

Products and services using NICT technologies were used at the Tokyo 2020 Olympic and Paralympic Games and field experiments were conducted toward the practical use of simultaneous interpretation. The use of NICT's speech translation technologies is also expanding in many fields. Translation Bank, a large-scale joint effort of the Ministry of Internal Affairs and Communication and NICT to accumulate bilingual data, is expanding to many fields by a big ripple effect including translation by different open source software (OSS) communities (Linux Foundation, Libre Office, etc.), translation related to the Japanese tea ceremony and other cultural activities, and translation for the financial sector, which is a good model case of collaboration between the government and private companies.



When she asked what her favorite fruits are and replied, "apples and bananas," MICSUS provides Web information on how to prepare delicious bananas, which brings a smile to the elderly user.

Fig.3 : Field experiment of MICSUS multimodal conversation system to support elderly care

DIRECT

The Data-driven Intelligent System Research Center (DIRECT) promotes R&D of technology for obtaining knowledge on the Internet and elsewhere (social intelligence) in a form easy for humans to understand and for inferring hypotheses by combining that knowledge, applying analogical reasoning, etc. It also conducts R&D on social intelligence communication technology that will enable a virtual personality, which possesses social intelligence and hypotheses, objectives, and policies obtained from that knowledge using deep learning, to converse with a user based on his or her interests, background, context, and other attributes.

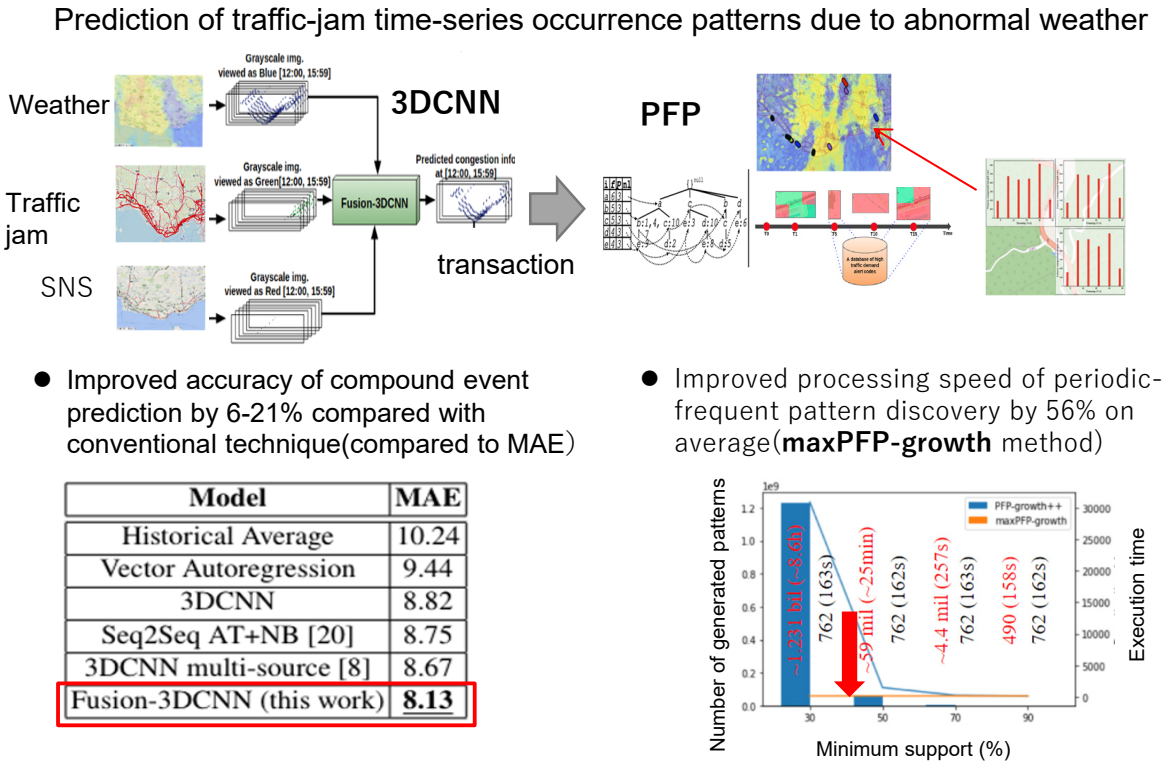
In the R&D of social intelligence communication technology, there is a need for a powerful and massive neural network such as BERT, so we developed an enhanced version of RaNNC automatic parallelization deep-learning middleware that can automatically parallelize the training and reasoning of a massive neural network regardless of its architecture and perform high-speed training using multiple GPUs. As a result, we were successful in making RaNNC the only software in the world that can automatically partition a massive neural network with 200 billion parameters and easily perform parallel training. RaNNC has been released on github (https://github.com/nict-wisdom/rannc). In addition, RaNNC can be applied to the scaling up and accelerating of training not only for transformer-based neural networks like BERT, but also for other types of neural networks such as CNN. In this capacity, RaNNC shows promise in contributing to the formulation of solutions to social issues.

The ultimate objective of social intelligence communication technology is dialogue technology. In this field, we are conducting R&D on WEKDA, a next-generation dialogue system that can chat with the user by applying deep learning to a huge volume of information found on Web pages, and MICSUS, a multimodal dialogue system that can ease the burden on elderly care by checking the health status of elderly users and converse with them using WEKDA. We have performed many field experiments of MICSUS to evaluate its ability in conversing with various types of users including the elderly and confirmed that it is capable of checking the health status of users and chatting with them with a high level of conversation quality (Fig. 3).

Big Data Integration Research Center

With the aim of grasping diverse situations in the real world at all times and supporting optimal behavior, the Big Data Integration Research Center promotes R&D of cross-data analysis technology to collect various types of event data in the real world and discover, learn, and predict cross-sectional correlations from those data, and of federated AI technology for constructing common prediction models for grasping current situations and supporting behavior without sharing individual private data. Here, we are developing the "xData Platform" equipped with these base technologies to provide application programming interfaces (APIs) and a user development environment while working on co-creative problem solving using the data and know-how of local governments, service providers, and other entities.

We have so far completed a basic design for federated cross-data analysis that aims to improve prediction performance while protecting private data, and conducted basic tests by implementing this design on the xData Platform and local servers (xData Edge). We have also developed a compound event prediction technique (3DCNN-PFP) that combines multimodal event prediction (3DCNN) using temporal/spatial 3D raster images and a data mining technique for discovering periodic-frequent patterns (PFP) of events at high speed. By combining 3DCNN-PFP with an extension to enable prediction of traffic-jam time-series occurrence patterns due to abnormal weather or other phenomena, we have improved the prediction accuracy by 6-21% and the processing



Model	MAE
Historical Average	10.24
Vector Autoregression	9.44
3DCNN	8.82
Seq2Seq AT+NB [20]	8.75
3DCNN multi-source [8]	8.67
Fusion-3DCNN (this work)	**8.13**

Fig.4 : Performance improvement in mobile environment risk prediction

speed by an average of 56% (Fig. 4).

We have begun discussions on the technology transfer of information assets to environmental monitoring operators to support the standard environmental monitoring work of local governments. The idea here is to make use of information assets for predicting warnings of photochemical oxidants derived from short-term predictions of environmental quality and to expand them to support early warnings and alarms about photochemical oxidants in local governments. The operators have developed an application that uses the information assets customized according to the collected data and monitors workflow of each local government. Additionally, based on such early warnings displayed on the application, we conducted pilot tests in collaboration with three local governments for use in standby (releasing) preparations in anticipation of issuing (releasing) a warning. We then conducted interviews with staff and confirmed the effectiveness of the application in easing workload as in making prior notifications of emission restrictions to factories and making prior decisions as to the need for staff who issue standby warnings. We have also begun studies on the licensing of these information assets. Furthermore, in collaboration with private companies, we have studied a basic design for behavior navigation to avoid traffic risk due to abnormal weather, etc. and an application for promoting the digital transformation (DX) of driving operations and management by extracting and storing in a database various types of driving conditions and events from the image log of a drive recorder using multimedia sensing.

Advanced reality technology

The Advanced Reality Technology Laboratory conducts R&D of technologies for deepening mutual understanding among people through communication that overcomes the limitations of space, time, and body. To this end, we are digitalizing people and the environment in the real world, reconstructing them in cyber space, and conveying non-verbal information and multisensory information to people at distant locations. In particular, we are 1) pursuing the essence of reality that humans experience from multisensory information through human behavior analysis and functional neuroimaging, 2) developing AI technology for digitalizing, understanding, and extending people, things, and the environment in the real world, and 3) developing XR (VR/AR/MR) interface technologies for conveying the above to remotely located people in a realistic and natural manner by diverse means including video, audio, and haptic media.

Additionally, in FY2022, we developed Realistic and EXpressive 3D avataR (REXR) technology for constructing a realistic 3D avatar of a person from the video of a single camera and richly reproducing that person's facial expressions and gestures. This technology makes it possible to construct the 3D shape, texture, and posture of the body and the 3D shape of the face and facial expressions and to then finely reproduce from any viewpoint small, ever-changing facial expressions and gestures to the same extent as the input video (Fig.5). We presented this achievement at IEEE Conference on Virtual Reality and 3D User Interfaces (IEEE VR 2022) in March 2022 and issued a press release from NICT (https://www.nict.go.jp/press/2022/03/14-1.html).

Contributing to Japan's AI strategy

In conjunction with the beginning of its 5th Mid-to-Long Term Plan, NICT ranked AI as one of its research areas that must be strategically promoted and established the AI Research and Development Headquarters in UCRI. In collaboration with other research institutes within NICT such as the Center for Information and Neural Networks (CiNet) and the Strategic Planning Department, the AI Research and Development Headquarters promote research and development of AI based on Japan's AI Strategy 2021[*2] (decided by the Council for Integrated Innovation Strategy on June 11, 2021). It is also participating as a core center in the "AI Japan R&D Network" along with AIST and RIKEN and is engaged in a variety of activities including the dissemination of AI-related information.

Reference

*1 https://www.soumu.go.jp/main_content/000678485.pdf (in Japanese)
*2 https://www8.cao.go.jp/cstp/ai/index.html (in Japanese)

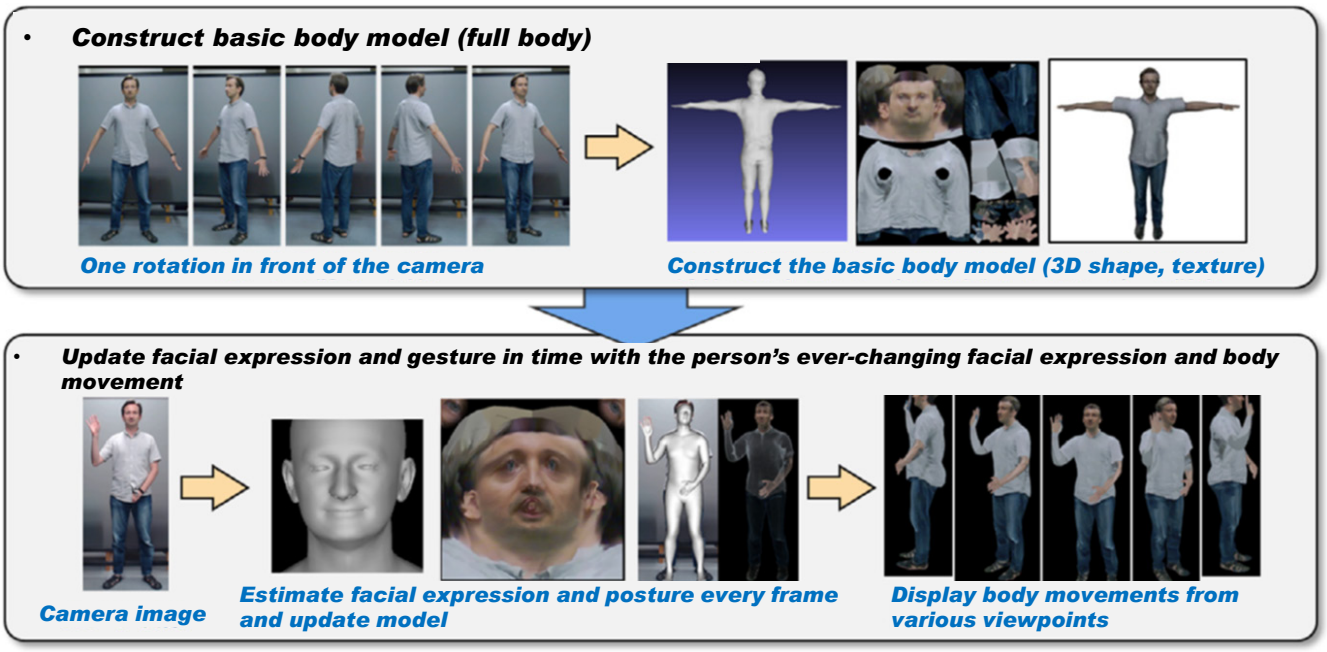


Fig.5 : REXR Technology: Constructs a 3D avatar from the video of a single camera and reproduces the person's ever-changing facial expressions and gestures from various viewpoints.

Frontier Science Area
Advanced ICT Research Institute

Director General WADA Naoya

At the beginning with NICT's current Medium to Long-term Plan, the Advanced ICT Research Institute has been set out to become an organization focused on research and development in the field of "Frontier Science Research." The addition of "Science" to the name of our research domain reflects our commitment to pioneering the future of ICT with the spirit of "cultivating the unexplored fields of the frontier with the plow of science without fear of failure." With this minds, we will conduct cutting-edge and fundamental R&D certified by advanced academic knowledge.

Kobe Frontier Research Center

Superconductive ICT technology

We are researching and developing multi-pixel technology essential to achieving a high-speed, high-performance superconducting nanowire single-photon detector (SSPD) with the aim of achieving an SSPD array on a scale of 200 – 300 pixels in combination with a superconducting digital signal processor. Our aim here is to perform imaging with single-photon sensitivity.

The fabrication yield of superconducting nanowires is a key factor in increasing the number of SSPD pixels. On making observations of current superconducting nanowires with a scanning electron microscope (SEM), we discovered many locations with short circuits in the gap between nanowires and came to understand that resist residue in those gaps plays a role in lowering yield (Fig. 1, top). Then, on investigating patterning conditions that would leave no resist residue in nanowire gaps to the extent possible, we found that drawing with an optimal electron beam dose and developing the wafer vertically could significantly reduce resist residue in nanowire gaps and, when combined with optimized dry etching conditions, could provide a fixed improvement effect in fabrication yield (Fig. 1, bottom). We also investigated film-formation conditions of superconducting thin film. Here, we optimized those conditions by lowering the high gas pressure to obtain a uniform film quality of fine crystal grains and succeeded in extending film-formation time from about one second in conventional film formation to about five seconds. Finally, we confirmed that sufficiently high internal efficiency could be achieved in an SSPD fabricated using NbTiN thin films formed by such a low film formation rate.

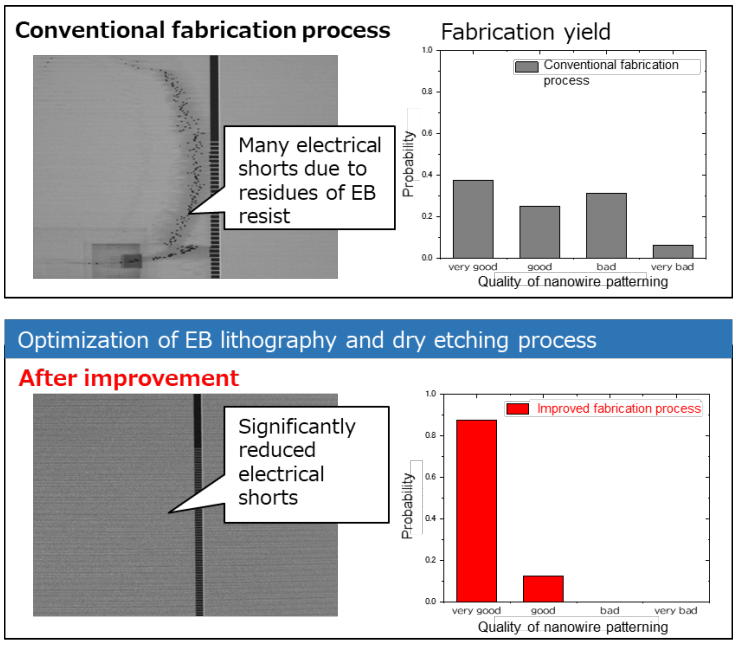


Fig.1 : Optimization of fabrication conditions for superconducting nanowires and improvement in yield

Nano-scale functional assembly ICT technology

We have been studying means of optimizing the structure and fabrication process of organic electro-optic (EO) polymer optical modulators toward low-voltage and short-wavelength operation as fundamental technology for ultra-high-speed light control devices such as small-sized optical modulators. We have so far succeeded in developing an EO polymer transparent to red light that exhibits a large EO effect and have used it to demonstrate short-wavelength (640 nm) optical modulation operation with high efficiency ($V\pi L$ = 0.52 Vcm) more than three times greater than that of a conventional C-band EO

polymer modulator (VπL = 1.8 Vcm) as a world's first (Fig. 2). We have also prototyped and evaluated a 150-GHz-band wireless optical modulation device and developed stacking technology toward wideband and high-efficiency devices as fundamental technology for ultra-wideband electromagnetic-wave control devices such as wireless optical modulation devices and electric-field sensors.

Bio-ICT technology

As a new information detection method using biological materials, we have constructed a measurement system that attaches bacteria that responds to the input of chemical substances to a substrate surface and detects with high throughput the rotational movement of that bacteria, which is modulated according to the type, concentration, etc. of that input substance. We then proposed sensing technology based on a new concept that applies Bayesian inference and machine learning to the data collected by this system to identify the chemical label of the unknown input solution. After clarifying the framework of this technology and closely assessing its effectiveness, we summarized the concept of bacteria sensing technology for identifying chemical information and presented a paper on this technology in *Scientific Reports*.

In the area of constructing novel information devices using biological materials, we proposed a concept for constructing a novel information processing system combining DNA nanotechnology and artificial molecular devices. Then, on the basis of this concept, we fabricated a sorter and integrator at the molecular level as basic elements for actually controlling the flow of information-carrying molecules, quantified their performance, and confirmed their effectiveness (Fig. 3). This achievement attracted interest as a basis for using biomolecules to artificially reproduce energy-saving and resource-saving information processing of objects that give rise to combinatorial explosions as actually occurs with cells. The paper describing this research appeared in the international scientific journal *Science*.

Neuro-network ICT technology

Living organisms are made up of a variety of molecules. They adapt to their environment, which also consists of many different molecules. In higher animals, the brain detects external molecules by using molecular sensors intrinsic to their body and produces specific reactions to better adapt to the environment. We aimed to quantitatively describe signal processing in the neural network, by which the brain transforms sensory input into motor output for organismal adaptation.

More specifically, we clarified how a few brain cells of a fly decide whether to continue reproduction or stop reproduction for survival, upon sensing environmental signals, such as temperature, light, and food resources. We also deciphered how a single master gene (e.g., the *fruitless* gene that directs the formation of a neural circuit) determines the cell fates of many different cell lineages, reflecting quantitative differences in transcriptional states among cells. We further showed that quantitative changes in *fruitless* signaling result in diversification of a *fruitless* output trait during evolution.

