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NICT REPORT

New ICT technology strategy toward Society 5.0

National Institute of Information and Communications Technology


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

Message from the President

As we welcome the New Year of 2026, I would like to extend my sincere greetings to all of you.

I also wish to express my heartfelt appreciation for your continued understanding and support of the National Institute of Information and Communications Technology (NICT).

At the end of March this year, NICT's Fifth Medium-to-Long-Term Plan, which has spanned five years, will come to a close. During this period, we have steadily accumulated research achievements of significant scientific and societal value, which is core to NICT's mission, while also reporting numerous cases in which our research results have been successfully implemented in society.

In the networking field, notable progress includes the introduction of two-core fiber into submarine optical cables based on multicore optical fiber technology, as well as the commercial deployment of AI-based network failure detection systems. With respect to Beyond 5G (B5G), we have advanced research and development in areas where NICT has particular strengths, including Terahertz technologies, Space-time synchronization, and the integration of terrestrial and non-terrestrial networks (TN/NTN). We have also made active contributions to international standardization efforts. In March of last year, NICT participated for the first time with an independent exhibit at Mobile World Congress (MWC) 2025 in Barcelona, helping to elevate Japan's presence on the global stage. In addition, at the Osaka–Kansai Expo in May, we showcased our work at the Beyond 5G Ready Showcase. In August, we held a pre-opening of the Beyond 5G Innovation Bridge, a new hub designed to accelerate open innovation in B5G research and development.

In the AI field, NICT's simultaneous interpretation and consecutive translation systems were widely deployed at the Osaka–Kansai Expo. We also regard the development of NICT's own large language model as a critical initiative, both for building safe and high-performance domestic AI models grounded in high-quality Japanese-language training data that reflect Japan's culture and institutional context, and for establishing reliable evaluation frameworks for such models. At the GPAI Tokyo Expert Support Center, which promotes international partnerships on AI, we have been conducting case studies on agentic AI, advancing projects on multilingual and multicultural AI, and supporting student community initiatives.

In the quantum information and communications field, the Tokyo QKD Network, which has been under development for many years, has undergone operational trials involving numerous corporate partners. These trials have validated applications such as 4K video-encrypted web conferencing and interoperability testing with RIKEN's quantum computer. We have also demonstrated efforts to extend QKD networking across continents via the International Space Station (ISS), and enhanced the quantum-secure cloud platform to ensure the safe handling of data requiring ultra-long-term confidentiality.

In the cybersecurity field, the CYNEX Alliance, NICT's industry–academia–government collaboration initiative, has grown to include more than 100 member companies and is actively engaged in threat analysis, workforce development, and security product evaluation. In addition, the CREATE Center, launched last February to advance research in AI for Security and Security for AI, has initiated collaborative research with U.S. research institutions and universities.

In the advanced electromagnetic technology field, remote sensing, space environment technologies, electromagnetic environment engineering, time–space standards, and digital optical platform technologies form a foundational layer for a safe and secure Society 5.0, as well as for B5G / 6G. The Cloud Profiling Radar (CPR) aboard the EarthCARE satellite, launched in May of the year before last in collaboration with ESA and JAXA, has been delivering stable observation data that contribute to understanding how clouds influence climate change. Our space-time synchronization technology is also being applied to verify high-precision clock synchronization among servers inside Meta's data centers.

In frontier science, we are developing advanced core technologies that can lead to fundamental breakthroughs for the next generation. For deep-ultraviolet LEDs, we conducted virus inactivation trials using actual railway vehicles. In the 300 GHz terahertz transmission and reception domain, we achieved date rates of 40 Gbps using a CMOS chip. CiNET has also begun exploring the application of its brain models in various design domains. By continuing to strengthen cross-disciplinary collaboration, we expect these efforts to open up new ICT fields one after another.

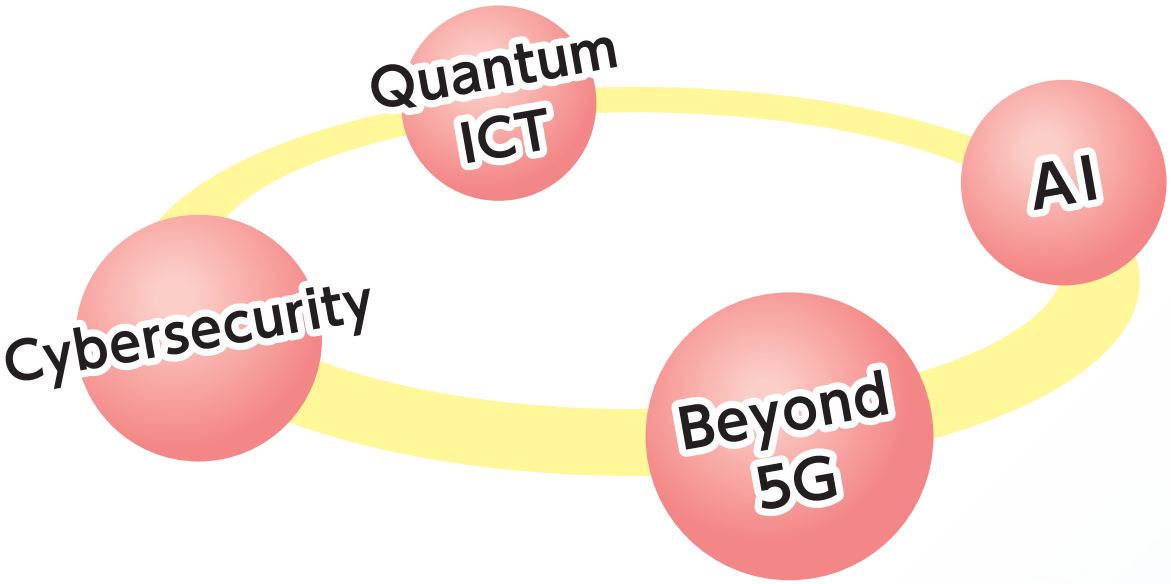
With the establishment of the Takaichi Cabinet last October, becoming a "nation built on advanced technologies" has been reaffirmed as a core national policy. Expectations for national research agencies like NICT continue to grow as part of this direction. Under the sixth Medium- to Long-Term Plan beginning in April, we will build on the progress of the past five years, further strengthen our capabilities, and pursue innovations that generate new value while expanding social implementation across a wider range of fields. We respectfully request the continued support and cooperation of universities, research institutions, industry, government bodies, and the public at large.