Deep-ultraviolet (DUV) ICT technology

There are great expectations for virus inactivation using aluminum gallium nitride (AlGaN) DUV-LEDs having a peak emission wavelength of 265 nm that overlaps the maximum absorption wavelength of DNA and RNA. We have successfully developed a high-power DUV-LED irradiation system consisting of only one chip with light output power over 500 mW, which is approximately ten times stronger than the commercially available DUV-LED under room-temperature and continuous wave operation. In collaboration with the Institute of Medical Science, The University of Tokyo (IMSUT) we

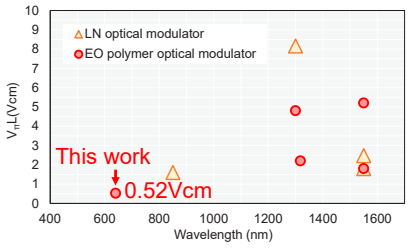


Fig.2 : Comparison of optical modulators

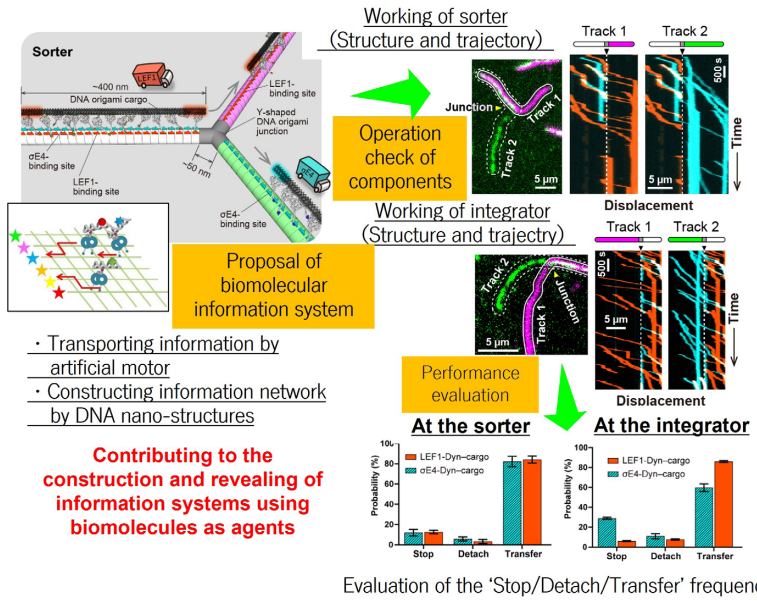


Fig.3 : Study of elemental technology for an information processing system combined with biomolecules

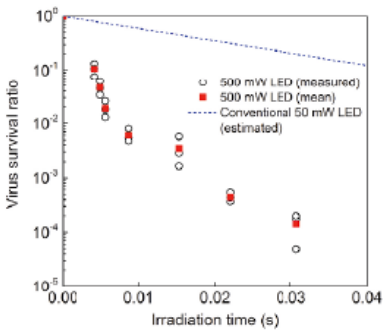


Fig.4 : Inactivation effect of DUV-LED on COVID-19 (SARS-CoV-2) in aerosol

have carried out quantitative research on the optical inactivation effect against COVID-19 (SARS-CoV-2 coronavirus) in both liquid and aerosol. This research verified that the 265 nm high-power DUV-LED irradiation system could rapidly inactivate SARS-CoV-2 in both liquid and aerosol. Besides being used for low-cost and high-efficiency disinfection of object surfaces, this 265 nm high-power DUV-LED is also expected to be applied to air purifiers or air conditioners to rapidly inactivate SARS-CoV-2 in aerosol, which can help prevent the spread of infections and improve public health (Fig. 4).

Koganei Frontier Research Center

Quantum ICT technology

We have been making progress in the standardization of quantum cryptography technology through social implementation tests and have been conducting Proof of Concept (POC) demonstrations for use cases such as electronic health records, genome data, corporate confidential information, and financial data using the quantum secure cloud on the Tokyo QKD Network. We conducted, in particular, a joint performance test with Nomura Securities and Nomura Holdings on the low-latency characteristics, high-capacity tolerance, and continuous-operation characteristics of quantum cryptography in relation to financial data (Fig. 5).

In addition to the above, we have been actively involved in standardization activities at ITU-T, ISO/IEC, and ETSI including the preparation of a system of eight Recommendations at ITU-T representing the framework of Japanese technology in this field. We also completed the first draft of the Japanese version of a Protection Profile (PP) targeting Evaluated Assurance Level (EAL) 2 requirements as guidelines for evaluating and testing quantum key distribution (QKD) equipment.

Ultra-high frequency ICT technology

To realize high-speed, large-capacity terahertz (THz)-band wireless communications, high output power of the local oscillator (LO) signal is necessary and an important factor for THz-band transceivers. We developed a 213-233 GHz x9 frequency multiplier for the LO signal of the THz-band transceiver designed using bulk CMOS technology, which is widely used in integrated circuits because of its high reliability, low power consumption, mass producibility and other features (Fig. 6). The x9 frequency multiplier chain consists of two x3 multiplier (tripler) circuits, intermediate frequency (IF) amplifiers before each tripler stage, and injection-lock-type power amplifier in the final stage. The peak output power of the x9 multiplier chain reaches +4 dBm at a frequency of 225 GHz. The proposed frequency multiplier has high performance per channel in terms of saturation power, suppression of undesired harmonics, power consumption, and die size compared with other reports on silicon CMOS processes while also achieving low phase noise.

Green device

We have developed a variety of device process technologies essential to the fabrication of vertical gallium oxide (Ga_2O_3) field-effect transistors (FETs) with the plan of pursuing full-scale device development from FY2022. Among these, we devoted particular effort to the research and development of etching process technologies and developed deep dry etching technology and a process for removing surface damage caused by etching.

Continuing on, we applied this series of etching processes developed in FY2022 to the fabrication of Schottky barrier diodes having an even simpler structure than FETs. The structure of a fabricated vertical Ga_2O_3 Schottky barrier diode (SBD) is shown in Fig. 7 (a). This device features an edge-termination structure for alleviating electric field concentration by first filling a deep trench with SiO_2 and then fabricating a staircase field plate on top of the trench. This trench staircase field plate worked effectively achieving a breakdown voltage exceeding 1,600 V and an on-resistance of 7.6 mΩcm², which correspond to one of the best achievements in device performance for Ga_2O_3 SBDs in the world (Fig. 7 (b)).

Center for Information and Neural Networks (CiNet)

NICT's 5th Medium to Long-term Plan calls for accelerated research of the human brain function with a view to creating

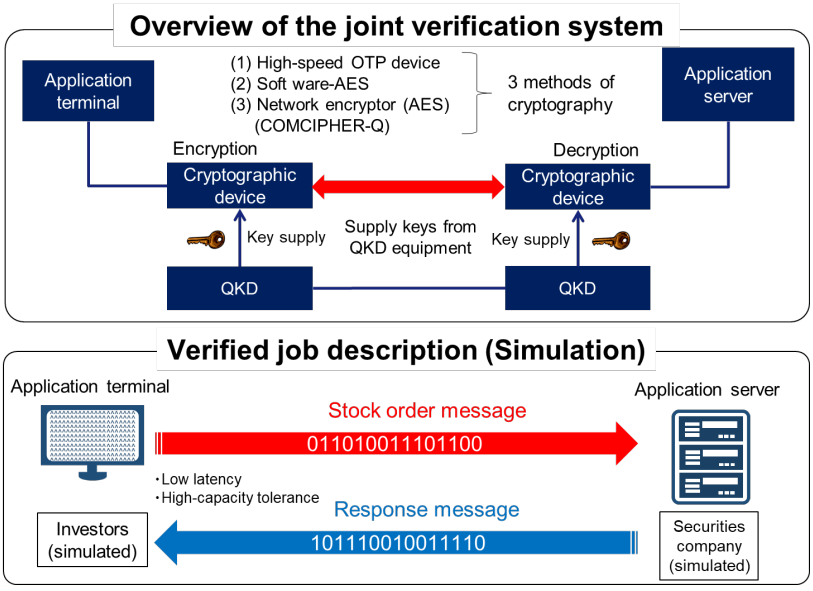


Fig.5 : Outline of joint verification system

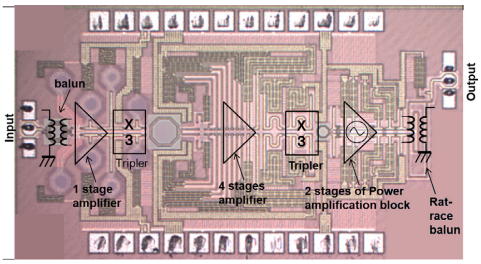


Fig. 6 : Chip photograph of x9 multiplier circuit for 225 GHz signals

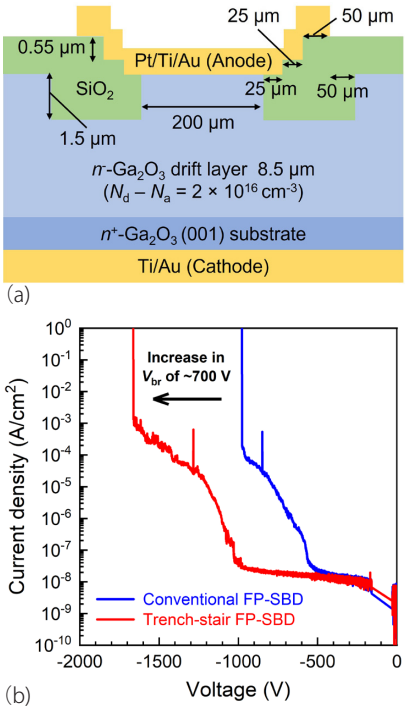


Fig.7 : Ga_2O_3 Schottky barrier diode with a staircase trench field plate: (a) cross-sectional diagram, (b) reverse current vs. voltage characteristics

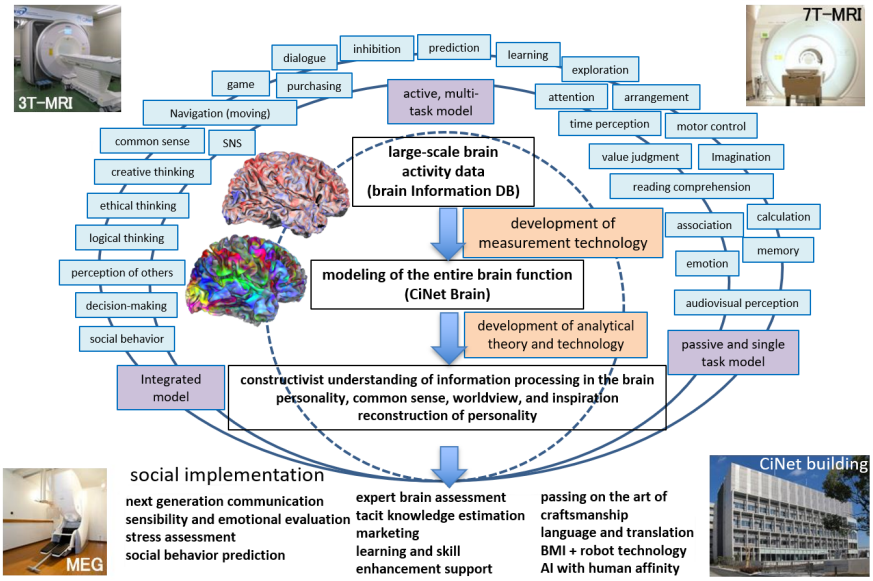


Fig.8 : CiNet Brain: Model of the entire brain

a human-centric ICT society as advocated by Japan's Society 5.0 initiative. Targeting, in particular, higher-order brain functions such as human cognition, emotion, perception, decision-making, action, sociability, and language, CiNet is working to construct "CiNet Brain" as a model encompassing all brain information processing by collecting and analyzing brain activity data under diverse perceptual and cognitive conditions (Fig. 8). This is being highly evaluated as an application to artificial intelligence (AI) that mimics the human brain. Social applications of the results of this research are also progressing. For example, we are working with a company on conducting objective evaluations of impressions and sensations felt by a user in response to products or services using brain information read from brain activity as a result of audio-visual stimuli.

R&D on measurement/analysis of brain functions for constructing an artificial brain model

We have constructed an experimental system that can selectively present smells (olfactory stimuli) within magnetic resonance imaging (MRI) equipment. We have shown with this system that smells change visual subjective evaluations and generate a difference even at the corresponding brain activity level. These results are attracting attention since they provide neuroscientific evidence of cross-modal phenomena between the sense of sight and sense of smell. Additionally, considering a scenario in which a native speaker of Japanese hears natural utterances in English, we have constructed a model that uses those brain waves to identify the brain wave response for different linguistic characteristics and evaluates listening proficiency from brain wave indices. This achievement shows promise as a technology for evaluating the degree of information comprehension from brain information.

R&D on expanding applications of brain information communication technology (brain ICT)

We are using knowledge of brain functions related to human motor functions to generate results that can be implemented in society. We have clarified through MRI measurements that the inhibition mechanisms across brain regions mature with development but deteriorate with age. This result provides the first visualization of lifespan changes in the interregional inhibition mechanisms in the human brain. We also clarified how the interhemispheric inhibition mechanism between the left and right motor cortices relates to finger dexterity. We have teamed up with a company to implement the above knowledge in a motor training program for the elderly as an example of social implementation of brain ICT.

Industry-academia-government collaborative research activities for enhancing social acceptance of brain ICT

At CiNet, we have been working to convey our research results widely to industry and have been actively pursuing joint research with companies. At the same time, we have come to recognize the importance of clarifying issues and their solutions in obtaining social acceptance of human brain function research and its results when being engaged in this pioneering research. To therefore conduct research that takes into account ethical, legal, and social issues (ELSI), we have established an ELSI research group within CiNet and have commenced ELSI-related activities in collaboration with Osaka University Research Center on Ethical, Legal and Social Issues (ELSI Center), a leader in this field. We have also been active in the "AI Technology Estimating Perceptual Information From Brain Information" project under the PRISM program of Japan's Cabinet Office, where we have been surveying and researching the social acceptance of this technology and holding study meetings and discussions toward social implementation.

B5G Field

Beyond 5G Research and Development Promotion Unit

Director General HOSAKO Iwao

Beyond 5G Research and Development Promotion Unit is actively engaged in the research and development of advanced elemental technologies within NICT as a "command tower" overseeing R&D toward the Beyond 5G era. We aim to make Beyond 5G function as a place where any industry and individual players in different fields, which up to now have been physically and socially divided, can collaborate and co-create. In short, we see Beyond 5G as a social platform that will enable anyone to create new value as needed and that will lead to the fulfillment of Sustainable Development Goals (SDGs) and the emergence of Society 5.0.

Study of Beyond 5G Architecture and Concept Testing

Beyond 5G will not be limited to providing key features such as ultra-high speeds, ultra-low latency, and massive connectivity. It will also actively link systems outside of conventional communication fields such as by extending communication coverage to the sky and the sea and merging the real world and virtual world. In the Beyond 5G era, we can expect social problems to be solved and society as a whole to be optimized, which up to now has been difficult to achieve. To this end, it will be necessary to establish architecture as an open platform based on the principle that a flexible configuration that allows systems of disparate fields to be linked must be guaranteed. As the first step toward many studies while building a consensus on this architecture among a wide range of stakeholders, NICT has released Beyond 5G/6G White Paper (English version 2.0) (Fig.1). In this architecture, it is assumed that a wide variety of functions and data extending beyond industry boundaries will become available so that needed functions can be selectively and adaptively combined to configure individual Beyond 5G services. Our goal, therefore, is to design a mechanism that promotes the use of a system that merges physical space and cyber space (Cyber Physical System: CPS). This system will feature an orchestrator that optimizes services by handling diverse function groups in an integrated manner from a cross-industry viewpoint and service enablers that lower the entry barriers to creating and developing services by hiding the above complexity to service providers.

Terahertz Wireless Testbed Platform Technology

In FY2021, we developed characterization technology for terahertz antennas with frequencies exceeding 300 GHz with the aim of establishing evaluation technology (Fig.2).

This system measures antenna radiation patterns by separating the terahertz transmitter and receiver by up to 13 m and rotating the receiver antenna. We used this system to measure the antenna radiation patterns of a variety of antennas including an offset parabolic antenna, Cassegrain antenna, and standard gain horn antenna. The results of these measurements were reflected in a contribution to a draft report on terahertz wireless technology in the APT Wireless Group (AWG) under the Asia-Pacific Telecommunity (APT), an international standardization organization in the Asia-Pacific region. Additionally, with the aim of reducing the noise of terahertz signals, we tested phase-noise compensation technology using an injection-

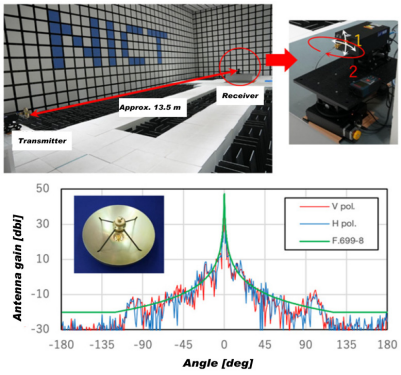


Fig.2 : Far-field measurement system for measuring terahertz-band antenna patterns (top) and measured radiation patterns of Cassegrain antenna (bottom)

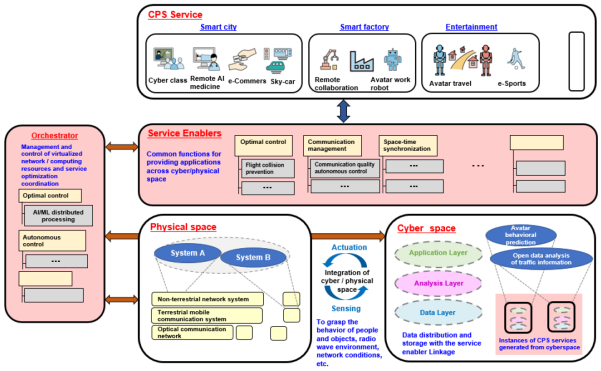


Fig.1 : Functional architecture of Beyond 5G (source: NICT Beyond 5G/6G White Paper (English version 2.0))

locked optoelectronic oscillator circuit technique. This method reduces phase noise by inputting millimeter waves and terahertz signals generated by conventional technology into an optoelectronic oscillator circuit that can reduce phase noise through a high Q factor and long cavity based on an optical fiber loop. Inputting a signal at a frequency of 102 GHz resulted in a 5 dB improvement in single-sideband phase noise at a frequency offset of 2 kHz. Using this technology as a local oscillation signal source in transmitters and receivers is expected to achieve multi-level modulation/demodulation technology for multicarrier systems with narrow frequency spacing.

Terahertz Spectrum Measurement Platform Technology

With the aim of achieving high-accuracy spectrum measurements in the terahertz region, we proposed a high-accuracy terahertz wave generation, control, and measurement technique traceable to a national standard using bi-directional wavelength conversion between infrared and terahertz waves as an advanced platform technology for generation, control, and measurement. Figure 3(a) shows a schematic diagram of spectroscopic measurement of terahertz waves using wavelength conversion.