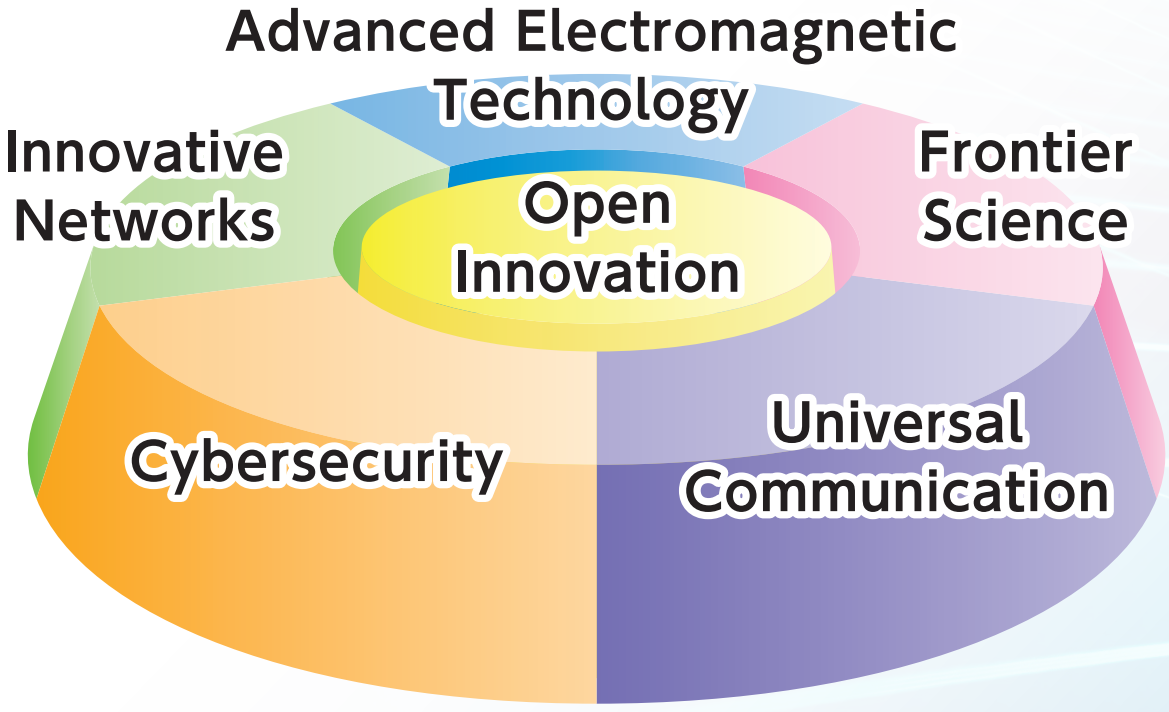
In closing, I would like to extend my sincere wishes for your continued health and success, and above all, for a more peaceful world. I offer these words as my New Year's greeting.

President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki

New ICT technology strategy toward Society 5.0





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

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

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

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

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

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

PR movie for NICT

A Future with N

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

https://youtu.be/YOenAWHhRIA

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Advanced Electromagnetic Technology Area
Radio Research Institute

Director General NAKAGAWA Katsuhiro

The Radio Research Institute conducts research and development on various technologies related to ICT, particularly radio waves, and promotes activities for utilizing these technologies in society. The Institute is aiming to realize Society 5.0 through the utilization of radio waves.

The Radio Research Institute has three Research Centers: the Radio Propagation Research Center chiefly studies the application of radio waves to the measurement of natural phenomena, etc.; the Electromagnetic Standards Research Center aims to contribute to establishing measurement standards for electromagnetic waves, fulfilling two external roles, i.e., "supporting national and international standards as a standards organization", and "researching and developing cutting-edge measurement technologies as a research organization"; and the Applied Electromagnetic Research Center supports research and development on the manufacture of diffractive optical elements (which are fundamental to optical technologies that utilize light diffraction) using digital hologram printing, and their applications, precise optical measurement technologies using digital holograms, etc.

Radio Propagation Research Center

Remote sensing technology

Under the urgent volcano observation scheme administered by the Cabinet Office (Disaster Management), we have completed baseline observations for 50 of the 51 volcanoes under constant monitoring by the Japan Meteorological Agency, excluding Ioto Island (Iwo Jima), located far away from Japan's mainland, using Pi-SAR X3, which has a world-class resolution of 15 cm. Regarding research and development on multi-parameter differential absorption lidar (MP-DIAL), we developed two types of seed lasers: an MP-DIAL–specific model designed for airtightness and wavelength tunability, and a hermetically sealed model with a fixed wavelength that is smaller, more stable, and suitable for communication and related applications. We successfully increased the output power of the pulse laser system operating at room temperature, improving the performance index of the pulse laser for coherent lidar, which was already the world's highest as of 2023, by an additional 29% approximately. For the Doppler lidar, which enables long-range wind observations, we demonstrated the feasibility of wind detection at distances of 20–25 km through simulations and achieved actual wind measurements at distances up to 20 km with a 1-second integration time.

On May 28, 2024 (UT), the EarthCARE satellite equipped with the Cloud Profiling Radar (CPR) was successfully launched. The first image from the CPR (Fig. 1) was released in a press release on June 27 of the same year, and the synergy image created using data from sensors onboard EarthCARE, including the CPR, was unveiled at a press conference on October 4 of that year. After the launch, external calibration experiments of the CPR using three Active Radar Calibrators (ARC) were continuously conducted. We successfully measured both the transmission power of the CPR and the reception power from