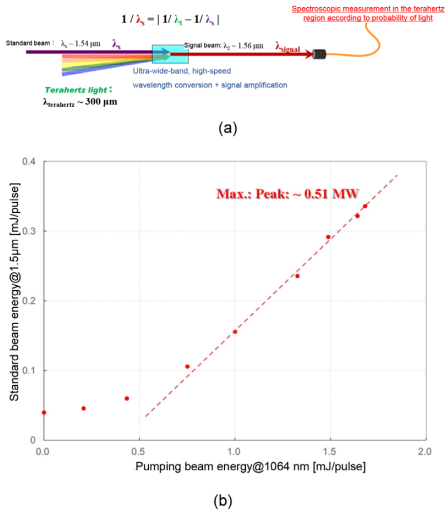


Fig.3 : (a) Schematic diagram of spectroscopic measurement of terahertz waves using wavelength conversion, (b) pumping energy dependence of frequency standard beam energy.

The spectrum of a wavelength-converted infrared beam in nonlinear crystal reflects the spectrum of the terahertz wave to be measured. Accordingly, by using a frequency stabilized and controlled infrared beam as a traceable pumping, seeding and signal beam, it becomes possible to control or measure the spectra of terahertz waves in a traceable manner as well. Here, we used an amplified optical standard beam fed by optical communication fiber as a frequency stabilized pumping beam.

Figure 3 (b) shows pumping beam (1064 nm) energy dependence of frequency standard beam (1.54 μm) energy. As the energy of the pumping beam increases, the energy of the standard beam likewise increases monotonically. We observed a maximum standard beam energy of about 0.34 mJ/pulse corresponding to peak power of about 0.51 MW when the input energy of the standard beam was about 40 μJ/pulse and the pumping energy was about 1.7 mJ/pulse. This is about 10^3 higher peak power compared to the initially delivered standard beam, which is sufficient for terahertz wave spectroscopic measurement via wavelength conversion. We plan to increase the energy of the standard beam to achieve a broader measuring range and higher sensitivity.

International Standardization Activities

Beyond 5G Research and Development Promotion Unit has been actively working on spectrum standardization in the frequency ranges above 275 GHz at ITU-R accomplishing the following results.

(1)At the 2021 WP1A meeting, NICT proposed that the working document be modified towards a draft revision of Report ITU-R SM.2352-0, which was carried forward to the next meeting as a preliminary draft revision of the Report.

(2)At the 2021 WP5A meeting, NICT contributed to updating the working document towards a new Report M.[252-296 GHZ.LMS.FS.COEXIST], and proposed that the working document towards a draft revision of Report ITU-R M.2417-0 be elevated, which was carried forward to the next meeting as a preliminary draft revision of the Report.

(3)At the 2021 WP5C meeting, NICT proposed that the working document towards a draft revision of Report ITU-R F.2416-0 be elevated, which was carried forward to the next meeting as a preliminary draft revision of the Report. NICT also submitted a contribution to add additional antenna patterns to a draft revision of Recommendation ITU-R F.699-8 and contributed to extend the frequency range covered by Recommendation ITU-R F.699-8 up to 450 GHz.

(4)At the 2021 WP5D meeting, NICT submitted a contribution to add THz technology to the working document towards a draft new Report ITU-R M. [IMT.FUTURE TECHNOLOGY TRENDS OF TERRESTRIAL IMT SYSTEMS TOWARDS 2030 AND BEYOND].

(5)At the 2021 AWG meeting, NICT contributed to developing an APT Report on 252 – 296 GHz fixed systems and an APT Report on walk-through imaging systems.

(6)At the 2021 APG meeting, NICT introduced THz standardization trends under WRC-23 agenda item 10 and contributed to developing APT Preliminary Views.

Activities at Terahertz Systems Consortium and Elsewhere

Amid growing attention to wireless communications technology using terahertz waves, discussions were held several times on use cases envisioned for 6G at the THz-6G Working Group (THz-6G WG) (Chair: Iwao Hosako, Director of Terahertz Technology Research Center; Vice-chair: Professor Tetsuya Kawanishi, Waseda University) organized in FY2020 within the Terahertz Systems Consortium. The results were reported at a lecture titled "Activities toward Terahertz Wireless B5G/6G" held as a webinar on March 1, 2022. A business seminar was also held in October of the same year with the aim of uncovering new users of terahertz technology.

Quantum ICT Field
Quantum ICT Collaboration Center

Director General SASAKI Masahide

The Quantum ICT Collaboration Center at NICT was established in 2021 as a core organization managing the "Quantum Security Innovation Hub," one of Japan's eight Quantum Technology Innovation Hubs.

Its mission is to (1) pioneer the new research field of "quantum security" by merging quantum cryptography and quantum communication with modern cryptography, information theory, and network technology, and demonstrate its basic concepts with implementations, and (2) derive architecture for a new infrastructure called the "quantum technology platform" (Fig. 1) that will merge quantum security, quantum computing, and quantum measurement/sensing and provide advanced computer-processing, metrology/sensing, and communication/cryptographic functions. With this mission defined, the Quantum ICT Collaboration Center will pursue research and development, implementation and testing on an open testbed, social development, and human resource development in an integrated manner while setting up an industry-academia-government co-creation environment through collaboration inside and outside NICT (Fig. 2).

Satellite Quantum Cryptography and Physical Layer Cryptography Technology

In 2021, the idea of "line-of-sight QKD" was raised as a new method of secure communications over ultra-long distances that can cover even communications between geostationary orbit and the ground as an achievement of satellite quantum cryptography and physical layer cryptography technology (Fig. 3). The paper proposing this new method presented a new direction in this field through its appearance in the New Journal of Physics. A total of five patent applications have been filed in relation to this method including the invention of a key sharing system that selects the most appropriate method according to the state of the communication channel. A patent was also granted in relation to basic concepts for configuring a secure communications network that hierarchically connects the satellite network, aircraft network, and ground network through quantum cryptography and physical layer cryptography.

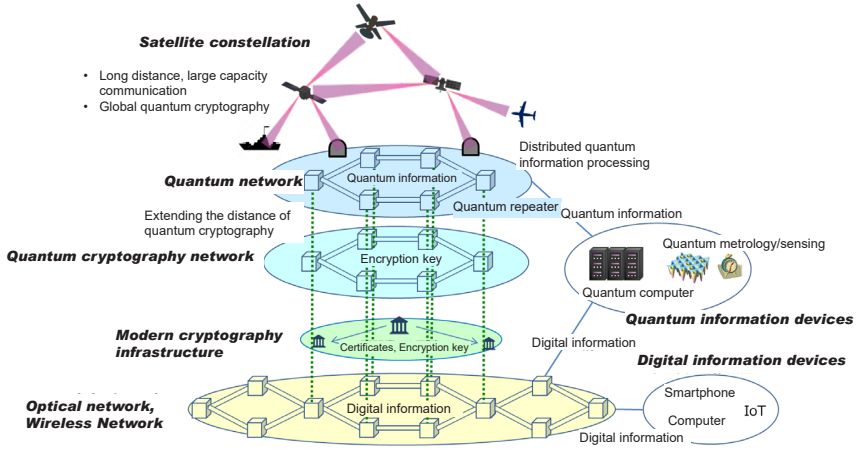


Fig.1 : Conceptual diagram of quantum technology platform

Open Testbed

We constructed a new quantum cryptography network connecting three sites, one in Koganei and two in the Fuchu district of Tokyo. This network connects to Tokyo QKD Network, a quantum cryptography network testbed that has been in operation since 2010. We are completing preparations for constructing a quantum cryptography network testbed on an even larger scale.

Social Development

We are promoting the social implementation of post-quantum public key cryptography in collaboration with outside enterprises and of quantum secure cloud technology toward the development of an

electronic-medical-record data processing system for supporting medical treatment in collaboration with medical institutions.

International Standardization Activities

With a view to international standardization of quantum key distribution devices and quantum cryptography networks, we have participated in 22 standardization meetings (ITU-T: 17, ISO: 3, ETSI: 13) and contributed 60 papers (ITU-T: 29, ISO: 5, ETSI: 26). Through these activities, a series of basic Recommendations on quantum cryptography networks and security were completed in October 2021 with Japan maintaining its leadership in this area. At present, the standardization of quantum secure clouds and protocol interworking and the editing of Recommendation drafts are in progress (Fig. 4).

Human Resource Development

Continuing on from last year, we held an NICT Quantum Camp as a set of programs for developing "quantum natives." In addition to providing a training program overseen by lecturers and advisors (17 in total) invited from outside NICT the same as last year, we held for the first time a public seminar targeting anyone interested in quantum ICT. We also increased the scale of the programs significantly compared with the previous year such as by increasing the number of positions available for the hands-on program for selected members and for the exploratory research program for training advanced quantum ICT researchers (for the former, 49 positions this year compared to 30 last year, and for the latter, 5 positions this year compared to 2 last year).

To disseminate the achievements described above, we have participated in panel discussions at major quantum-related international conferences (QCrypt2021, etc.). We also held Quantum Innovation 2021 (December 7 – 9, 2021), an international symposium in the field of quantum technology, as a joint effort of Japan's eight Quantum Technology Innovation Hubs. This event brought together 1,200 participants from 37 countries.

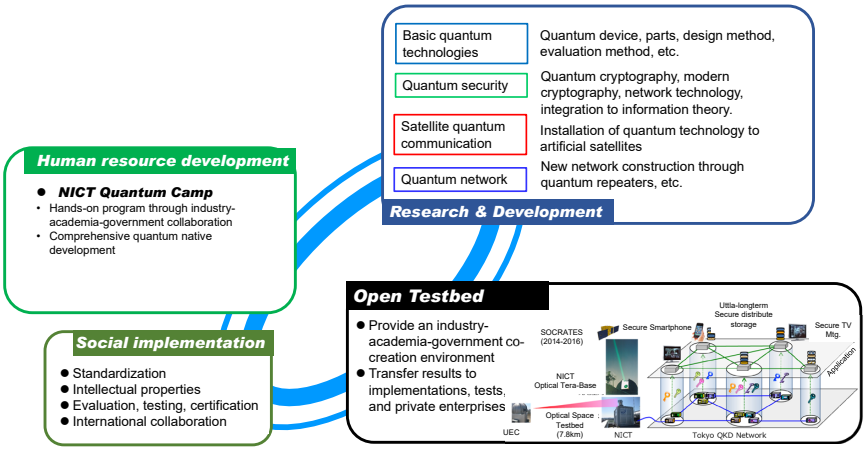


Fig.2 : Mission of Quantum ICT Collaboration Center

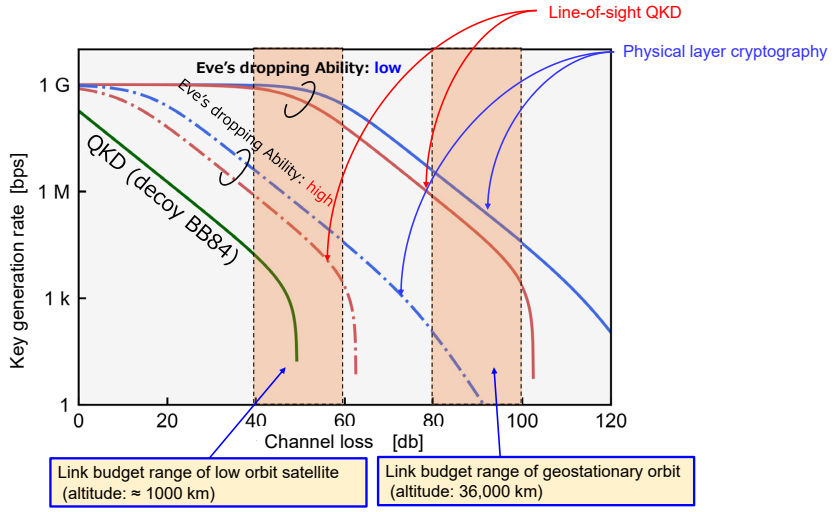


Fig.3 : Comparison of quantum-cryptography key generation rate between line-of-sight QKD and physical layer cryptography

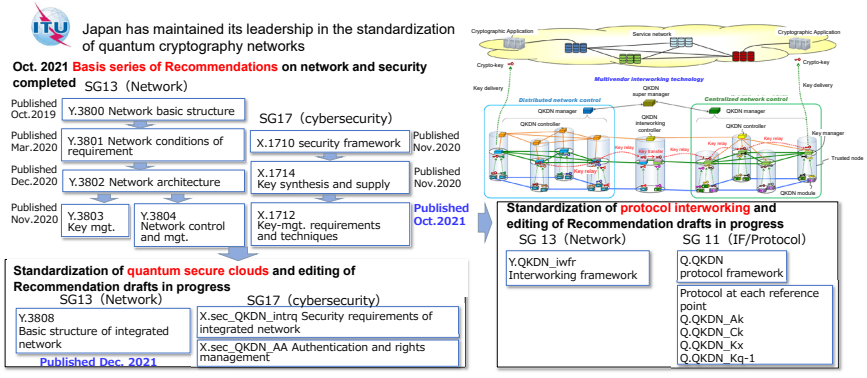


Fig.4 : ITU-T Recommendations related to quantum cryptography networks participated in by Quantum ICT Collaboration Center

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General KOJIMA Fumihide

NICT's ICT Testbed Research and Development Promotion Center conducted the following activities in FY2021.

Study of Testbed Direction toward the Beyond 5G Era

As an environment that can facilitate a wide variety of system and service testing Beyond 5G, we extended the network testbed based on the existing wired/wireless network infrastructure to include a platform layer that envisions data usage and diverse applications and a middleware layer that supports emulation and visualization (Fig. 1). We began to promote flexible functional extensions in line with trends in technology development and to pursue cyclical evolution of Beyond 5G testbed functions.

Accelerated Construction and Use of "Beyond 5G/IoT Testbed with High-reliability and High-elasticity"

We began construction of "Beyond 5G/IoT Testbed with High-reliability and High-elasticity" (Fig. 2) as a technology testing environment for the Beyond 5G network. We also reconfigured a taskforce from the viewpoint of promoting Beyond 5G R&D and data linking and began studies with concerned parties from government, industry, and academia including testbed users. Based on the results of these studies, we began a study on the continuous enhancement of functions and performance toward a testbed environment that can contribute to the realization of Beyond 5G.

In addition, stable operation of NICT's JGN (High Speed R&D Network Testbed) and StarBED (Large Scale Computer Environment) has facilitated use by many organizations including 96 cases of use inside and outside NICT (number of cases involving joint research agreements).

International Collaboration using 100 Gbps International Circuits

We have concluded Memorandums of Understanding (MOUs) with various institutions in Japan and abroad in relation to collaborative activities based on the 100 Gbps high-speed network in the Asia-Pacific-Oceania region (APOnet) (Fig. 3) and on extensions of the Asiapacific-Europe Ring (AER), an Asia-Europe research and education network, using the JGN 100 Gbps international circuit. In this way, we have constructed a worldwide circuit-connection environment capable of using circuits of 200 Gbps and greater including not only Asia and Europe but also Oceania to con-

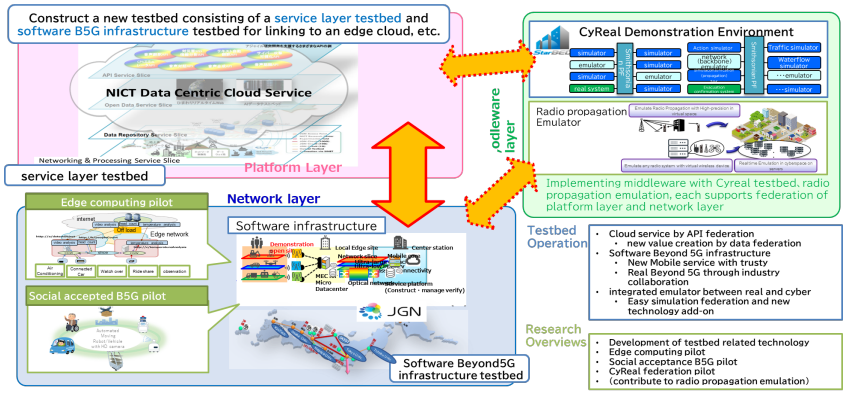


Fig.1 : Overview of Beyond 5G testbed

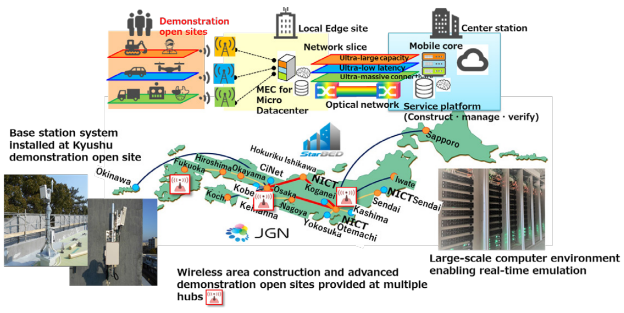


Fig.2 : Configuration of "Beyond 5G/IoT Testbed with High-reliability and High-elasticity

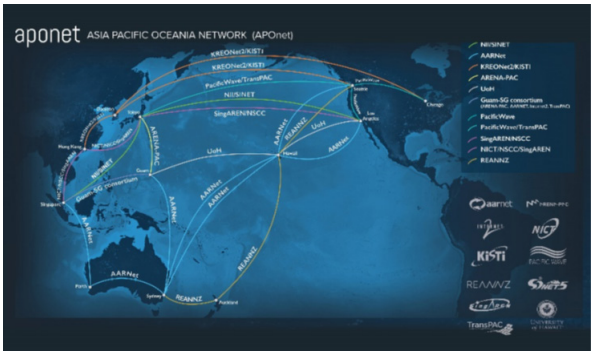


Fig.3 : Network topology of APOnet

tribute to technology testing toward the Beyond 5G era. At the same time, we strengthened mutual circuit-backup capabilities with international research and education networks and reinforced our cooperative relationships with research and educational institutions inside and outside Japan. This international circuit environment made possible through the above achievements has come to be used by Supercomputing Conference (SC), the Data Mover Challenge, a technical competition in transferring massive amounts of data, and other events, and for international technical demonstrations expanded to Asia such as Himawari Real-time Web (an application enabling viewing of moving images taken by the meteorological satellite Himawari).

Furthermore, to effectively promote international joint research through this testbed, we exchanged opinions with the National Science Foundation in the United States on "Japan-U.S. Joint Research for Next Generation Core and B5G/6G Networks" as Japan-U.S. Network Opportunity 3 (JUNO3). As a result of these discussions, we were able to coordinate with the relevant departments in NSF and NICT and carry out a joint call for proposals based on content that exceeded the originally envisioned standards. Specifically, we held discussions on slice technology and software router implementation technology for setting up and fully equipping a test environment on "Beyond 5G/IoT Testbed with High-reliability and High-elasticity", exchanged opinions on future testbed usage scenarios, and created an effective forum for developing Beyond 5G-related technologies by reflecting those scenarios in the joint call for proposals.

Study of Data Analysis and Visualization Technologies for Data-driven Services

We developed eight data visualization libraries (APIs) for space-time-data geographic information system (GIS) application development and released all of them on GitHub and elsewhere. In addition, we constructed a wide-area, distributed cloud among NICT and eight Japanese universities and a large-scale space-time GIS database, and converted all digital national land information databases of the Ministry of Land, Infrastructure, Transport and Tourism into binary vector tiles and achieved scalable visualization of these databases on 2D and 3D time-series GIS applications.