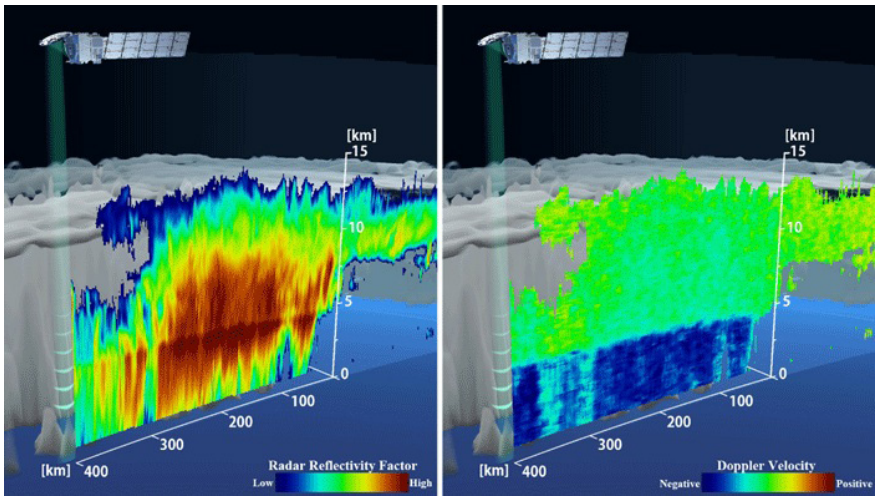


Fig.1 : First image of CPR installed in the EarthCARE satellite; (left) echo strength; (right) Doppler speed

the ARC transmission with an accuracy of ±0.5 dB, revealing that the antenna pattern of the CPR in orbit was almost unchanged from that measured during ground tests, and that the transmission system and the reception system of the CPR had an offset of approximately 2 dB independently compared to the link budget calculated based on radar characteristics from ground tests and satellite position. After incorporating the results of external calibration experiments and refining the ground processing algorithms, L1 data (engineering values) and L2 data (physical values) from the CPR were publicly released in January and March 2025, respectively.

Space environment technology

We developed and released online the "Plasma Bubble Alert" system, which automatically detects plasma bubble occurrences using analyses and disturbance index derivation from VHF radar and other observational data in the Southeast Asian region, incorporating AI and other technologies. etc. It visualizes this detection together with propagation forecast information.

We completed development of an engineering model (EM) for a space environment sensor that can be simultaneously installed with the meteorological observation equipment on the Himawari-10 geostationary meteorological satellite. We also completed the basic design of the proto flight model (PFM) for the entire subsystem to be installed on Himawari-10 based on the results of the EM development.

As for data assimilation for the ground-to-topside model of the atmosphere and ionosphere for aeronomy (GAIA), we improved the assimilation method, such as estimation through assimilation of uncertain parameters included in the GAIA, to improve the stability and precision of the calculations, and implemented a system for assimilating multiple observations of the ionosphere (GNSS total electron content and satellite radio occultation observations) to verify its performance.

We built and started operating a prototype for a system that evaluates energy and instability accumulated in solar active regions using numerical modeling, and that visualizes the risk of occurrence of solar flares in order to verify the criteria for issuing an alert (Fig. 2).

We have established a manual clarifying various roles for responding to large-scale solar flares, such as phenomena analysis, public announcements, and communication with the relevant ministries and agencies. The initial response team operates on a 24-hour basis to assess s any X-class or larger solar flare. For large solar flares that may cause a great social impact, we announce it on the web and at a press conference, inform relevant ministries and agencies about it. Reports including domestic and overseas social impacts are also disseminated through our website, the Space Weather User's Forum, and relevant domestic and international academic societies. In addition, we established a system for sharing information with members of the Public-Private Council on Enhancing the Stability of Space Systems by using a mailing list in cooperation with relevant ministries, and in June 2024, registered it as a distribution destination for the new alert system based on social impact.

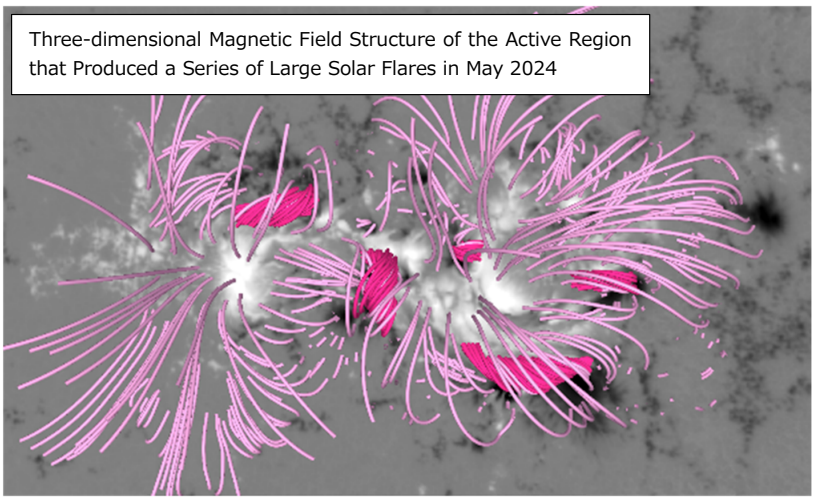


Fig.2 : An example of numerical modeling to evaluate energy and instability accumulated in solar active regions

Electromagnetic Standards Research Center

Electromagnetic compatibility technology

To set practical limit values for electromagnetic noises, we developed two types of limit setting models (strongest noise source and all noise sources are respectively considered) based on the probability distribution of the received noise power, assuming wideband electromagnetic noise sources distributed in a given density, and established international technical report for a limit-setting model assuming the strongest noise source. We also derived limit values up to 40 GHz for protecting 5G systems using this method and established that the draft of international standards would include these values (Fig. 3).

Through joint research with the University of Fukui, we started designing and manufacturing large vacuum tubes called gyrotrons and successfully achieved stable terahertz wave oscillation. In addition, we established a technology for three-dimensionally visualizing temperature distribution in an area irradiated by the terahertz waves, with a confocal laser scanning microscope by injecting a temperature-sensitive fluorochrome into a tissue-equivalent phantom mimicking the dielectric properties and shape of the skin or cornea, enabling precise measurement and evaluation of changes in the temperature elevation distribution in the tissue-equivalent phantom caused by continuous irradiation, which is necessary for assessing human safety from terahertz wave exposure.