Study of Software-defined Network Testbed and Linking with Service Layer Testbed

We worked on constructing a foundation for a software-defined network testbed toward the Beyond 5G era. Additionally, with a view to achieving a data-driven society, we proceeded with the construction of a service layer testbed to contribute to the development and testing of applications that combine diverse types of data and created data-analysis and visualization sample programs through collaborative activities at related forums.

Construction of CyReal Demonstration Environment

With the aim of constructing the CyReal Demonstration Environment that will enable the simulation and emulation of physical phenomena and the linking and testing of actual devices and software, we moved forward with the implementation of support software making flexible and efficient use of StarBED experimental resources (Fig. 4) and created a number of use cases in conjunction with a wireless simulator and emulation environment. Here, in the research and development of support software that will enable the construction of the CyReal Demonstration Environment, we consider that the testing of systems and services assuming ultra-massive connectivity in the Beyond 5G era will require real-time emulation that runs application implementations in a real environment in real time to evaluate user-side characteristics, which cannot be evaluated by strict simulation techniques. We designed a basic test environment that takes into account a tradeoff with the computing resources needed for achieving this environment. Additionally, in terms of emulation technology that appropriately reflects radio wave parameters that were not originally assumed, we enabled real-time coordination with a simulator in relation to physical phenomena including radio wave parameters. We also enabled the use of CyReal as a platform for cyclical evolution to simplify the incorporation of new R&D results.

Joint R&D and Social Verification Experiments with Companies in Different Fields and Industries

To promote the social implementation of ICT technologies having a high affinity with Beyond 5G, we teamed up with multiple companies in different fields and industries to develop on-premise data collection and distribution systems that can be constructed through the integrated use of ultra-high-frequency IoT wireless technology, AI technology, and autonomous mobile robots that will make up the Beyond 5G society. We also carried out Proof of Concept demonstrations through a joint system that included both system developers and operators.

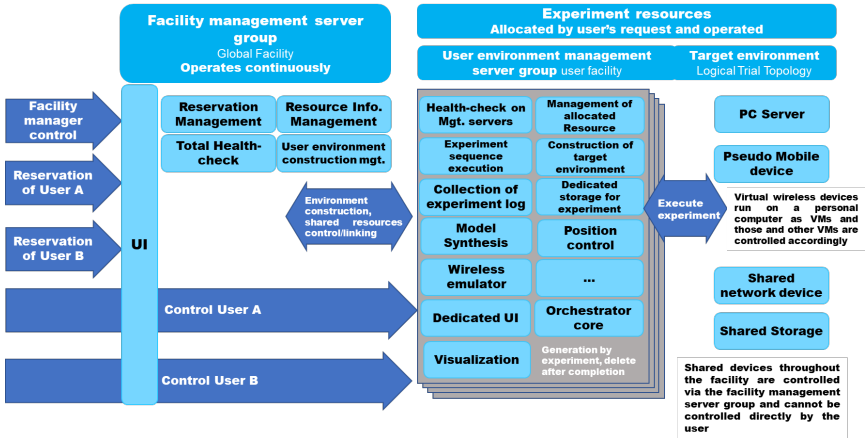


Fig.4 : CyReal: Architecture of cyber and real testbed

Open Innovation

Innovation Promotion Department

Executive Director YAMAGUCHI Shuji

The Innovation Promotion Department seeks to maximize NICT research and development results by fulfilling its mission as follows.

- ***Promote efficient and effective R&D and strengthen collaboration with government, industry, and academia by making effective use of external research resources through joint research, commissioned research, and funded research.***
- ***Contribute to open innovation through the implementation of R&D results in society by appropriately securing and effectively using intellectual property and participating in effective standardization activities through collaboration with government, industry, and academia.***

Promotion of Joint Research and Researcher Exchanges

NICT was involved in 464 joint-research contracts in FY2021. Of these, 243 were newly concluded contracts with 231 of those being domestic contracts and 12 being international contracts (Fig. 1). As a type of joint research, we have also been promoting "funded joint research" in which the collaborator provides NICT with research expenses. In concluding a contract, we perform a supporting role by consulting with the research departments of concern, negotiating with the collaborating research institution, preparing a contract template, upgrading a contract-conclusion manual, and providing storage/search functions for related information.

As for researcher exchanges, we promoted the dispatching and accepting of researchers and contributed to intensifying collaboration among government, industry, and academia by promoting mutual cooperation in the field of information and communications. Additionally, we promoted research exchanges with universities through a cooperating graduate school system by having NICT researchers give lectures at graduate schools and accepting research trainees for guidance in research.

Promotion of Commissioned Research

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

We promote efficient and effective R&D by making good use of external research resources for R&D themes that can be made more efficient by integrating them with NICT's own research. Research results in FY2021 came to 102 papers, 204 oral presentations, 71 standardization proposals, and 50 applications for industrial property rights (22 domestic and 28 international).

(2) Promotion of commissioned research on R&D of innovative information and communications technology

With the aim of establishing the elemental technologies for achieving the Beyond 5G next-generation communications infrastructure as the platform for diverse industries and social activities in the 2030s, we promoted R&D at private companies and

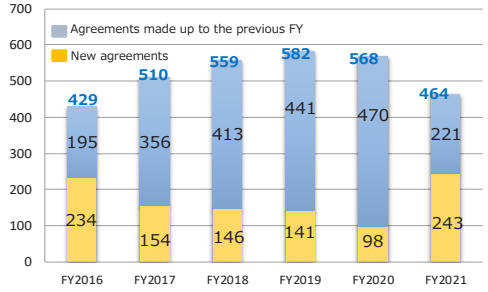


Fig.1 : Trends in number of joint research contracts

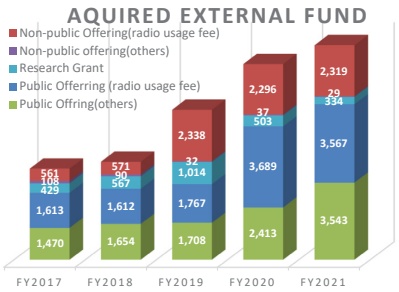


Fig.2 : Trends in captured income from competitive research funds

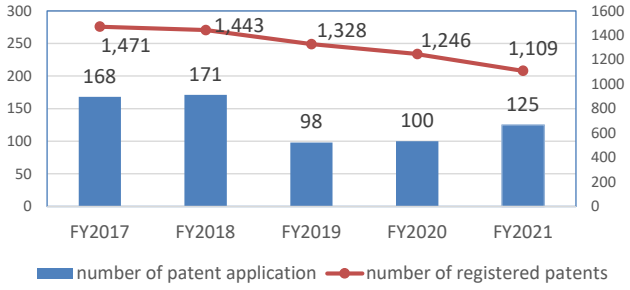


Fig.3 : Trends in patent applications and registered patents

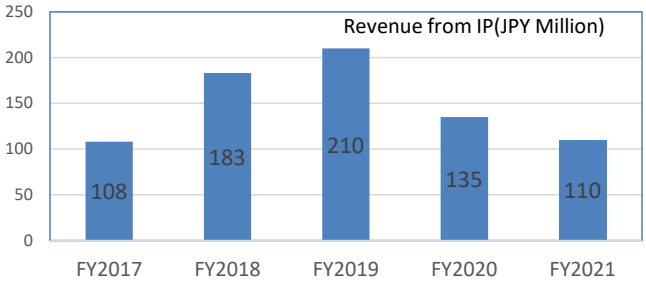


Fig.4 : Trends in revenue from intellectual property

universities through "Innovative ICT R&D Commissioned Research" in the "Beyond 5G R&D Promotion Program" launched in 2020. Research results for this program in FY2021 came to 53 papers, 339 oral presentations, 5 standardization proposals, and 78 applications for industrial property rights (58 domestic and 20 international).

Support for Acquiring and Appropriately Implementing External Funding

Expanding funded research from other institutions and grant-in-aids for research can demonstrate the superiority of NICT technology in responding to government policies and meeting social needs. It can also improve the R&D capabilities of NICT itself, enhance collaboration with other research institutions, and cultivate new technology seeds. In FY2021, the acquisition of about 9,800 million yen in external funding helped to drive research at NICT (Fig. 2). In this endeavor, we surveyed the content and rules of various research funding systems to provide researchers with essential information, supported researchers in completing applications, contracts, and audits, and strived to reduce the load on researchers, follow correct procedures, and make tasks more efficient.

Promotion of Proactive Acquisition and Use of Intellectual Property

With a view to implementing NICT R&D results widely in society, we have been collaborating with researchers and related departments using expertise in intellectual property to promote the proactive acquisition and use of intellectual property. Here, we aim to contribute to open innovation by consistently providing intellectual property services—from appropriate protection of intellectual property at the invention and creation stage to its use tied to technology transfer agreements—while working together with researchers.

The number of patent applications in FY2021 came to 125 (67 domestic and 58 international) while the number of registered patents held by NICT came to 1,109 (737 domestic and 372 international) as of the end of FY2021. Compared with the previous fiscal year, the number of domestic patent applications decreased slightly with that of international patent applications increasing (Fig. 3).

In addition, the number of new technology transfer agreements in FY2021 came to 18 bringing the number of these agreements by the end of the fiscal year to 133. Technology transfer revenue for FY2021 came to about 110 million yen, which was a slight decrease from the previous fiscal year (Fig. 4).

To introduce NICT technology seeds transformed into intellectual property to industry, we actively presented intellectual property and technology use cases on the Web and through technology briefings and introductions. As one example of an event oriented to outside parties, we co-sponsored with the Japan Science and Technology Agency (JST) an "NICT New Technology Presentation Meeting" (held online on October 14, 2021 with 273 participants). At this event, researchers themselves introduced NICT technologies to companies interested in industry-academia collaboration and responded to individual questions.

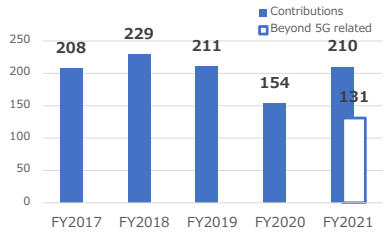


Fig.5 : Trends in number of Contributions to International Standardization Organizations

Promotion of International Standardization

Based on an NICT action plan on standardization formulated for achieving strategic and important standardization activities, we have been intensifying and promoting international standardization activities so that NICT research results can be used widely in the real world with a focus on Beyond 5G technology seeds while contributing to Japan's international competitiveness. Specifically, we have been promoting R&D that could be reflected in international standards and providing support for proactively submitting those results as contributions to international standardization organizations and various forums including the International Telecommunication Union (ITU). In addition to actively participating in meetings at standardization organizations, NICT submitted a total of 210 contributions to international standardization organizations (Fig. 5) and 104 to domestic standardization organizations in FY2021 based on R&D results. Additionally, given that NICT is a neutral party with specialized knowledge, it has been actively dispatching individuals to serve on various standardization-related committees in Japan.

Open Innovation
Global Alliance Department

Executive Director YAMAGUCHI Norifumi

Collaboration with leading overseas research institutes and universities is becoming increasingly important to disseminate NICT's research results to the world, achieve a synergetic effect in R&D results through international collaboration, produce even better results in the research and development of information and communications technology, and accelerate the deployment of those results. The Global Alliance Department promotes international collaboration in NICT's R&D activities and the international deployment of those R&D results with the aim of maximizing R&D achievements and making them known around the world.

Promotion of International Research Collaboration

We have been exchanging memorandums of understanding (MOUs) with leading overseas research institutes and universities and promoting joint research and personnel exchange to facilitate international collaboration. In FY2021, we exchanged 19 new MOUs with overseas universities and research institutes (for a total of 77 MOUs with 24 countries and 75 institutes as of the end of March 2022) to promote international R&D and proactively pursued the international deployment of NICT R&D results (Fig. 1).

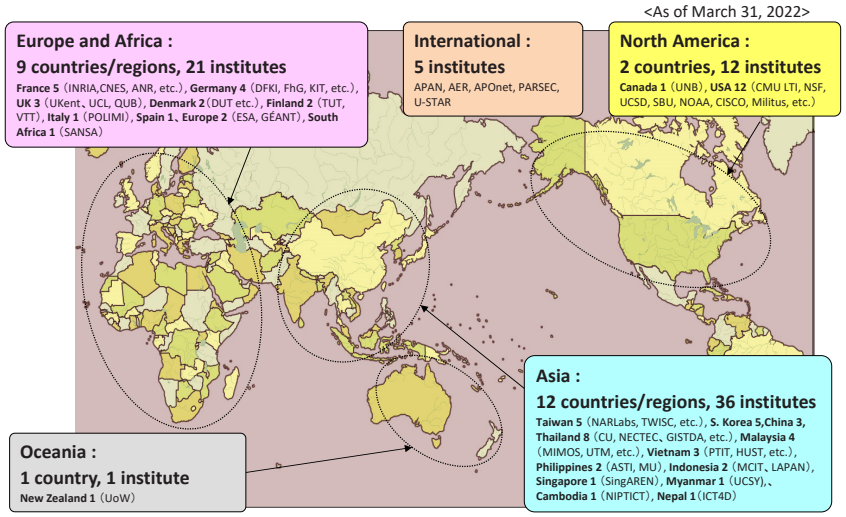


Fig.1 : Overseas institutes with which NICT has exchanged research memorandums (the end of March 2022)

Promotion of International Joint Research with the United States and Europe

Under the Japan-US Network Opportunity 2 (JUNO2) international joint research program in the network area managed jointly with the US National Science Foundation (NSF), five joint research projects under the theme of trustworthy networking were concluded in August 2021 and a final Principal Investigator (PI) meeting was held online. Additionally, based on a report of a Japan-US online workshop on programmable networking held jointly with NSF in November 2020, a call for proposals for the Japan-US Network Opportunity 3 (JUNO3) international joint research

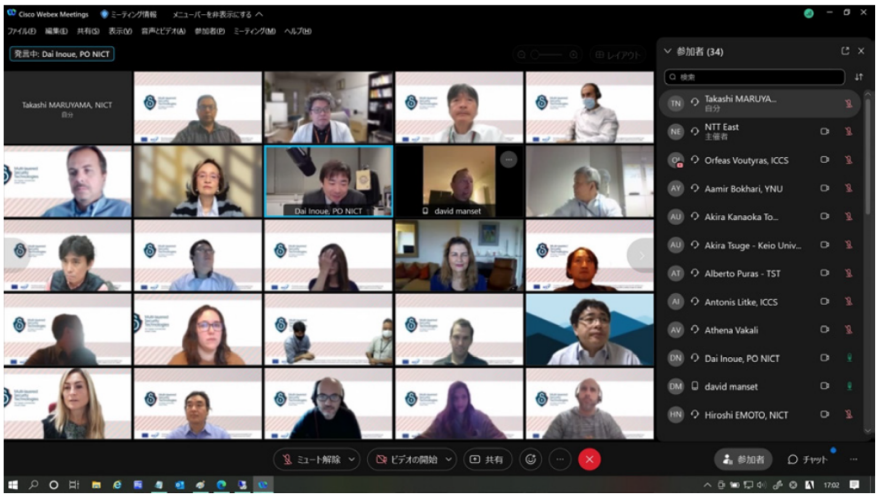


Fig.2 : Online final review of EU-Japan collaborative research project (multi-layer security technology for smart cities), August 2021

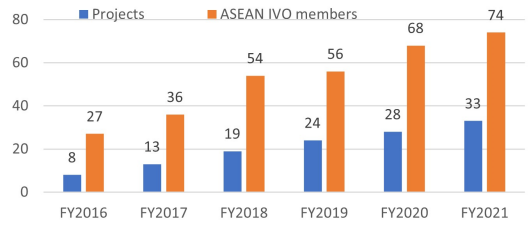


Fig.3 : ASEAN IVO members and projects

Fig.4 : Exhibit at Thailand National Science and Technology Fair 2022 (August 2022, Northern Bangkok, Nonthaburi province)
(left: Mr. Don Pramudwinai, Thai Deputy Prime Minister and Minister of Foreign Affairs of Thailand (center), Mr. Anek Laothamatas, Thai Minister of Higher Education, Science, Research and Innovation (right of center), and Japan booth personnel; right: the NICT exhibit being described to Mr. Don Pramudwinai).

program in the network area was made both externally and internally resulting in the submission of 12 proposals with a total of 5 proposals (4 external and 1 internal) selected as candidates. In parallel with the above, 3 new joint research projects (including 1 internally proposed) were launched under the Collaborative Research in Computational Neuroscience (CRCNS) international joint research program, whose participants include the United States, Germany, France, Israel, Spain, and Japan (NICT), and a call for new joint research proposals for the initial period of FY2022 was made.

In Japan–European international joint research run jointly by the European Commission and Japan's Ministry of Internal Affairs and Communications (MIC), a Final Review was conducted online for a joint research project (multi-layer security technology for smart cities) initiated in 2018 (Fig. 2). Studies were also conducted together with MIC on the future direction of this theme.

Promotion of Collaboration and International Joint Research Projects with Southeast Asia

The ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO), which was established in February 2015 in collaboration with research institutes and universities in the ASEAN region, heightened its visibility in this region and grew into a large joint research body with 74 participating institutes (Fig. 3). Under this organization, work on 14 joint R&D projects (launched in FY2017–FY2021) progressed with the aim of pursuing ICT solutions to social problems common to the ASEAN region. Since its inception, ASEAN IVO has conducted a total of 33 projects with the participation of 367 individuals from 202 institutes.

In addition, the ASEAN IVO Forum 2021 to formulate new projects for the following year was held in two formats: oral presentations through online simultaneous participation held on November 18, 2021 and poster presentations open to the public in a hybrid format running from the end of November 2021 to the beginning of January 2022. Participants presented ideas on a total of 26 projects targeting a variety of fields including food, environmental protection and disaster prevention, secure and smart communities, and health and welfare. The Forum provided an opportunity to hold lively discussions and form a variety of groups that eventually came to propose 29 new projects. Of these, the steering committee selected 5 projects.

Fig.5 : Talk by SHIGA Nobuyasu, Planning Manager, at the Workshop on Synchronization and Timing Systems (May 2022, Denver, United States)

Exhibits at International Exhibitions

With the view to disseminating NICT R&D results on the international stage, we proactively held exhibits at a variety of events and international exhibitions including the Thailand National Science and Technology Fair 2022 (August 2022, Thailand) (Fig. 4) and the Workshop on Synchronization and Timing Systems (May 2022, Denver, United States) (Fig. 5).

Activities at Overseas Centers

Please see the chapter titled "Oversea Centers Activities" for information on collaborative activities at each of the three overseas centers in the U.S.A (Washington D.C.), France (Paris), and Thailand (Bangkok).

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director HIGASHIGAWA Rei

NICT is engaged in promoting business development for information communication ventures that deliver new ICT services, enhancing and improving information communication infrastructures that enable the utilization of new and diverse ICT services, promoting a barrier-free information environment where everyone can freely use ICT services, promoting basic technology research in the private sector, and supporting international exchange in research and development in the field of information communication, which is the foundation of social life and economic activities. Through these initiatives and with a view to contributing to the revitalization of industries and the realization of a safe, secure, and prosperous life, and to supporting the widespread use of highly convenient ICT services in daily life and economy, NICT has been carrying out the following programs to efficiently and effectively implement various promotional activities in the field of information communication.