We also built a survey website containing radio frequency electromagnetic field (RF-EMF) information, including RF-EMF exposure level monitoring data, and conducted a survey by asking 802 people

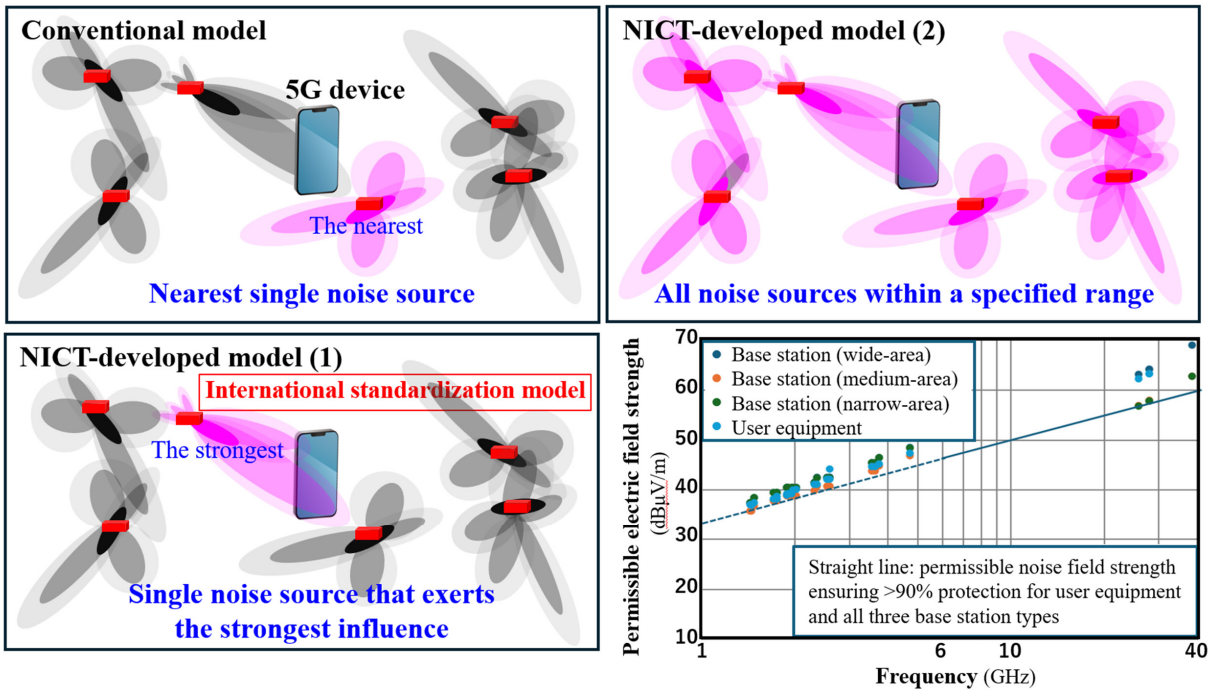


Fig.3 : Overview of the electromagnetic noise limit-setting model and proposed limit values derived from the model

about subjective RF-EMF exposure levels just after viewing the website and five weeks later, respectively, needs and concerns with regard to the use of wireless devices, awareness of carcinogenic risks, etc. Survey results showed that respondents are classified into four groups: a non-anxious group, an anxious group, an uninterested group, and a highly-interested group. We found that the website view was most effective for the anxious group. We observed that anxiety in the non-anxious group temporarily increased just after viewing the website, although after five weeks, it fell to the same level as before viewing. On the other hand, reduction of the anxious group's anxiety was lasting, in general.

We started a verification service for 330 to 500 GHz that complies with the special measures concerning specified experimental testing stations, and made preparations to start a service for 500 to 750 GHz by preparing a power comparison system, etc.

Space-time standards technology

To maintain Japan Standard Time (JST), we regularly and continuously evaluate its clock rate using an optical lattice clock, keeping the difference between JST and Coordinated Universal Time (UTC) within approximately ±5 ns. In addition, by calculating a mean atomic time from multiple hydrogen masers, we have reduced the frequency instability to the 10^{-16} level over a period exceeding one year.

Regarding the development of atomic clock chips (CLIFS), we have advanced the optimization of wafer-level gas cell fabrication processes and begun establishing the production environment for physical packaging. For the wavelength-variable surface-emitting laser chips, we observed the Rb absorption spectrum, developed a new digitally controlled RF oscillator chip, and verified its performance by embedding it in an atomic clock loop.

As for wireless two-way interferometry (Wi-Wi), we developed a method to estimate the positions of fixed base stations and the trajectories of mobile terminals through graph optimization that combines Wi-Wi measurements with robotics techniques, and constructed a radio-wave phase measurement system. We also confirmed that the clock synchronization accuracy of Wi-Wi modules remained around 30 ns across a variety of environments (different distances, reflection conditions, presence or absence of line-of-sight, and low reception power. Furthermore, we demonstrated that Wi-Wi can operate using commercial Wi-Fi chipsets.

In research on the cluster timescale, we constructed a wired optical network incorporating small atomic clocks and implemented a distributed time-synchronization algorithm. Based on experiments using three wired nodes, we demonstrated that the algorithm achieved sub-nanosecond synchronization, generating a stable timescale across the network

We also engaged in standardization activities related to CLIFS, Wi-Wi, and cluster timescale technologies within 3GPP and IEEE 1588. Three use cases assuming the application of Wi-Wi were approved as 6G use cases in 3GPP and were included in the official 3GPP 6G use-case document (Fig. 4).

Applied Electromagnetic Research Center

Digital optics technology

Regarding hologram printing technology (HOPTEC), we have been developing closed-loop-control exposure equipment, which enables positioning finer than a quarter of the record wavelength λ, and improved the stiffness of the exposure

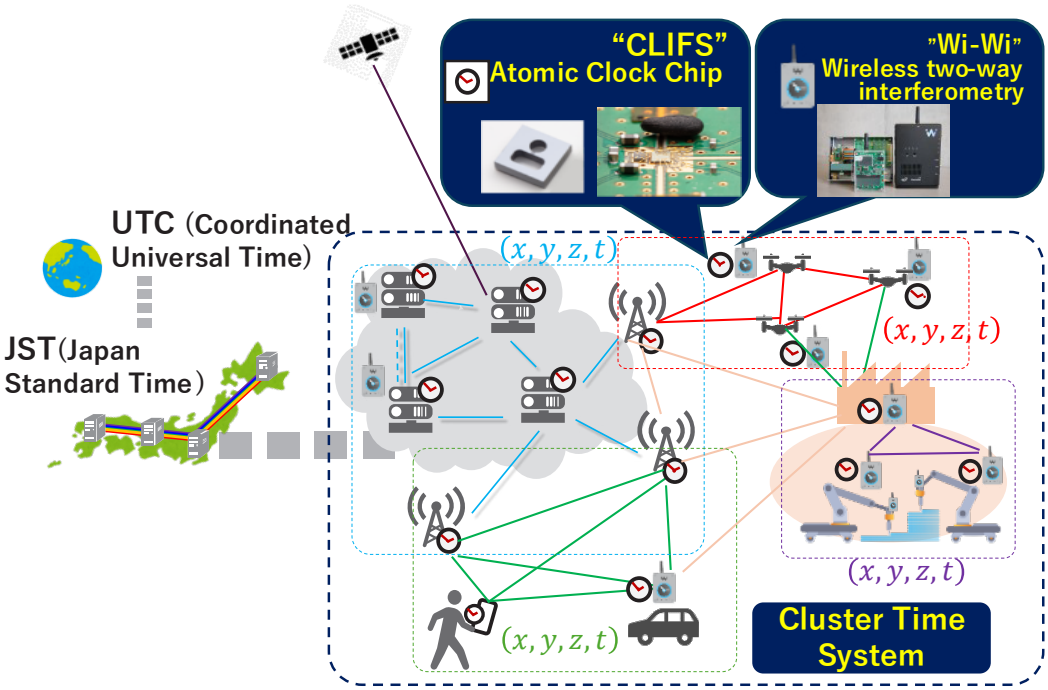


Fig.4 : Image of future network using space-time synchronization technology

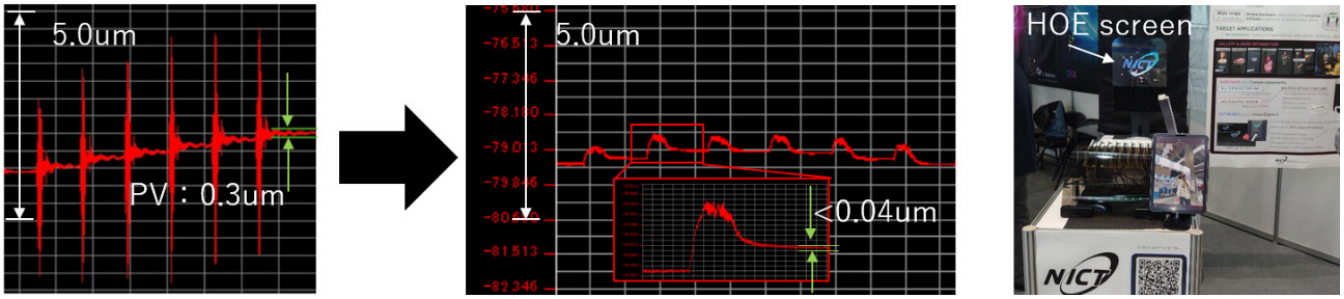


Fig.5 : (Left) Effect of higher stiffness of exposure equipment, (right) demonstration exhibition for a next-generation AR system

equipment to counteract equipment vibrations that cause noise in hologram cells, improving the average amplitude of vibrations upon the stage stop to a tenth of λ (left in Fig. 5). Furthermore, this enables the stable manufacture of optical elements with the 260 mm x 260 mm square workpiece size with low noise. We used this equipment to manufacture a next-generation AR system in cooperation with a company that was developing a special projector, and exhibited a demonstration of the system at COMPUTEX 2024, accelerating cooperation toward social implementation (right in Fig. 5).

As for holographic optical elements (HOEs), we extended the frequency band within which holograms can operate to the near-infrared frequency band (0.8 μm band), which is used for communication, achieving an initial diffraction efficiency of 40%. To enable the application of HOEs with both angle-of-arrival compensation and function for guiding light toward optical fiber to wavelength-division multiplexing (WDM) transmission systems, we successfully carried out multiple recordings of optical elements supporting multiple wavelengths on the same hologram, achieving a peak efficiency of 82% and 68% for 455 nm and 525 nm, respectively. We also finished prototyping and concept checks with regard to HOEs for beam combiners with a wavefront modulation function in order to greatly downsize the optical system for wavefront multiplexing multibeam transmission and substitute for it.

Regarding natural light digital holography, we successfully developed an LED holographic quantitative phase 3D microscope system that connects with a commercially available optical microscope, has a spatial resolution with a lateral resolution of 1.55 μm and a depth resolution of 1 μm, and can simultaneously measure fluorescence images. We also developed a method for simultaneously measuring spectral information through computational coherent multiplexing by generating wavefronts with two mirrors with different curvatures and making the wavefronts interfere with each other, as well as a method for similarly measuring spectral information using a birefringent lens and liquid crystal phase elements instead of a convex lens.

Innovative Networks Area
Network Research Institute

Director General HARAI Hiroaki

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

Advanced ICT Device Laboratory

Our researchers at the Advanced ICT Device Laboratory aim to rapidly materialize their novel ideas into tangible devices. To support this, a research and development environment for device infrastructure technologies has been established. Our researchers, who are engaged in a variety of device technology fields, including optical and electronic semiconductors, dielectrics, superconducting materials, organic materials, and integrated heterogeneous materials, are promoting research on the world's most advanced ICT devices. Furthermore, we contribute to creating new information and communications concepts, such as all-band communication technology and photonic/radio wave convergence technology. Aiming to advance the field of device research, we established an open lab environment that is widely available not only to NICT's researchers but also to external researchers and students from companies and universities. In particular, more than 100 students and trainees use the lab annually, contributing to developing human resources in device technology. We also hold collaborative meetings for researchers to interact with each other and come up with innovative ideas on devices and breakthroughs in device manufacturing. In 2025, as many as 102 researchers and students participated, engaging in lively discussions on device technology.

Network Architecture Laboratory

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

We implemented a system that performs attribute-based data distribution control by combining attribute-based encryption with in-network storage, which consists of distributed ledger (blockchain) technology and ICN (Information Centric Networking) for enhanced reliability and improved network utilization efficiency. This system enables data confidentiality and integrity to be guaranteed within the network, while also achieving faster access and improved communication efficiency. Using this system, we constructed an environment on the Beyond 5G/IoT Testbed with High-reliability and High-elasticity for developing and demonstrating diverse applications such as content distribution and medical information distribution, and conducted operational verification (Fig. 1).