Providing Information and Exchange Opportunities for ICT Startups

Through online as well as face-to-face meetings, NICT provides information and exchange opportunities to help ICT ventures develop their businesses. In particular, "Kigyouka Koshien" (Entrepreneurs' Championship) and "Kigyouka Banpaku" (Entrepreneurs' Expo) are held to promote the commercialization of promising, novel, and impactful technologies and services by ICT ventures.

"Kigyouka Koshien" is an event aimed at discovering and nurturing young talents, such as technical college and university students who are poised to become the future leaders of ICT startups, while "Kigyouka Banpaku" is an event where ICT startups engage in business matching by presenting new and innovative businesses.

The "Kigyouka Koshien" was held on March 8, and the "Kigyouka Banpaku" was held on March 9, 2022, both at the Marunouchi Building Hall and Conference Square (Chiyoda Ward, Tokyo). As part of measures to prevent the spread of COVID-19, only judges, ICT mentors, and other relevant personnel were allowed to enter the venue on the day of each event. Presenters selected from around the country gave online presentations from their hometown, and judging was conducted by a panel of judges in the venue.

From the nine teams that participated in the "Kigyouka Koshien," National Institute of Technology, Oshima College Agricultural Support Study Group (Representative: Hajime Taguchi) won the Minister of Internal Affairs and Communications Award for "Smart Gathering NEXT." CeTrax (Repre-

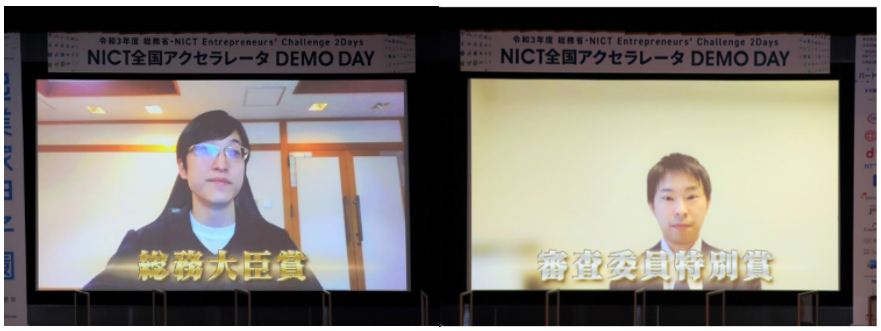


Fig.1 : Presentation by the winners at the "Kigyouka Koshien" (March 8, 2022)

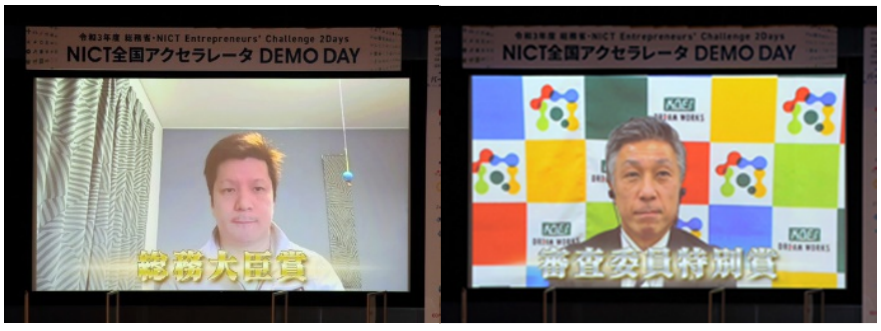


Fig.2 : Presentation by the winners at the "Kigyouka Banpaku" (March 9, 2022)

sentative: Daisuke Inagaki) won the Special Jury Award for "Supporting developing countries with Japanese clinical engineering technology - Medical device management and learning system" (Fig. 1).

At the "Kigyouka Banpaku," from the ten participating companies, ARUM Inc. (Representative Director: Takayuki Hirayama) won the Minister of Internal Affairs and Communications Award for "ARUMCODE1: manufacturing AI for revolutionizing productivity of high-mix, low-volume production in the metal processing industry." KOEI DREAMWORKS Co., Ltd. (President: Yasuhiro Sugawara) won the Special Jury Prize for "Promoting DX in the equipment industry using the Haikan-kun® pipe exploration robot" (Fig. 2).

Innovative Venture Grants Program (SBIR)

Under the Beyond 5G R&D Promotion Project R&D Policy (Ministry of Internal Affairs and Communications, January 2021) and as part of the Beyond 5G R&D Promotion Project, NICT provides subsidies to small and medium-sized enterprises such as ventures and startups that possess innovative technology seeds and ideas and are willing to take on difficult challenges.

Promotion of Barrier-free Information Environment

1. Production of programs with subtitles, sign language, and explanations

(1)Promoting the production of programs with subtitles, explanations, and sign language

In FY2021, NICT provided subsidies to 120 broadcasters nationwide to contribute to the broadcasting of programs with subtitles, explanations, and sign language (total of 50,257 programs).

(2)Subsidies to promote the provision of sign language translation video

In FY2021, NICT provided subsidies for 113 broadcast programs with composite display of sign language translation videos to contribute to the provision of opportunities for hearing-impaired persons to obtain information from broadcasts.

(3)Subsidies to promote live-broadcast subtitled programs

In FY2021, NICT provided subsidy to one broadcaster to establish facilities that contribute to the promotion of live-broadcast subtitled programs.

2. Provision and development of communications and broadcasting services for the disabled

Through subsidies to promote the provision and development of barrier-free communication and broadcasting services, NICT supported five projects in FY2021 to contribute to the provision of communications and broadcasting services that help improve convenience for disabled persons.

3. Provision of information related to barrier-free access to information

NICT provided useful information for the disabled, the elderly, and related business operators, as well as information on the overview and results of NICT's barrier-free information accessibility project (subsidy system), through the "Portal site for barrier-free access to information" (Fig.3) on the NICT website.

At the 49th International Home Care and Rehabilitation Exhibition (Tokyo Big Sight, October 5-7, 2022), NICT presented the results of its subsidy program for FY2021 and introduced "KoeTra," an NICT transferred technology, as well as information on NICT's initiatives related to barrier-free access to information. (Fig.4)

Fig.3 : Portal site for barrier-free access to information (At present only available in Japanese)

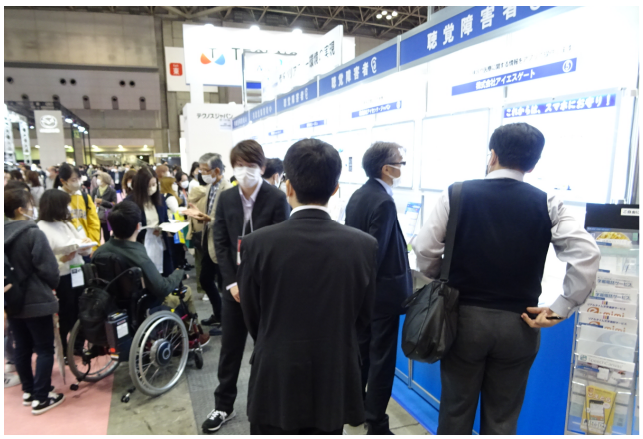


Fig.4 : NICT exhibition corner

Research Highlights

Researchers

Research Highlights

Researchers

Advanced Electromagnetic Technology Area

Clarification of radiofrequency electromagnetic field exposure levels from mobile phone base stations in the living environment

First large-scale and long-term measurement of radiofrequency electromagnetic field exposure levels in Japan

NICT investigated the time trends of radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile phone base stations in urban areas, suburbs, and underground shopping malls. Thus far, we have measured in RF-EMF exposure levels from mobile phone base stations at more than 500 locations in urban areas, suburbs, and underground shopping mall. We then compared the results of past measurements (about 10 years ago) in the same areas and found that the RF-EMF exposure levels are on an upward trend but are sufficiently lower than the level set in the Japanese Radio Radiation Protection Guidelines. Since FY2019, NICT has been conducting the first large-scale and long-term measurements of RF-EMF exposure levels in Japan. RF-EMF exposure levels in the living environment are obtained by combining spot measurements using an electric field probe, measurements using a portable measuring device, and measurements in a wide area using a car mounting measuring equipment.

Although we are surrounded with devices that use RF-EMF, these RF-EMF from mobile phones, mobile phone base stations, wireless LANs, etc. are used within a range that does not adversely affect the human body, in accordance with the Japanese Radio Radiation Protection Guidelines. Meanwhile, overseas, there have been cases where adverse health concerns due to RF-EMF from fifth-generation mobile phone system (5G) have become an obstacle to the deployment of 5G, and similar concerns have been raised in Japan as well.

One of the reasons for these concerns is that while RF-EMF are definitely existed in living environments, because they are invisible, we don't know how much the actual levels are. Therefore, there is a need to comprehensively monitor the strength of RF-EMF from various sources, accumulate data, and widely share information on RF-EMF exposure levels.

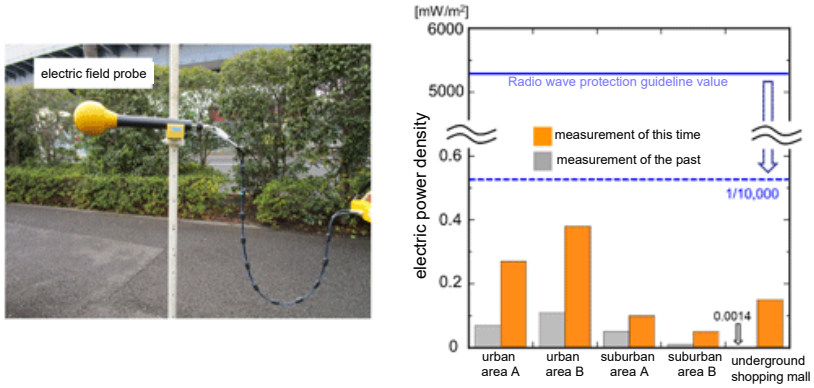


Fig.1 : Measurement of electric fieldscene and results of radio wave exposure levels (median)

NICT measured RF-EMF exposure levels from mobile phone base stations at more than 500 locations in urban areas, suburbs, and underground shopping mall. Measurements were performed using a special measuring device (electric field probe) in accordance with the measurement procedures stipulated in Japanese Radio Law (see Fig. 1, left). The large volume of data obtained from the measurements were statistically processed to analyze regional differences and changes from past measurements.

Comparison of the results by region showed that the level of RF-EMF exposure in urban areas tended to be higher (about four times) than in suburban areas. This trend has remained un-

changed from the past (about 10 years ago) to the present. RF-EMF exposure levels in underground shopping mall were slightly higher than those in suburban areas (see Fig. 1, right).

Comparison of past and present measurement results for each region showed an increasing trend in exposure levels (about three times higher) in both urban and suburban areas (see Fig. 1, right). In addition, RF-EMF exposure levels in underground shopping mall have increased significantly (about 100 times), probably because mobile phone services were not available in some areas of the shopping mall at the time of past measurements, and services have now improved.

Although RF-EMF exposure levels are on an upward trend, they were found to be sufficiently low in all the areas (median value of approximately 1/10,000 or less) compared with the level set in the Japanese Radio Radiation Protection Guidelines (see Fig. 1, right). The RF-EMF exposure levels obtained in the latest measurements were about one-fifteenth of the results of recent overseas measurements (see reference).

These findings were published in the International Journal of Environmental Research and Public Health in July 2021.

Going forward, we will continue to promote large-scale measurements of RF-EMF exposure levels in Japan, where full-scale introduction of 5G is being carried out, through wide-area measurements using electric measuring vehicles.

Reference

Teruo Onishi, Miwa Ikuyo, Kazuhiro Tobita, Sen Liu, Masao Taki, and Soichi Watanabe, "Radiofrequency Exposure Levels from Mobile Phone Base Stations in Outdoor Environments and an Underground Shopping Mall in Japan," International Journal of Environmental Research and Public Health, Sept. 2021.
https://doi.org/10.3390/ijerph18158068
DOI: 10.3390/ijerph18158068

Frontier Science Area

Successful joint verification test for low latency transmission of highly confidential data using quantum cryptography for large-volume financial transaction data

NICT, Nomura HD, Nomura Securities, Toshiba, and NEC have jointly verified the effectiveness and practicality of quantum cryptography for future social implementation using stock trading operations as a use case, where high-speed, large-volume, low-latency data transmission is strictly required. The test which started in December 2020 is the first in Japan to verify the low-latency and large-volume transmission tolerance of highly secure data transmission conforming to the message transmission format (FIX format), which is a standard format used in actual stock trading operations. As a result, in our assumed use case, we were able to confirm the following two points: (i) the throughput is maintained with low latency at a level of a conventional system, even if quantum cryptography is applied, and (ii) even if a large number of stock orders are placed, highly secure and high-

speed quantum cryptographic communication can be realized without depleting cryptographic keys. The success of this test is expected to accelerate the social implementation of quantum cryptography, including a broad range of sectors other than finance.

The threat of cyber-attacks on financial institutions is increasing, and the potential impact on the financial system has become a serious concern. In particular, in the financial sector, the circumstances surrounding systems have changed significantly due to the accelerated development of digitalization, and further strengthening of security measures is required.

On the other hand, in stock trading, "algorithmic trading," in which a computer system automatically determines the timing and quantity of stock trading orders and repeats them according to stock prices, quotation information, volume of trading, and other factors, is widely used. A large number of transactions are conducted every day. In Japan, the daily trading volume of stocks and other securities on stock exchanges is more than 3 trillion yen, and a communication system that can handle a large amount of transaction data is required for the processing of such stock trading. In addition, in stock trading, delays in transaction processing can lead to opportunity losses. Therefore, stock exchanges provide a communication network infrastructure that can process orders with a response time of less than milliseconds.

In this project, Nomura HD, Nomura Securities, NICT, Toshiba and NEC have jointly verified the applicability of quantum cryptographic communication to the financial sector, which is the only cryptographic communication method guaranteed to be undecipherable by any third party (eavesdropper who has unbounded computational power, including large scale quantum computing).

In addition, NICT has been examining the data-encryption method combined with QKD for social implementation and has adopted two encryption methods: the one time pad (OTP) method and the Advanced Encryption Standard (AES) method.

Based on the results of the test, we will work on measures for the utilization of quantum cryptography and quantum secure cloud systems, as well as the formulation of appropriate implementation plans, in order to steadily implement quantum cryptography in society in the future.

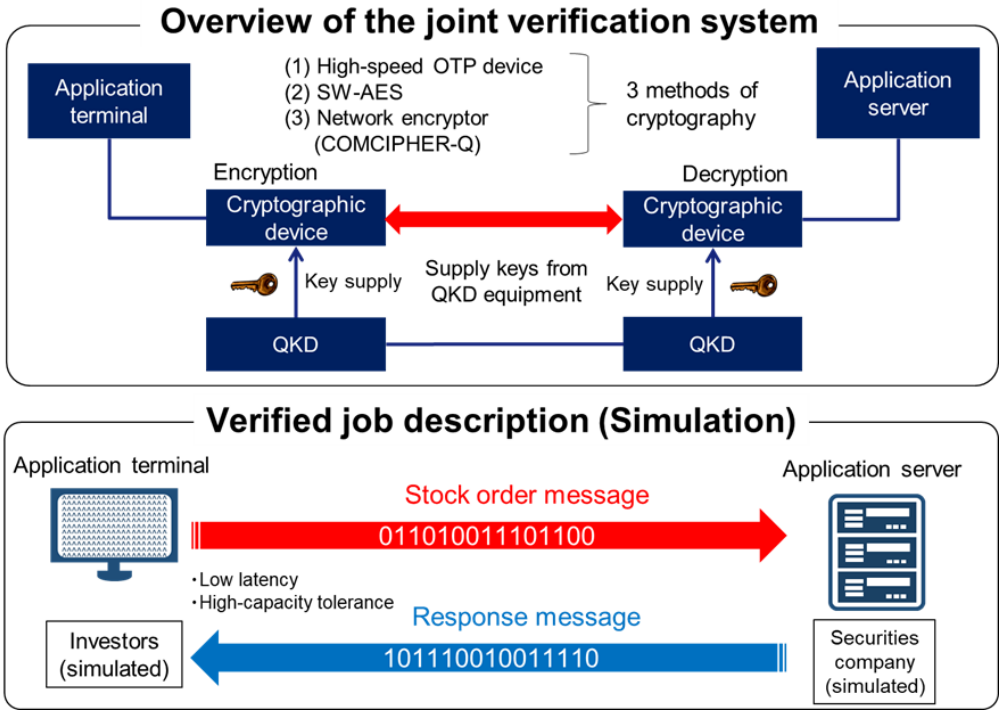


Fig.1 : The outline of the joint verification system

Advanced Electromagnetic Technology Area

Successful demonstration of high-resolution synthetic aperture radar for observing ground surface from aircraft

Achieving the world's highest resolution at 15 cm, twice that of conventional radars, with next-generation radar

NICT Radio Research Institute Remote Sensing Laboratory succeeded in carrying out high-resolution ground surface observation using an aircraft-mounted synthetic aperture radar, Pi-SAR X3, which can image the ground surface regardless of time of day and weather by using radio waves (improvement from 30-cm resolution with conventional Pi-SAR2 to 15-cm resolution with Pi-SAR X3). With a resolution of 15 cm, the radar has the world's highest performance, making it possible to acquire high-definition images at twice the resolution of conventional radars. This technology makes it possible to grasp the extent of damage more thoroughly in the event of an earthquake or other natural disasters, potentially contributing to smooth and effective rescue operations and restoration work. Going forward, we will promote efforts for its social implementation, such as for early detection of disasters, environmental monitoring, and sea surface monitoring for ships and ocean debris.

NICT has been conducting research on aircraft-mounted synthetic aperture radar using X-band radio waves, and in 2008, succeeded in developing a radar (Pi-SAR2) capable of imaging the ground surface at a resolution of 30 cm.