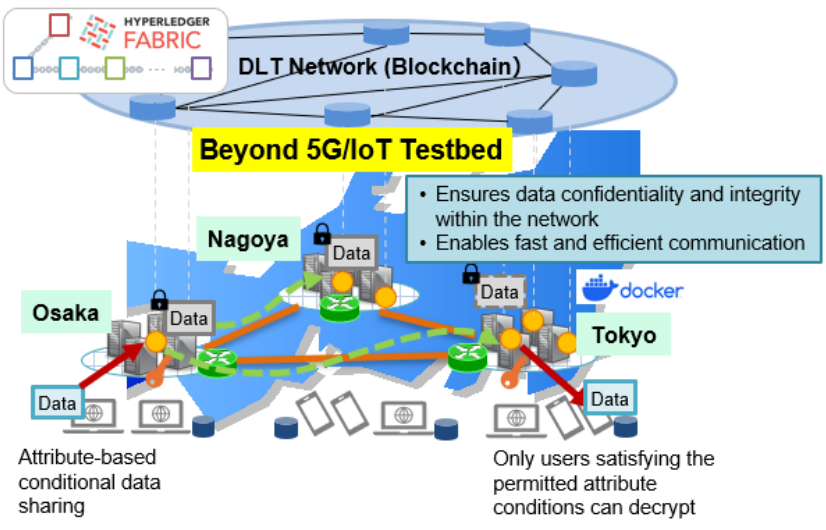


Fig.1 : Operational verification of the in-network storage implementation on the B5G testbed

Photonic ICT Research Center

Our Research Center is engaged in cutting-edge research and development of technologies for ultra-high-capacity optical fiber networks utilizing the spatial and wavelength domains, technologies for using optical network resources more efficiently, and access technologies that integrate optical and wireless communications.

1) Photonic network laboratory

Our laboratory is engaged in research on ultra-high-capacity optical fiber networks and has achieved several new world records in this field. Among these is the record for transmission capacity over optical fiber.

A standard cladding diameter 19-core optical fiber has been demonstrated to transmit more than 1 petabit per second in the past, but over relatively short distances, well below 1,000 km. A world record for long-distance high-capacity transmission, achieving data transmission at 1.02 petabits per second over a distance of 1,808 kilometers has been demonstrated by developing a novel standard cladding diameter 19-core optical fiber with low loss across multiple wavelength bands used in commercial optical fiber transmission systems and an optical amplification system to support the new optical fiber. The capacity-distance product of 1.86 exabits per second - km is the highest ever recorded (Table 1). The newly developed technology is expected to make a significant contribution to both the expansion of the communication capacity and the long-range extension of optical communication infrastructure in the future, when communication demand increases.

2) Optical access technology laboratory

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

In access networks, both optical fiber communication (wired), which excels in high capacity, and wireless communication, which excels in mobility and connection availability, are important. The technology that connects such communication methods seamlessly will become increasingly important from the perspective of network flexibility. Therefore, to enable seamless connection and high capacity of wired and wireless communications, we established a technology that diversifies multiple wireless channels. By utilizing both the 100 GHz and 300 GHz bands, we achieved a transmission capacity of 220 gigabits per second. This technology enables high-capacity data transmission by utilizing multiple channels according to application. Furthermore, we developed a technology to reduce the dispersion effects in transmission methods that are designed for short-distance optical fiber communication, enabling changes only in optical intensity. This new fundamental technology was demonstrated to achieve a transmission capacity of 200 gigabits per second with a simple configuration.

Table 1 : New optical fibers with standard cladding diameter and world records achieved by NICT

					Achievement
Optical Fiber	Uncoupled 4-Core Fiber	Uncoupled 4-Core Fiber	15-Mode Fiber	Coupled 19-Core Fiber	New Coupled 19-Core Fiber
Cross-sectional View					
Achieved Records	Jun. 2021	Oct. 2023	Mar. 2023	Mar. 2023	Apr. 2025
Data Rate (petabit/s)	0.319	0.138	0.273	1.7	1.02
Distance(km)	3,001	12,345	1,001	63.5	1,808
Capacity Distance Product (exabit / s・km)	0.95	1.71 Previous World Record	0.27	0.107	1.86 World Record
Wavelength Bands	S, C, L	S, C, L	C	C, L	C, L
MIMO Processing Load	None	None	Large	Moderate	Moderate

Wireless Networks Research Center

Looking ahead to the Beyond 5G era, we are promoting research and development of wireless network technologies that will globally expand three-dimensional seamless communication networks ranging from the ground and ocean to space by integrating non-terrestrial networks (NTNs) and terrestrial networks (TNs), enabling connectivity under all circumstances and environments.

1) Next-generation wireless technology

We are conducting research and development of highly reliable network infrastructure technologies to support new applications such as cybernetic avatars (CAs). High-reliability end-to-end (E2E) communications are essential for collaborative teleoperation by multiple teleoperators (TOs). Assuming a connectivity-management architecture that flexibly integrates public/private networks and NTNs (e.g., satellites, HAPS, drones), we have proposed related use cases to 3GPP.

To achieve highly reliable communications in this environment, we developed a Multiple QoS (MQoS) node featuring communication quality visualization, jitter absorption, and dynamic path switching functions (Fig. 2). We constructed a collaborative tele-operational demonstration by multiple TOs using a dual-arm robot located at NICT. At domestic and international events, we demonstrated the impact of communication quality degradation and its improvements to government officials and general users in an easy-to-understand manner. We also presented this result at IEEE Globecom 2025, a flagship international conference in the communications field. To address congested environments, we are also promoting the development of high-density operation technology through interference detection and management. Furthermore, in terms of technologies that are difficult to verify in real environments, we expanded our wireless emulator capable of wireless evaluation in virtual environments, allowing us to address a millimeter-wave band with a bandwidth of 800 MHz and a delay resolution of 1 nanosecond. With a maximum delay of 500 milliseconds and a

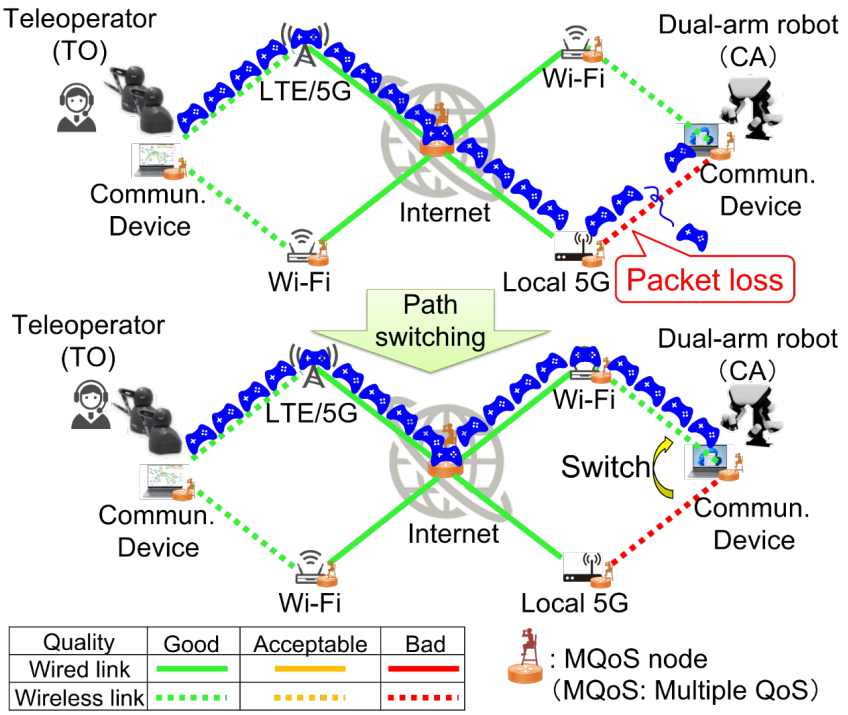


Fig.2 : Monitoring, visualization, and dynamic path switching functions for stabilizing teleoperation communication quality using MQoS nodes