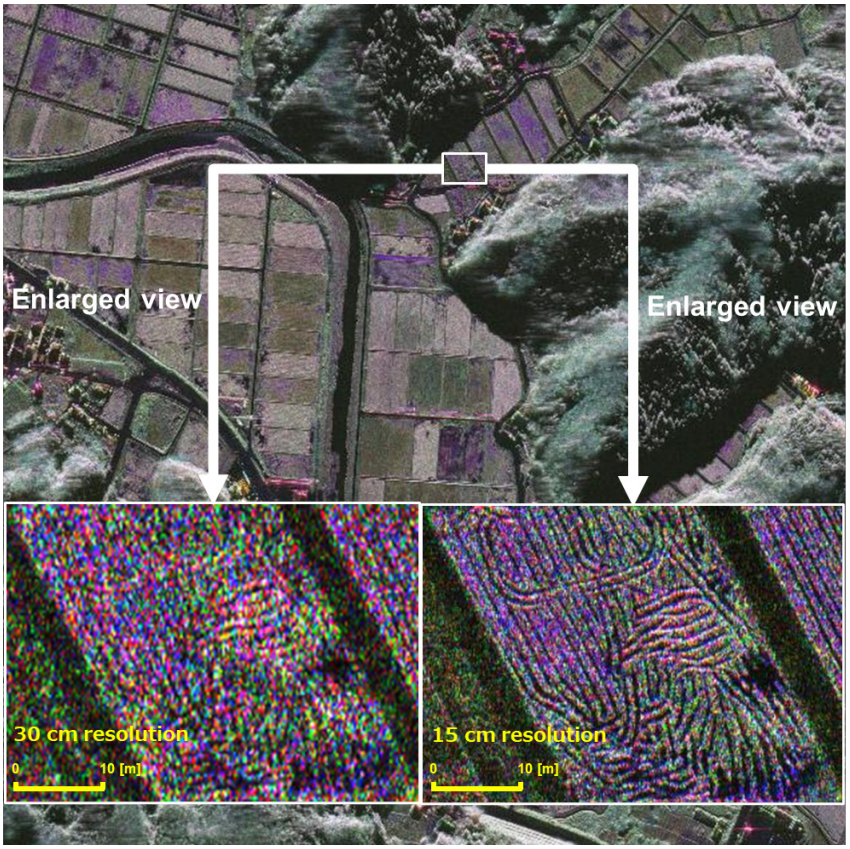


Fig.1 : Image of a suburb of Wajima City observed by Pi-SAR X3 in December 2021 and enlarged view of the area framed in white (rice field)
Enlarged left image: 15 cm resolution; enlarged right image: 30 cm resolution (equivalent to Pi-SAR2's resolution)

With Pi-SAR X3, we have succeeded in clearly observing farm tractor tracks on rice paddies, which were difficult to observe with Pi-SAR2, making it possible to observe ground surface changes caused by earthquakes and other phenomena in more detail than previously possible.

Image data obtained from test and disaster observations after development have been utilized in applied research and provided to other research institutes and government agencies to promote their utilization. In addition, some of the developed technologies have been deployed in society and are being put into practical use. Meanwhile, we also received requests from users of the image data for a new system that can image the ground surface at an even higher resolution.

To verify the achievement of the world's highest resolution of 15 cm, NICT conducted the first test observation over the Noto Peninsula in December 2021 using an aircraft mounted with Pi-SAR X3. The radar is equipped with the following: a transceiver and an antenna that support broadband (twice the band compared to conventional radars), a high-speed and large-capacity observation data recorder (write speed: 10x, capacity: 8x; both compared with conventional radar) for recording the broadband reception signals, and an onboard processing device for processing and imaging the observation data in near real time. Figure 1 shows 15-cm and 30-cm resolution images obtained from the test observations with Pi-SAR X3. The 15-cm resolution image clearly shows the tracks created by the wheels of a tractor on rice paddies.

Going forward, we will continue to improve image quality by optimizing the system. From FY 2022, we will enhance the technologies used for monitoring earthquakes and other natural disasters, and for environmental monitoring, such as for land utilization, deforestation, ocean oil spills, oceanic waves, and crater observation in normal times.

Advanced Electromagnetic Technology Area

Photorealistic 3D rendering on transparent AR display using high-precision measurement data

NICT Digital Optics Laboratory has developed a transparent augmented reality (AR) display system that enables a large number of people to simultaneously experience photorealistic 3D rendering without the use of 3D glasses (with the naked eye) by applying hologram printing technology (HOPTEC). The system consists of a holographic film developed by NICT along with multiple small projectors. In addition, NICT and Toppan Printing have succeeded in 3D rendering of images generated from highly accurate face measurement data obtained using Toppan Printing's Light Stage.

With the growing importance of online communication, the volume of information presented through 2D images alone has become insufficient. Thus, expectations are rising for photorealistic 3D rendering as a communication tool.

NICT has developed a transparent AR display system that enables users to experience 3D rendering with the naked eye using a simple configuration consisting of only a holographic film and several small, inexpensive projectors. This system uses about 30 small projectors to project full-color images, which can be viewed by a large number of people without the use of 3D glasses at a diagonal of 35 cm, a horizontal viewing angle of 60 degrees, and a vertical viewing angle of 10 degrees. We also worked with Kyoto Tachibana University in the development of the light beam control technology.

In addition, to explore the possibility for new avenues of communication using the system, NICT and Toppan Printing conducted demonstration experi-

ments on the system to recreate the high-resolution face measurement data that include skin texture taken on Toppan Printing's Light Stage and succeeded in projecting natural facial expressions.

Going forward, NICT and Toppan Printing will continue to work together to explore new avenues for communication using 3D content. Likewise, by leveraging the knowledge and technology we have cultivated thus far, we will apply the system to various fields, not only to the entertainment field, such as for virtual characters and digital twins that connect virtual and real spaces, but also to the medical field, such as for surgical training and surgical support based on 3D rendering of the human body.

Going forward, NICT will enhance the definition of 3D content, simplify and improve the flexibility of the system, and enable support for various types of 3D data (e.g., CAD data, BIM data, point-cloud data, etc.). We aim to develop technologies that contribute not only to communications but also to other fields (e.g., construction and education).

Toppan Printing aims to build a platform for digital content generation that can be adapted to various fields by accumulating different kinds of measurement data related to the human body and making use of its know-how and expertise on management and operations under high security.

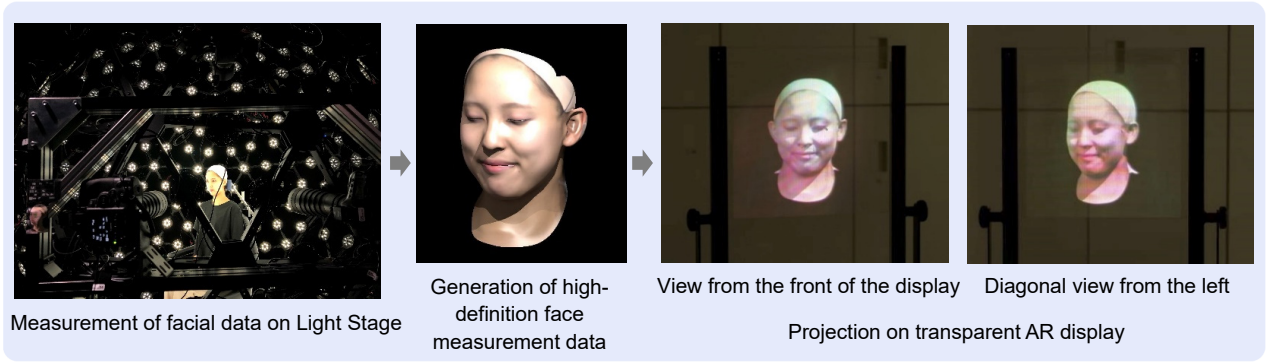


Fig.1 : 3D rendering of image generated from high-resolution face measurement data on a transparent AR display and the model herself

Frontier Science Area

Development of nanomachines that move autonomously while sequentially reading programs embedded in a DNA nanotube

May lead to breakthroughs in the research of controllable information-processing systems that mimic living organisms

The research group of Researcher IBUSUKI Ryota and Senior Researcher FURUTA Ken'ya at the NICT Advanced ICT Research Institute has developed in collaboration with the University of Hyogo nanomachines that move along a DNA nanotube track in a programmable manner thereby achieving a new molecular transport system.

The developed nanomachines, which are based on natural biological molecular motors, read "navigation cues written as DNA base sequences" on a DNA nanotube track and move autonomously along that track according to those cues. Furthermore, by developing multiple types of nanomachines that read different types of cues and embedding those cues such as "go right" or "go left" in the track, this research group achieved a molecular transport system that sorts "cargo (molecules)" on a nanometer scale according to the embedded program.

Here, the creation of nanomachines that move autonomously along a DNA nanotube, which are much easier to control than a natural cytoskeletal track, may lead to breakthroughs in the research of information-processing systems that mimic living organisms.

This achievement was published in the March 11, 2022 issue of *Science*, a comprehensive scientific journal in the United States.

Nanomachines that can move freely and control molecules on a nanometer scale are being researched around the world since they have the potential of being applied to many fields. Since the 2000s, progress had been made in DNA nanotechnology that uses DNA not as genetic information but as extremely small building materials to design and fabricate desired structures. However, it had not been possible to create nanomachines that could move fast and autonomously on such structures. This is because such a tiny machine is usually exposed to intense noise due to the thermal agitation of surrounding molecules. To therefore control nanomachines with existing technology, it had been necessary to input energy that

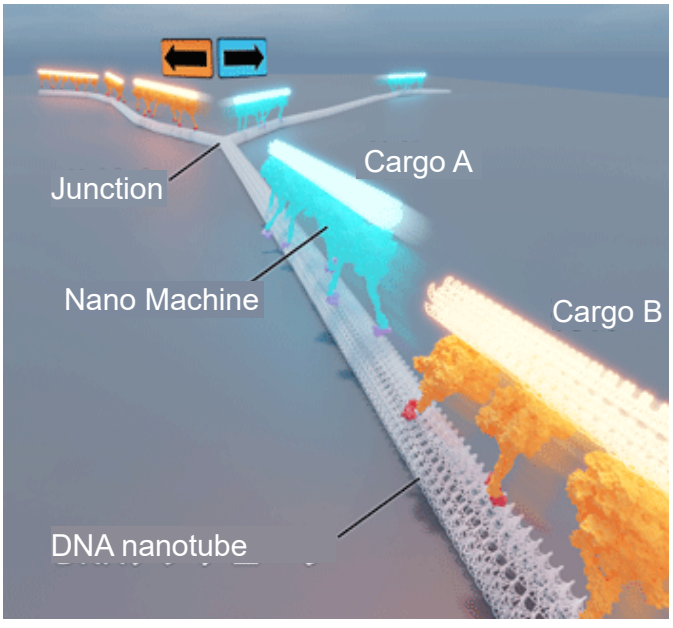


Fig.1 : New molecular transport system

could overwhelm the thermal noise while giving step-by-step cues that are provided by operators. As a result, attention came to be focused on biologically derived nanomachines, that is, on "biomolecular motors" that can move on their own in one direction if given energy only 20 times that of thermal noise.

The research group developed nanomachines that bind to DNA and move autonomously by combining DNA binding proteins with the biomolecular motor dynein (Fig. 1). It also established control technology whereby a nanomachine reads "navigation cues written as DNA base sequences" on a track laid out on a glass substrate and moves autonomously according to a program written with a combination of those navigation cues (dictating movement direction, speed, etc.). This technology enabled the construction of a new molecular transport system that can automatically sort multiple types of nanometer-size "cargo" and conversely integrate different items of "cargo" at one location all on a Y-shaped DNA nanotube functioning like an expressway junction.

Reference

Ryota Ibusuki, Tatsuya Morishita, Akane Furuta, Shintaro Nakayama, Maki Yoshio, Hiroaki Kojima, Kazuhiro Oiwa, and Ken'ya Furuta, "Programmable molecular transport achieved by engineering protein motors to move on DNA nanotubes," Science, vol.375, no.6585, pp.1159-1164, March 2022
URL: https://doi.org/10.1126/science.abj5170
DOI: 10.1126/science.abj5170

Innovative Network Area

World's first demonstration of autonomous platooning flight and autonomous anti-collision by direct communication between drones

For more efficient and safer flight operation in an era with many drones flying about

NICT Wireless Systems Laboratory has developed a system that enables direct communication between drones to share each other's position information without ground-based flight operators or networks. Using this system, we have also succeeded in holding the world's first demonstrations of platooning flight technology that enables three drones to follow a leader drone at a fixed distance and fly in formation as well as an anti-collision system that enables four drones flying in the same airspace to avoid colliding with each other in an autonomous manner.

The move toward the use of drones in a variety of fields such as agriculture, surveying, security, distribution, disaster surveys, and inspections is gaining momentum and an era in which many drones will be flying about in the sky above us will soon be here. In Japan, regulations are being eased, and the possibility exists in this fiscal year of beyond visual line of sight flights over manned zones, which is called "Level 4" in the "Roadmap for the Aerial Industrial Revolution" compiled yearly by the "Public-Private Council for Unmanned Aerial System (UAS) Promotion and Regulation."

In our research and development, we

have developed an "inter-aircraft communication system" that enables drones to broadcast and share each other's position information obtained from a global navigation satellite system (GNSS) using radio waves of the 920 MHz band for specified low power radio stations (20 mW output with use in the sky allowed and no radio-station license required). With this system, drones can interoperate with each other by connecting to a flight controller mounted on each drone.

This system incorporates flight control algorithms for "autonomous platooning flight in which drones automatically follow a leader drone (including takeoff and landing)" and "autonomous collision avoidance." With these algorithms, we performed the world's first demonstrations of autonomous platoon flight and autonomous anti-collision with four drones (Figs. 1 and 2). The lines shown in the figures show the flight trajectories of these drones. In Fig. 1, it can be seen how three drones can follow the leader drone while maintaining formation. In addition, Fig. 2 (left) shows how four drones moving toward each other from the north, south, east, and west are able to avoid colliding with each other at a center point by changing their routes diagonally to the right, while Fig. 2 (right) shows how each drone is then able to return to its planned path.

This system is not limited to use between drones—it can also be used between drones and manned helicopters. We have shown that a drone can autonomously avoid approaching a helicopter by maintaining a distance of several km from it.

These technologies are expected to make the use of drones efficient and safe in airspaces that are supposed to become increasingly congested in the near future and to accelerate the industrial revolution in the sky.

Based on the results described above, we plan to study communication-control and flight-control systems for scenarios with many more drones flying in the same airspace. We will also work to enhance platooning flight technology and communication technology to achieve platoon-like formations according to the flight environment with the aim of putting our system to practical use.

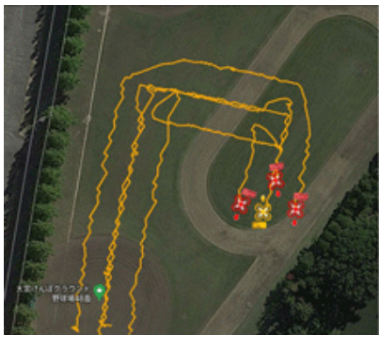


Fig.1 : Flight trajectories of autonomous platooning demonstration by four drones

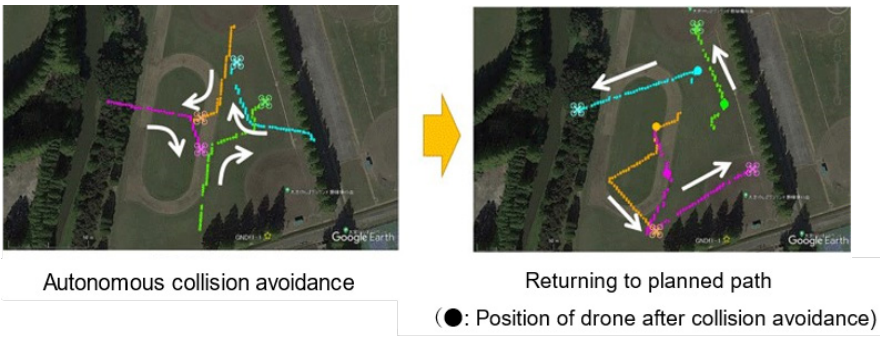


Fig.2 : Flight trajectories of autonomous anti-collision demonstration by four drones

Universal Communication Area

Development of a high-precision AI-based translation engine specialized for the financial sector

Collaboration between NICT and JFSA

NICT and the Financial Services Agency of Japan (JFSA) worked together to develop a new AI-based translation engine that can translate financial documents between Japanese and English in both directions with high accuracy.

The JFSA has collected, and provided to the NICT, translation documents owned by the JFSA and financial industry groups.

The NICT has refined them into data suitable for deep learning to develop the AI-based engine.The new engine will enable users to translate financial documents with high accuracy.According to our research, the ratio of highest quality translations that have reached the level of professional translators specialized for the financial sector has improved from about 20 % to about 50 %.

The NICT has started technology transfer of this engine to private companies since March 1, 2022.It is expected that this engine will contribute to strengthening Japan's roles as an international financial center.

The NICT has been demonstrating the effectiveness of its Translation Bank, which collects bilingual documents that form the basis of AI translation, in order to improve translation accuracy in multiple fields of industry.

As part of the "International Financial Center Initiatives," the JFSA has also decided to strengthen its capability for communicating in English and further enhance the sophistication of its financial sector policy.

The NICT and the JFSA worked together to collect a large quantity of bi-

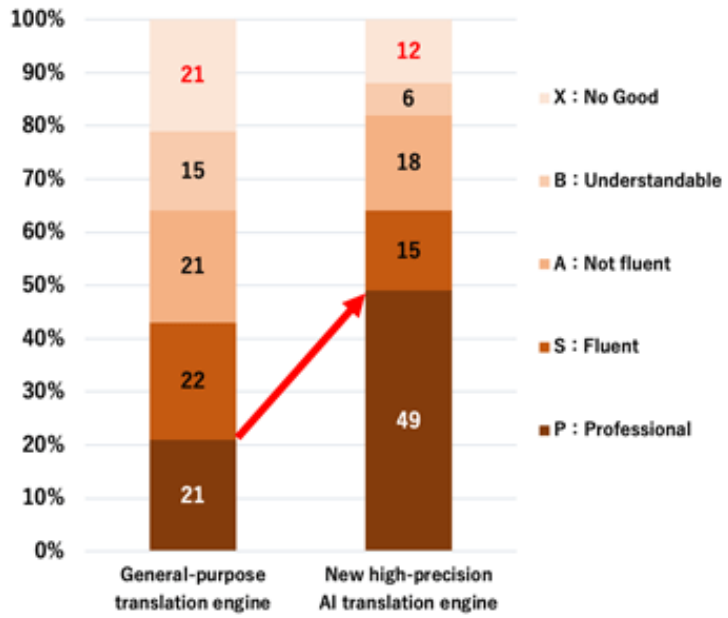


Fig.1 : Comparison between general-purpose and financial specific translation engines

lingual documents in the financial sector through public-private cooperation.

This has improved the accuracy of AI translation between Japanese and English by making better use of the data collected.

Specifically, under the leadership of the JFSA, various sets of Japanese and English documents were collected from financial industry groups.

The NICT has refined these documents into data suitable for deep learning to develop a new high-precision AI-based translation engine.

When we compared the quality of the translation of the same text between the new AI engine and a general purpose one, we found that the ratio of the highest quality translations reaching the level of professional translators specialized for the financial sector has risen to about 50 %; the ratio of the NG (No Good) level was also reduced by half, thus achieving overwhelmingly higher precision (See Fig.1).

The NICT will also continue to collaborate with the JFSA on the collection of finance-related translation documents for implementing an eco-system to improve the quality of translation, including responses to continuously emerging new words and concepts in the financial sector.

Innovative Networks Area

World's first successful transmission of 1 petabit per second in a standard cladding diameter multi-core fiber

Wide-band wavelength division multiplexing technology significantly expands transmission capacity allowing Pb/s transmission in only 4 spatial channels

Researchers from NICT report the world's first demonstration of more than 1 petabit per second in a multi-core fiber (MCF) with a standard diameter of 0.125 mm. The researchers, led by Benjamin J. Puttnam, constructed a transmission system that supports a record optical bandwidth exceeding 20 THz by exploiting wavelength division multiplexing (WDM) technology. It incorporates the commercially adopted optical fiber transmission windows known as C and L-bands and extends the transmission bandwidth to include also the recently explored S-band. Two kinds of doped fiber amplifiers along with Raman amplification with pumps added in a novel multi-core pump combiner, enabled transmission of 801 wavelength channels over the 20 THz optical bandwidth. The large number of wavelength channels were transmitted in each core of a 4-core MCF that is notable for having the same cladding diameter as a standard optical fiber.