maximum Doppler of 50 kHz, we were able to reproduce a variety of environments, including satellite communications.

2) Space communications technology

We conducted free-space optical communication experiments using JAXA's optical satellite-to-satellite communication system, which is mounted on an optical data relay satellite. In the experiments, we successfully transmitted 5G NR LDPC and DVB-S2, next-generation error correction codes, over an actual ground-to-satellite optical communication link. This marked the world's first demonstration of successfully overcoming atmospheric turbulence effects. We widely publicized this achievement in a press release.

We also developed a new composite material using carbon fiber-reinforced plastic and graphite sheets in collaboration with domestic companies to address technical challenges related to heat dissipation structures for small planar antennas mounted on aircraft, etc. This new composite material achieved a thermal conductivity 6.6 times that of copper and a rigidity equivalent to aluminum plate, for which we filed a patent application. Furthermore, the heat dissipation structure of this new composite material realized a weight reduction of 50% or less compared to the structure of aluminum.

We completed its evaluation of the performance of a universal, compact, high-speed free-space optical communication device equipped with a 30–40 cm square ultra-compact optical communication terminal featuring a gimbal function. As a result, free-space optical communication at a transmission speed of 2 terabits per second was successfully demonstrated over a horizontal distance of 7.4 km in a terrestrial atmospheric propagation environment. This marked the world's first achievement of terabit-class free-space optical communication using a compact terminal capable of being mounted on a mobile platform. Aiming for a 2026 launch for a demonstration in space, we started developing a space model mountable on an ultra-small cube-shaped satellite measuring 10-30 cm edge length.

Resilient ICT Research Center

Resilient ICT Research Center was established in 2012 and has been conducting research and development on resilient ICT applying lessons learned from the Great East Japan Earthquake.

1) Advanced telemetry and control for optical networks

Optical networks enable long-distance, high-capacity communication, however, transmission quality can degrade due to physical phenomena unique to optical signals, resulting in numerous bit errors. Commercial optical communication systems employ Forward Error Correction (FEC) to correct these bit errors, however, if the error rate exceeds a threshold, failures such as link-downs and transmission delays may occur. To mitigate the degradation by time-dependent changes in crosstalk between cores in multi-core fibers, which are promising next-generation infrastructure, we have advanced the failure prediction model utilizing time-series optical signal data. We implemented an attention mechanism used in Large Language Models (LLMs), enabling the prediction of link-failures and designing of models that integrate with failure mitigation techniques. Furthermore, datasets are essential for performance improvements through Artificial Intelligence/ Machine Learning (AI/ML). New services that integrate diverse datasets are emerging, and the concept of "Data Spaces" aimed at enabling proactive and secure data sharing is attracting increasing attention. Therefore, we proposed a framework (Fig. 3) for sharing datasets acquired by the physical parameter measurement system using the Eclipse Dataspace Connector (EDC). We also conducted an international data sharing experimental demonstration with Fraunhofer HHI and presented a live demonstration in a demo session at the Optical Fiber Communication Conference (OFC) 2025, one of the world's largest conferences on optical communication technologies.

2) A Regional digital infrastructure: NerveNet

NerveNet is a distributed network formed by interconnecting multiple base stations. Each base station functions separately (e.g. communications, information processing, control, and power supply), enabling partial operation even during disasters or failures. Its mesh structure allows communication