The results of this experiment were accepted as a postdeadline paper presentation at the International Conference on Laser and Electro-Optics (CLEO) 2022 and presented on Thursday, May 19, 2022 at 7 PM local time.

Demand for enhanced data transmission capacity has inspired both investigation of new spectral transmission windows and advanced optical fibers exploiting parallelization in the spatial domain. In recent years, advanced fibers with the same cladding diameter as standard single-mode optical fibers, but able to support multiple propagation paths have been proposed. These fibers can multiply the transmission capacity

but are still compatible with existing manufacturing processes and have emerged as a likely candidate for near-term commercial adoption of these transformative communications technology.

NICT constructed the transmission system using 4-core MCF with standard 0.125 mm cladding diameter, WDM technology and mixed optical amplification systems. The system allowed transmission of 1.02 petabit per second over 51.7 km. Previously, 610 terabit per second was achieved in a similar fiber but only using part of the S-band. In this experiment, by broadening the Raman amplification bandwidth to the full S-band and using customized thulium-doped fiber amplifiers (TDFAs) for S-band and extended L-band erbium-doped fiber amplifiers (EDFAs), we were able to use a record 20 THz optical spectrum with total of 801 x 25 GHz spaced wavelength channels, each with dual-polarization-256 QAM modulation for high spectral density in all wavelength bands.

NICT will continue to promote research and development of advanced optical fibers for both near and long-term applications, seeking continuous improvement in optical communication systems for the benefit of society. We will further develop wide-band transmission systems and explore technologies for additional increases of transmission capacity of low-core-count multi-core fibers and other novel fibers. NICT will also aim to extend the transmission range of ultra-high-capacity systems.

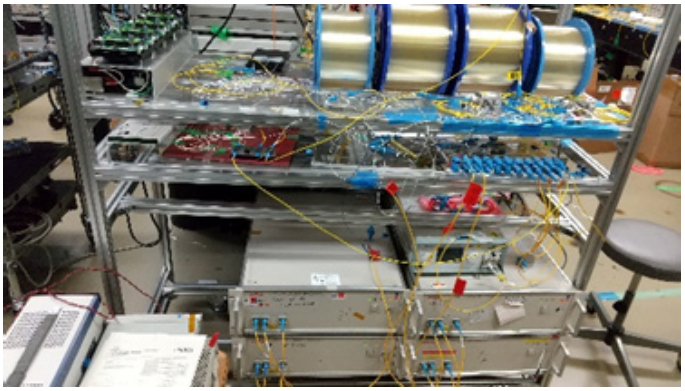


Fig.1 : Transmission system of this work

Reference

Benjamin J. Puttnam, Ruben S. Luís, Georg Rademacher, Yoshinari Awaji, and Hideaki Furukawa
"1 Pb/s Transmission in a 125μm diameter 4-core MCF,"
41st International Conference on Laser and Electro-Optics (CLEO) 2022, postdeadline session

Advanced Electromagnetic Technology Area

The world's first use of an optical lattice clock to keep national standard time

An accurate clock keeps an autonomous Japan Standard Time in sync with UTC

NICT is the first in the world to generate standard time referenced to an optical clock. By adjusting the time interval (the effective duration of the second) to match that generated by an intermittently operated optical lattice clock, the difference between the time generated at NICT and Coordinated Universal Time

(UTC) is reduced to less than five billionth of a second. This is less than a quarter of the previous difference, which could reach up to 20 billionth of a second.

Combining the optical lattice clock with the sophisticated time generation technology already applied to generate standard time based on synthesis of multiple conventional clocks, accurate time can be kept autonomously over long periods even without access to UTC, GPS time, or other national time systems.

This achievement will shape the discussion on a redefinition of the second in the International System of Units, envisioned for the year 2030.

The optical lattice clock developed by NICT produces light stabilized to an optical transition of the strontium atom. Over the past ten years, institutes around the world, including NICT itself, have measured the intrinsic frequency of this transition to be 429 228 004 229 872.99 Hz with a relative uncertainty of 1.9×10^{-16}. An optical frequency comb makes it possible to transfer this extremely small frequency uncertainty to an electronic signal without degradation. Deviations in the time interval of Japan Standard Time can then be measured with 16-digit accuracy by using this signal as a reference.

NICT has evaluated the interval of Japan Standard Time in this way since June 2021. Frequency adjustment of the generated standard time began in August 2021 and has been continuously performed once or twice per week to reduce the variation of Japan Standard Time relative to UTC (see Fig.1).

NICT is working to develop and promote new ways to utilize the highly accurate time and frequency available through Japan Standard Time for next-generation communications technologies (Beyond 5G / 6G) and for geodetic technologies based on Einstein's theory of relativity.

NICT is already engaged in further improvements to resilience in the face of natural disasters by decentralized time generation. In addition to the atomic clocks at NICT's headquarters in Koganei, Tokyo, clocks at its Kobe substation will soon also contribute to a Japan Standard Time that is both robust and accurate.

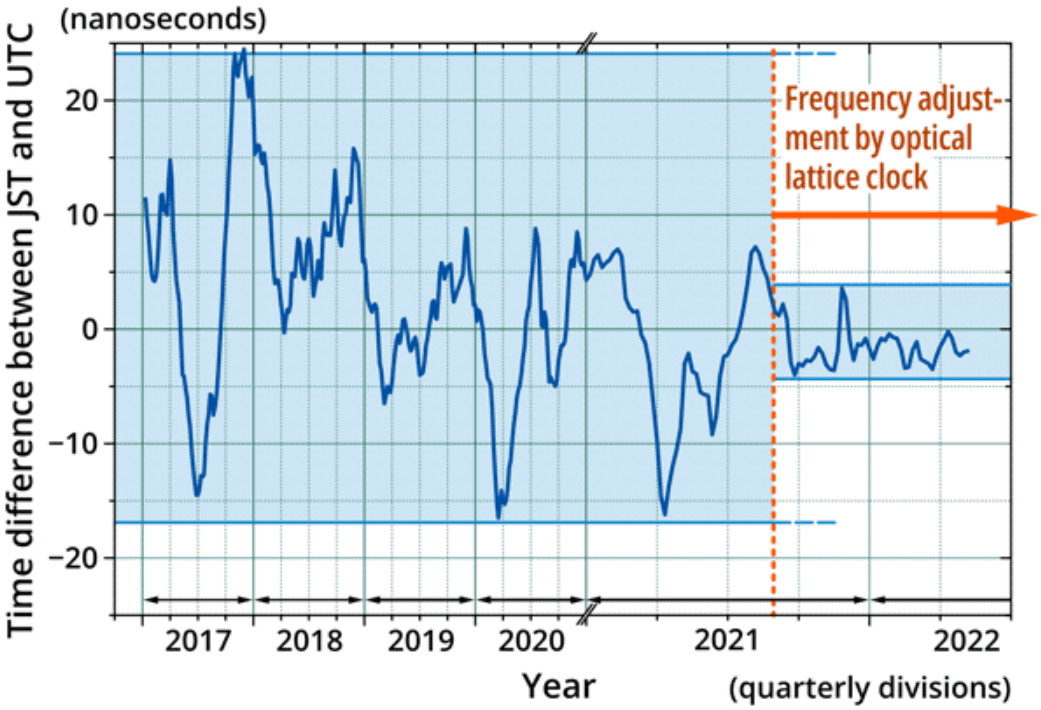


Fig.1 : The difference between Japan Standard Time (JST) and Coordinated Universal Time (UTC) has been reduced from typically ±20 ns to less than ±5 ns by the inclusion of the optical lattice clock since August 2021.

Frontier Science Area

Demonstration of a highly efficient modulator using the organic electro-optic polymer for visible light

NICT has successfully developed a highly efficient optical modulator using the organic electro-optic polymer (hereinafter referred to as EO polymer) for visible light. Conventional EO polymer optical modulators could operate in near-infrared light (wavelength 1,550 nm, etc.), but they couldn't be used for visible light (wavelength 380 nm to 780 nm) because of the large absorption loss at visible light. NICT has developed an EO polymer which has small absorption loss in visible light and a large electro-optic coefficient required for the optical modulator. The demonstrated optical modulator for visible light is smaller and more efficient than the conventional EO polymer optical modulator for near-infrared light.

The growth of global internet traffic has led to the demand for optical networks with high performing technology. NICT is developing the high speeds and low driving voltages optical modulator using EO polymer more than conventional lithium niobate (LN) optical modulator. Compared to LN optical modulators, EO polymer optical modulators have the problem that they can only be used with near-infrared light for optical communications. The EO polymer optical modulator can be applied to scan the light beam at high speed. To use it for display devices such as stereoscopic displays, it must be available in visible light.

In this research, we successfully developed an EO polymer which has low absorption and high electro-optic coefficient in visible light. This result was achieved by NICT's accurate measurement technology and molecular design based on the vast molecular structure library accumulated over many years. By designing the EO molecule structure to be short and rigid to suppress the absorption loss at visible light, this EO polymer has less than 1/20,000 absorption loss than conventional EO polymer and is available for visible light.

NICT designed and fabricated a Mach-Zehnder interferometer structure using microfabrication process. The waveguide size for operating at visible light is necessary to be small than conventional optical modulator for near-infrared light. We have adopted a ridge type waveguide (see Fig.1) which guarantees a single mode even if the width of the waveguide is relatively large. As a result, although high accuracy processing is required, the fabrication tolerance relaxed.

"I will continue to promote research and development of the optical phased array for next-generation display" said KAMADA Shun , researcher of Nanoscale Functional Assembly ICT Laboratory, Advanced ICT Research Institute. We will also aim to develop EO polymers for green and blue other than red, and expand their, applications to full color stereoscopic displays.

This EO polymer optical modulator for visible light is expected to be applied to next generation display devices such as stereoscopic displays and smart glasses.

This achievement was published in the scientific journal "Optics Express" on May 19, 2022.

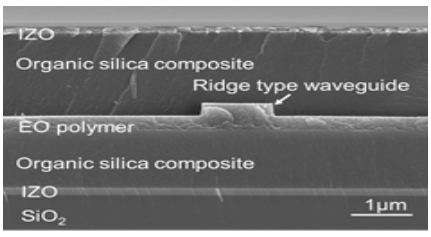


Fig.1 : Cross section of EO polymer optical modulator for visible light. IZO (Indium Zinc Oxide) electrode are placed at the top and bottom of waveguide.

Reference

Shun Kamada, Rieko Ueda, Chiyumi Yamada, Kouichi Tanaka, Toshiki Yamada, and Akira Otomo, "Superiorly low half-wave voltage electro-optic polymer modulator for visible photonics," Optics Express, vol.30, Issue 11, pp.19771-19780, 2022
https://doi.org/10.1364/OE.456271
DOI: 10.1364/OE.456271

Researchers

Person 1

MIKI Shigehito
Senior Researcher, Superconductive ICT Device Laboratory, Kobe Frontier Research Center, Advanced ICT Research Institute

MIKI Shigehito was born in Tokushima prefecture, Japan in 1975.

After earning a doctoral degree and working as a Post-Doctoral Fellow with JST-CREST, he joined NICT in 2005. He has been engaged in the research and development of superconducting nanostrip single photon detectors and their applications. Ph.D. (Engineering).

Realizing ultimate photon detectors using superconducting nanostrips for quantum technology applications

A single photon is the smallest unit of light—single photon detectors can observe such a minimum unit. In recent years, quantum technologies such as quantum information and quantum computing have been positioned as a primary strategic research topic not only in Japan but also worldwide. In these technologies, single photons are the most important alternative to the qubit, and hence photon detection is an indispensable technology. Superconducting nanostrip single photon detectors (SNSPDs) surpass other single photon detectors such as semiconductor detectors because of their excellent performance. We have paid significant effort to developing a practical SNSPD system and improving its performance. As a result of this effort, our SNSPDs have reached a system detection efficiency above 80%, dark count rate below tens of c/s, and timing jitter below tens of ps. Our SNSPD system has been applied to various quantum technologies. Very recently, SNSPDs were used in the development of a critically important method to freely control the pulse waveform of quantum light toward the realization of a large-scale quantum optical computer [1]. Furthermore, Hamamatsu Photonics, the world's leading company in photon detectors, successfully developed a multi-channel SNSPD system using NICT's SNSPD technology, which paved the way for the domestic production of an SNSPD system.

[1] K. Takase, A. Kawasaki, B. Kyu Jeong, T. Kashiwazaki, T. Kazama, K. Enbutsu, K. Watanabe, T. Umeki, S. Miki, H. Terai, M. Yabuno, F. China, W. Asavanant, M. Endo, J. Yoshikawa, and A. Furusawa, "Quantum arbitrary waveform generator," Science Advances vol.8, Issue 43, eadd40199, Oct. 2022.

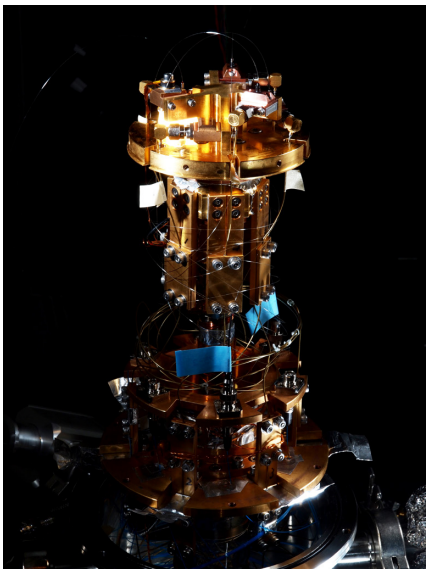


Fig.1 : Inside a cryogenic refrigerator for multichannel superconducting nanostrip single photon detector system

Q&A

What is the most interesting point in your research?

I have been studying superconducting nanostrip single photon detectors (SNSPDs). What has been most interesting for me is that I was fortunate enough to be involved in the research and development of SNSPDs from the very beginning at NICT and to see their eventual use in various applications.

What is the goal of this research theme?

To realize ideal photon detectors with ultimate performance (100% detection efficiency, extremely low dark count rate, low timing jitter, and ultra-high speed)

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

SNPDs we developed have emerged as promising detectors due to their excellent performance. Actually, our detectors have been in used various advanced applications such as quantum information technologies, and we have paved the way for their social implementation through a technology transfer to a private company.

Researchers

Person 2

Juan Liu
Senior Researcher, Advanced Reality Technology Laboratory, Universal Communication Research Institute, (Additional post) Brain Function Analysis and Imaging Laboratory, Center for Information and Neural Networks, Advanced ICT Research Institute

Juan Liu joined NICT in 2006 after receiving her Ph.D. in China and working as a researcher at ATR Labs. Her main areas of interest are the intersection of multisensory perception mechanisms, human-machine interfaces, and artificial intelligence. Ph.D. (Engineering).

Merging virtual and physical realities in telepresence via artificial intelligence and human factors

Current telecommunication technologies such as video conferencing applications have been keeping us connected and making telework/tele-education possible during the COVID-19 pandemic. However, this situation also highlighted the necessity and importance of face-to-face communication for establishing intimate relationships. On the other hand, immersive virtual reality (VR) provides users new experiences beyond those of daily life. Our vision of a future telecommunication system is an adequate and affordable telepresence solution that fills the gaps between video calls and face-to-face meetings by merging virtual and physical realities. Such a system should provide sufficient information for communication and support intuitive, multisensory interactions among people, robots and environments (virtual or physical) with low-cost input/output devices. To meet this goal, we combine the study of brain functions and human factors with the study of artificial intelligence and user interfaces to match technology with the needs and capabilities of people and compensate for information not available from input devices.

We began by digitalizing humans into realistic and expressive 3D avatars (REXR) [1] with high quality facial expressions from a single ordinary RGB camera (Fig. 1). In this process, we leveraged recent machine-learning techniques for 3D body reconstruction from 2D images and real-time markerless body-pose and facial-expression tracking [2]. Such high-fidelity 3D avatars can then be relocated, manipulated, and modified to accommodate different types of viewing devices and different virtual environments. This method is expected to enhance the feeling of togetherness and mutual understanding among remote people in a shared virtual environment (Fig. 2) similar to face-to-face communication in real space.

Fig.1 : Online processing flow of REXR technology

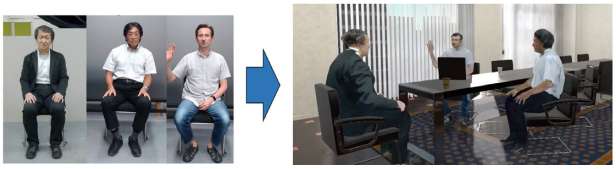


Fig.2 : Application image of REXR technology

[1] NICT press release (in Japanese), https://www.nict.go.jp/press/2022/03/14-1.html
[2] M. Joachimczak, J. Liu and H. Ando, "Creating 3D Personal Avatars with High Quality Facial Expressions for Telecommunication and Telepresence," *2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 2022, pp. 856-857, doi: 10.1109/VRW55335.2022.00279.

Q&A

What is the most interesting point in your research?

This research theme is interdisciplinary giving me the opportunity to exchange ideas and work with talented neuroscientists, technicians, and engineers. We incorporate scientific hypotheses, methods, and knowledge into system design and algorithm development to enhance our understanding of both human cognition and artificial systems toward a common goal—telepresence.

What is the goal of this research theme?

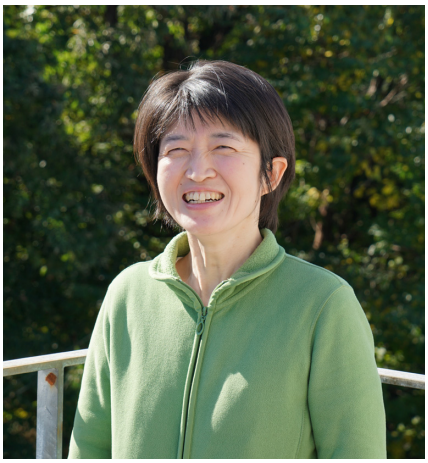
I am pursuing telepresence technologies to share experiences and seamlessly interact with remote people, robots and environments. The relationship between virtual and physical reality is not only a technical issue—it also raises scientific and ethical questions. Breakthroughs in this field may break barriers and create more opportunities for everyone.

What are you aiming at as a researcher?

For me, doing research may fulfill my scientific curiosity, but what is more important is to help solve problems and inspire people. When people are impressed by our demonstrations or excited about the potential of our technology, their smiles are very gratifying and confirm the value of my work.

Researchers

Person 3



NISHIOKA Michi
Senior Researcher, Spacer Environment Laboratory, Radio Propagation Research Center, Radio Research Institute

She joined NICT in 2011 after completing her Ph.D. studies and working as a post-doctoral researcher. She has been involved in research of ionospheric disturbances, operation of routine ionospheric observation, and development of ionospheric monitoring systems. Ph.D. (Science).

Monitoring and understanding plasma density disturbances in the ionosphere

Earth's atmosphere above 60 km is partially ionized due to the absorption of solar ultraviolet rays and X-rays and the impact of energized particles. This ionized atmosphere is called the ionosphere, which ranges in altitude from 60 km to 1,000 km. In the ionosphere, the International Space Station and satellites move about and the aurora borealis glows. It has long been known that plasma-density disturbances in the ionosphere are mainly caused by upper sources such as solar or geomagnetic activity. On the other hand, it has only recently become known that plasma density in the ionosphere can also be disturbed by the lower atmosphere.

To monitor and research plasma density disturbances in the ionosphere, we create high-resolution and two-dimensional maps of ionospheric total electron content (TEC) using ground-based Global Navigation Satellite System (GNSS) receiver networks. With such TEC maps, we have been discovering ionospheric disturbances, such as those occurring after the 2011 Tohoku earthquake [1] and the 2013 Moore EF-5 tornado [2]. More recently, we succeeded in capturing the concentric spread of TEC disturbances around the world after the Hunga Tonga-Huanga Ha'apai volcanic eruption in January 2022. It was found that the concentric TEC disturbance over the southern hemisphere traveled through the Earth's magnetic field to the northern hemisphere and Japan [3].

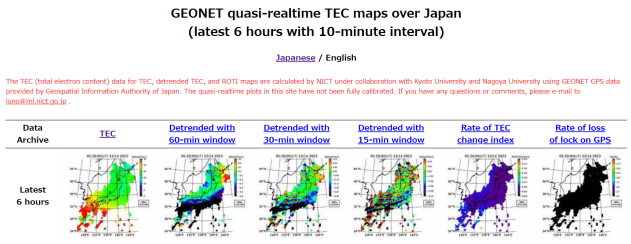


Fig. : Our web site that monitors the ionosphere using GNSS-TEC maps
https://aer-nc-web.nict.go.jp/GPS/QR_GEONET/index_e.html

[1] T. Tsugawa et al., "Ionospheric disturbances detected by GPS total electron content observation after the 2011 off the Pacific coast of Tohoku Earthquake," Earth Planets and Space, Vol.63, pp. 875-879, 2011
[2] M. Nishioka et al., "Concentric waves and short-period oscillations observed in the ionosphere after the 2013 Moore EF5 tornado," Geophys. Res. Lett., Vol.40, pp.5581-5586, 2013.
[3] NICT press release (Japanese) *https://www.nict.go.jp/press/2022/07/14-1.html, or A.* Shinbori et al, "Electromagnetic conjugacy of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption as seen in GNSS-TEC and SuperDARN Hokkaido pair of radars observations", Earth, Planets and Space, Vol.74, No.106, 2022

Q&A

What is the most interesting point in your research?

Using two-dimensional GNSS-TEC maps, we can distinguish between ionospheric disturbances originating from the lower atmosphere and those from upper sources. One of the interesting aspects of this study is that we can discuss how the ionosphere becomes disturbed using the novel data set of GNSS-TEC maps.

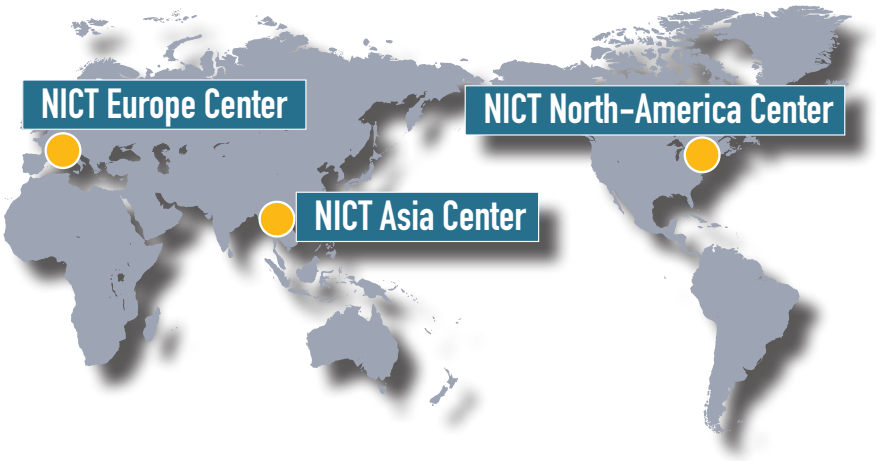
What is the goal of this research theme?

We aim to separate the effects of ionospheric disturbances from below and from above, and to clarify the mechanisms of each. In the future, we aim to use machine-learning and data-assimilation techniques to predict ionospheric disturbances, which will be useful in practical applications as well as in scientific research.

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

Ionospheric disturbances, whatever their cause, affect radio propagation in space. They therefore have a negative impact on positioning and communication. Since the importance of infrastructures using radio waves is increasing these days, the monitoring and predicting of ionospheric disturbances is becoming increasingly important.

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

NICT Asia Center strives to build relationships with research institutes, universities, and other organizations, centered in the Southeast Asia region. The center also supports NICT R&D activities in this region and disseminates information on NICT activities.

This year marks 20 years since the establishment of CRL Asia Research Center in Bangkok, Thailand in 2002 as the predecessor of NICT Asia Center. During this time, we have been supporting NICT R&D activities while adapting to changes in the ICT R&D environment surrounding the Southeast Asia region. However, the COVID-19 pandemic has greatly impacted our activities, which had to be limited to an online platform in the first half of 2022.

As an example of our activities in 2022, I would like to introduce a joint research project among Japan, Malaysia, Brunei, and Indonesia that the Asia Center participated in and promoted. Forests in the Southeast Asia region feature a widespread distribution of soil, namely peat, that burns easily when dry due to its large content of carbon. When weather conditions cause this peat to dry up, large-scale forest fires may erupt, and there have been incidents in which the resulting haze, not only has a great impact on the local ecosystem but also on the lives and health of the region's inhabitants. As an initiative for determining such peat conditions by using IoT sensors, Networked ASEAN Peatland Communities for Transboundary Haze Alert (Net-Peat) was launched in January 2022 as a joint research project with the support of the Asia-Pacific Telecommunity (APT). This joint project was proposed by Malaysia along with Japan, Brunei, and Indonesia. Immediately after the launch of this project, an online workshop was held in February 2022, but in July and November, in-person workshops were held in Indonesia and Malaysia, and IoT sensors installed in peatlands were inspected on site. In other words, activities like those prior to the pandemic began to return.

Next, I would like to introduce an exhibit at Thailand National Science and Technology Fair (NST Fair) held by Thai government for the purpose of raising interest in science and technology. In 2022, while the overall space for exhibits was less than usual, the fair was held in August—the original period of the fair—for the first time in several years. The Asia Center managed exhibits on NICT R&D activities as well as joint research activities with Thai universities and other organizations. After the fair's opening ceremony, high officials of the Thai government made a visit to the venue. Last year, we had the opportunity of describing NICT's exhibit to Prime Minister Prayut Chan-o-cha, and following this year's opening ceremony, we also had the opportunity of describing NICT's exhibit to Mr. Don Pramudwinai, Deputy Prime Minister and Minister of Foreign Affairs during his visit to the venue. At this time, we also demonstrated translation from Japanese to Thai using VoiceTra, the multilingual speech translation application developed by NICT. Additionally, through the cooperation of university students from our Thai counterparts in joint research projects, many visitors including the younger generation were able to receive explanations in Thai, which helped to deepen their understanding of NICT activities.

In Thailand, there has been no need to present certificates of vaccination when entering the country since October 2022 and restrictions on the move of people have been eased. At the Asia Center, we will continue to support R&D activities centered in the Southeast Asia region including not only online meetings but also activities at research sites and in-person workshops.

Fig.2(a) :Group photo in NST Fair

Fig.2(b) : Explanation to Deputy Prime Minister in NST Fair

Fig.1(a) : APT workshop in Malaysia

Fig.1(b) : On-site inspection in Malaysia

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E-mail: int_asia@ml.nict.go.jp

Graduation Ceremony at Chulalongkorn University

A graduation ceremony at Chulalongkorn University where the Asia Center is located was held on November 10 and 11, 2022. Since restrictions with respect to COVID-19 are being eased in Thailand, this year's ceremony turned out to be a grand event just like those before the pandemic.

Fig.3 : The graduation ceremony
(in front of Maha Chulalongkorn Building)

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. At present, its office is located near the center of Washington, D.C. within walking distance of the White House and federal government agencies. It is also quite close to the offices of other National Research and Development Agencies of Japan. For example, it is only a few minutes away on foot from the Washington, D.C. offices of the Japan Science and Technology Agency (JST) and Japan Agency for Medical Research and Development (AMED).

The work of the North-America Center is centered about the following three activities:

(1) Promotion of joint research with U.S. research institutes
(2) Information collection, analysis, and reporting of various U.S. government polices including budgets and regulations related to R&D in the field of telecommunications and of R&D trends at research institutes, universities, and private companies
(3) Publicizing and promoting of NICT R&D results by participating in exhibitions and meetings

In terms of specific fields, we have been putting much effort into Beyond 5G/6G and quantum science and technology. The outcome document of the Japan-U.S. Summit Meeting held on April 16, 2021 made specific mention of these fields and a Japan-U.S. Joint Leaders' Statement issued on May 23, 2022 announced the acceleration of their R&D. With the aim of strengthening Japan-U.S. cooperation in research, we have been making progress in exchanging opinions with agencies and organizations associated with the U.S. government and in participating in related meetings in the United States (Fig. 1).

Startup companies are players having a great impact not only in the field of information-communications but also on society and the economy overall in the United States. We have therefore been conducting surveys on venture capital and startup companies in Silicon Valley on an ongoing basis and have been collecting and analyzing trends in startups that use a variety of advanced technologies including Beyond 5G/6G and quantum science and technology.

The digitalization of industry and lifestyles, which had been advancing rapidly in the United States due to the COVID-19 pandemic, continues unabated as things are not expected to return to the way they were even after the pandemic ends. Moreover, the international situation, which is becoming increasingly complicated, is having a great impact on a variety of policies and R&D projects in the United States. Against this background, the North-America Center aims to obtain an accurate understanding of conditions in the United States and serve as a bridge within the Japan-U.S. research scene making use of the knowledge so obtained. In this way, we hope to contribute to R&D activities in the field of information-communications at NICT, and by extension, in Japan.

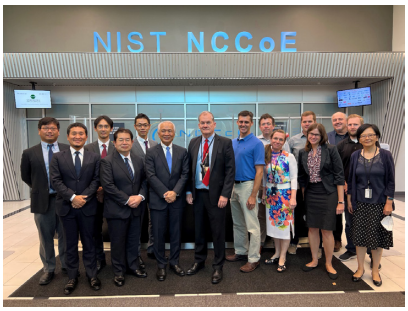

Fig.1 : NICT President, Dr. Tokuda (center left) and Director, Information Technology Laboratory, NIST, Dr. Charles H Romine (center right)

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Beautiful Nature in Shenandoah National Park

Washington, D.C. is, of course, an urban center, but fascinating national parks are within driving distance such as those located in the neighboring state of Virginia. Among these, Shenandoah National Park, which is a two-and-a-half-hour drive from the North-America Center, is a popular destination because of the beauty of its fall colors. It is said to evoke the images made famous by the popular country song "Take Me Home, Country Roads." I'm sure that anyone living in this area will make at least one visit here. Also of interest not far from Shenandoah National Park is Luray Caverns, which is said to be the largest series of limestone caves in the Eastern United States. They are also quite stunning and beautiful (Fig. 2).

Fig.2(a) : View from Shenandoah National Park

Fig.2(b) : Inside Luray Caverns

NICT Overseas Centers

Europe Center

Director of Europe Center
ISHITANI Yasuki

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

The Avenue des Champs-Élysées is known as the most beautiful street in the world. The NICT Europe Center is located in a business district just next to the Avenue des Champs-Élysées. It is close to the airport and major train stations in Paris, which makes it a convenient location for travel within France and the European region.

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

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

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

The NICT Europe Center continues to proactively build mutually beneficial relationships between NICT and European research institutes and related organizations by using the knowledge and networks that we have built up here in Europe.

Fig.1 : Mobile World Congress Barcelona 2022

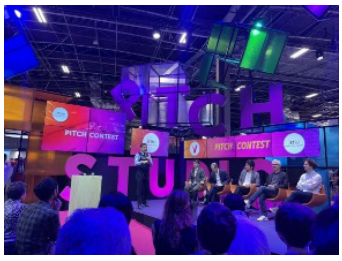

Fig.2 : VIVA Technology 2022, world-class startup festival in France

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A Losing Ticket

HIKITA Keita, Associate Deirector of Europe Center

I love Japan. In France, Japanese food such as sushi, Japanese culture such as hanami (cherry-blossom viewing), and Japanese anime such as Dragon Ball are popular, and people just naturally assume that you are a courteous person because you are Japanese. By living overseas, I have rediscovered the charm of Japan and become even fonder of my home country.

France is a leading country for horse racing in Europe with over 200 racetracks. A betting ticket is simply a receipt identified by a 2D barcode. You can easily purchase one from racetrack staff carrying a portable ticket terminal without having to go up to an actual ticket machine.

The Prix de l'Arc de Triomphe, the world's most prestigious horse race, was held on October 2, 2022. ParisLongchamp Racecourse, the venue for this event, is located in a highly spacious public park called Bois de Boulogne. Out of nine races held on that day, seven were ranked as Grade 1 (G1) races making this day a festival-like event in the horse racing world.

Four Japanese horses entered the race, the most up to then, and there were great expectations that one would be the first Japanese horse to become champion. Many Japanese attending the race from Japan rushed forward to get a glimpse of the majestic figures of these horses representing our country. However, after a thrilling two minutes and 35.71 seconds, the winner was a British horse. But win or lose, I love Japan!

(a)

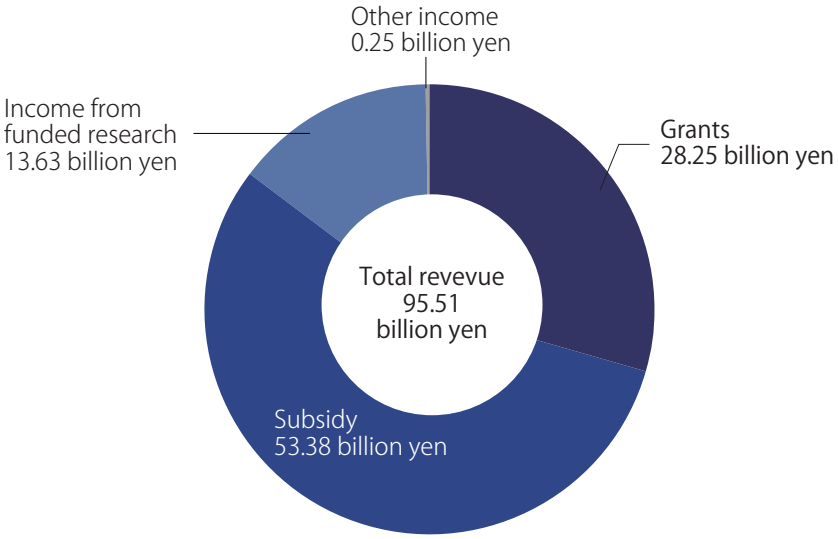
(b)

Fig.3 : (a) Betting tickets identified by a 2D barcode in France
(b) Prix de l'Arc de Triomphe horse race held at ParisLongchamp Racecourse

Budget

The original budget for FY2022

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



Total expenditure for FY2021 was bil-lion yen in a reported basis.

Yen-dollar conversion ratio: 125.98yen/dollar (Aplil 2022)

Work Force

1,295 (as of April 1, 2022)
(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

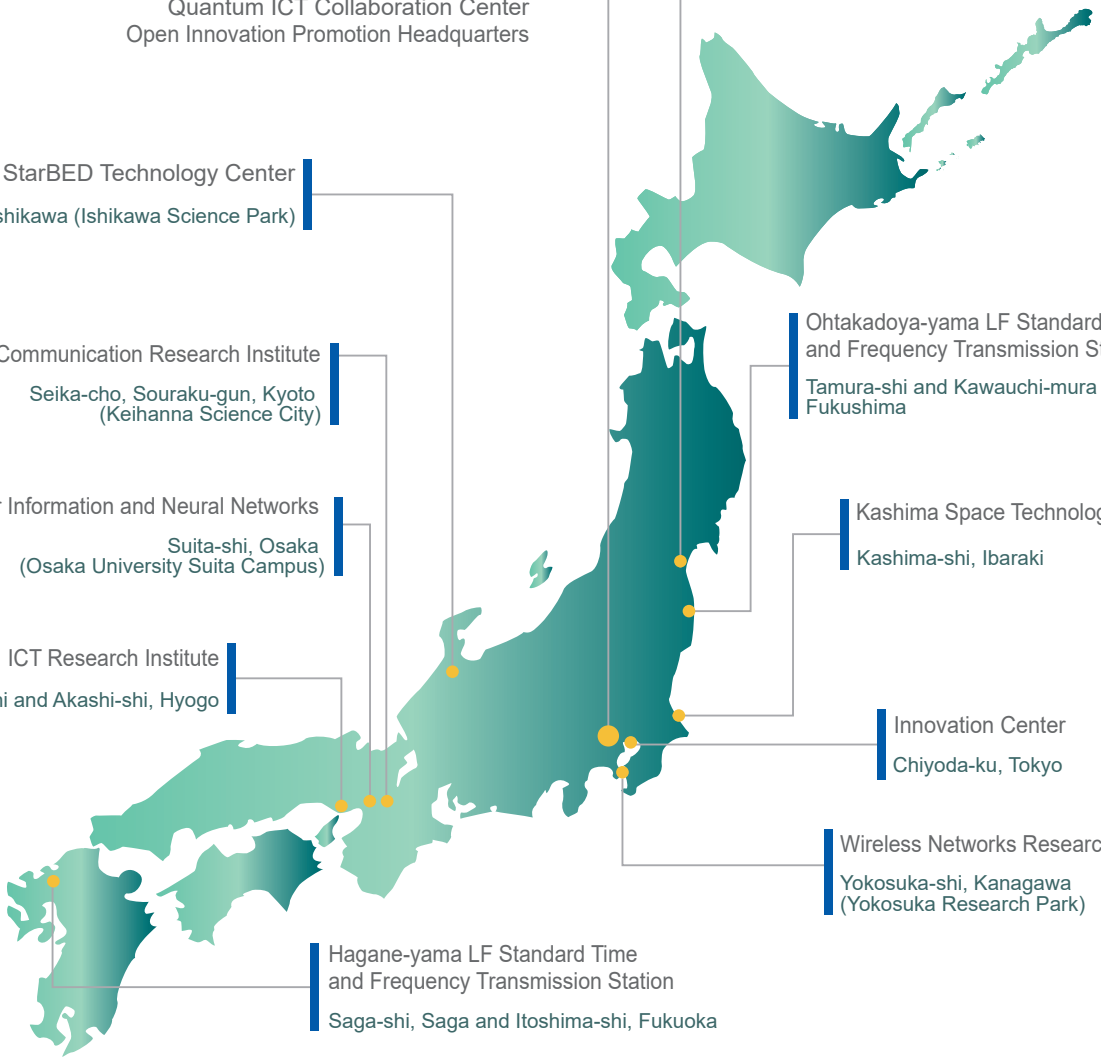
Resilient ICT Research Center
Sendai-shi, Miyagi
(Tohoku University Katahira Campus)

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

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

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

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



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

Kashima Space Technology Center
Kashima-shi, Ibaraki

Innovation Center
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

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

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