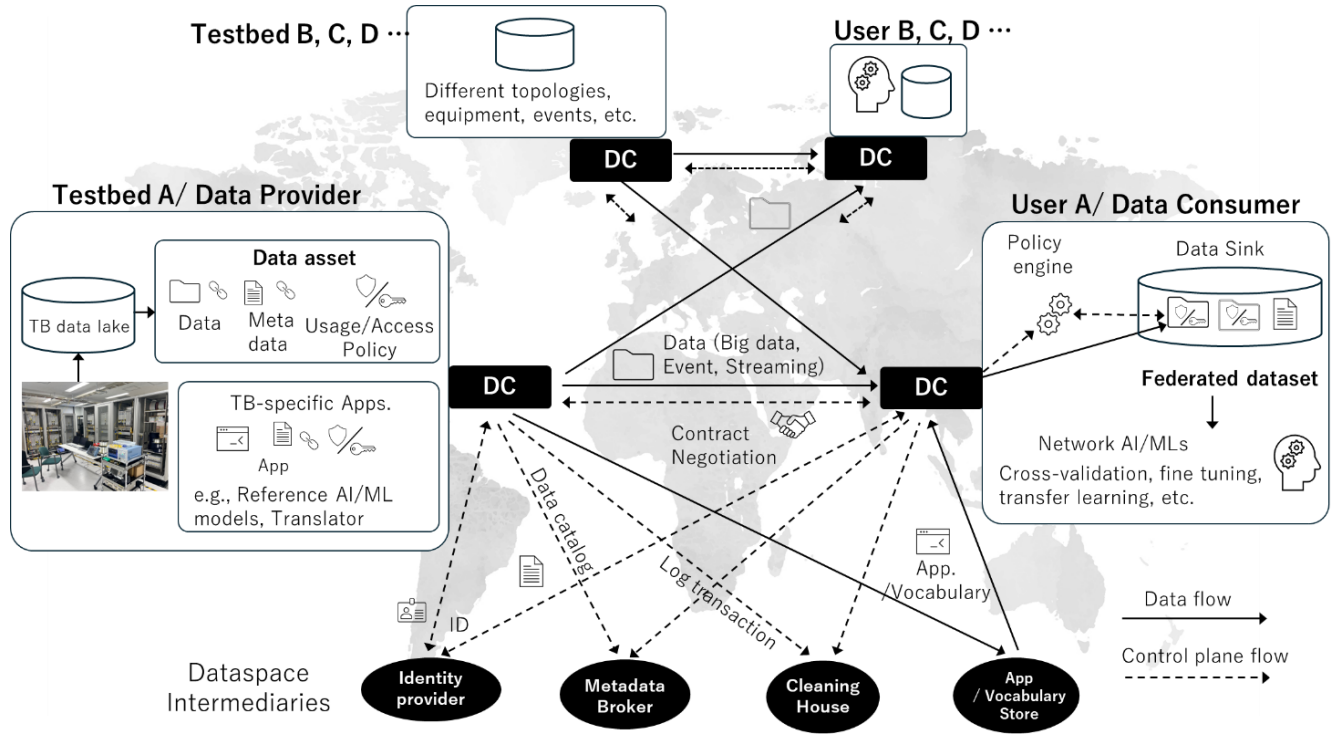


Fig.3 : International optical network testbed data sharing with data sovereignty

to be maintained by bypassing damaged sections. The power design ensures its operation for at least three days during power outages using solar power generation and storage batteries. Leveraging these characteristics, on February 28, 2025, NICT with support from the Asia Pacific Telecommunity (APT), deployed NerveNet as a Smart Village Network in the tea factory area of Gampola City, Sri Lanka. (Fig. 4). A handover ceremony was held and local operation started. This project originated from a 2018 landslide warning survey and has received technical support from BHN association, NICT, etc. for over five years since 2020. The introduced system features functions such as river water level monitoring, weather observation, emergency alerts, voice amplification, and environmental measurement, enabling wide-area communication via LoRa and multi-hop wireless communication technology. We believe that local stakeholders will expand installations and add applications. Furthermore, these efforts have been included into APT Report on Local-Area Resilient Information Sharing and Communication Systems, published by ASTAP (APT Standardization Program Forum), April 2025.

Fig.4 : An outdoor installation of one of the ten NerveNet base stations deployed in Gampola, Sri Lanka.

Cybersecurity Area

Cybersecurity Research Institute

Director General INOUE Daisuke

Countermeasures against increasingly sophisticated and complex cyberattacks have become an urgent national issue. In NICT's Fifth Medium- to Long-Term Plan, the Cybersecurity Research Institute is working on the six areas shown in Fig. 1.

1. *In collaboration with industry and academia, the Cybersecurity Laboratory and the Security Fundamentals Laboratory of NICT have been working on the research and development of cybersecurity technologies and cryptography technologies, respectively. The laboratories have worked to spread the achievements they have made through their research and development, and encouraged their implementation in society.*
2. *As part of projects based on the government's cybersecurity strategies, the Cybersecurity Nexus promoted the formation of a cybersecurity hub for industry-academia-government collaboration, the National Cyber Training Center conducted cybersecurity exercises, and the National Cyber Observation Center made efforts for the improvement of security measures for IoT devices.*
3. *Furthermore, in order to accelerate technological innovation in the fields of AI and cybersecurity, NICT established the AI Security Research Center on February 1, 2025.*

Cybersecurity Laboratory

Data-driven cybersecurity technology

We developed a system to identify infected IoT devices by combining data obtained through NICTER, OSINT sources, and banners collected via real-time scanback. Using this system, we identified infected IoT devices (particularly those located in Japan) and notified the organizations operating these infected IoT devices, as well as their manufacturers, providing them with detailed information about their infection (Fig. 2).

To further enhance the functionality of the Cybersecurity Universal Repository (CURE), we developed CURE Watcher, which detects information about attacks targeting organizations in real-time. It does so by analyzing the vast amount of threat data accumulated in CURE, using IP addresses, domains, email addresses, and other properties as identifiers, and issues alert notifications when relevant threats are found. In addition, we developed an IoC (Indicator of Compromise) engine for security reports, powered by a large language model (LLM).

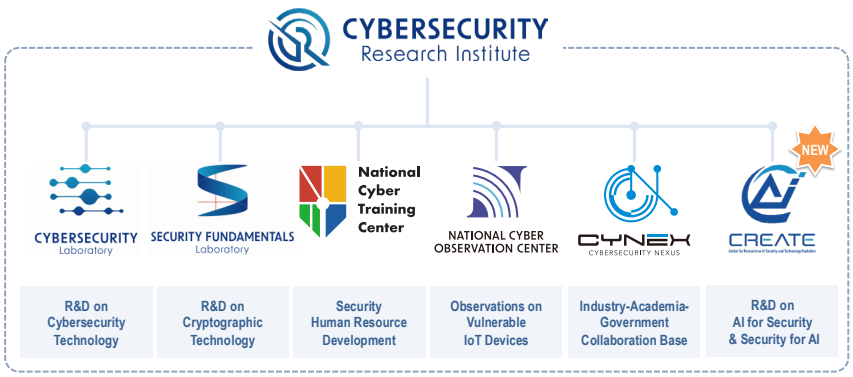


Fig.1 : Mission of CSRI

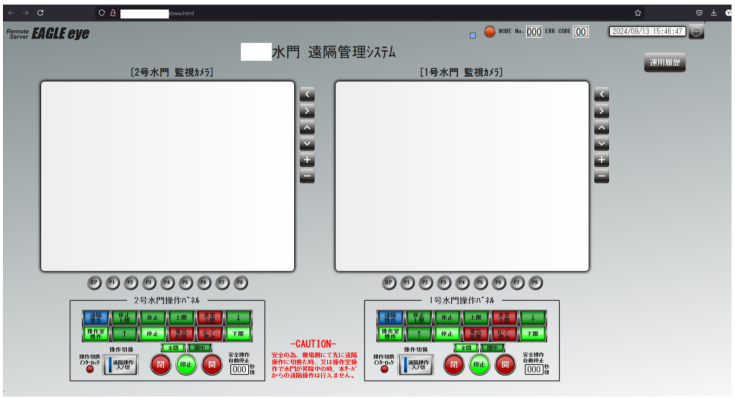


Fig.2 : Device for managing a floodgate control system found with the system used to identify infected IoT devices

Emerging security technologies

To enable comprehensive security verification across various 5G network use cases, we verified the separation of the control plane and user plane (C/U planes) on multiple hosts, the implementation of MEC applications, and multi-slice configurations using open source software (OpenAirInterface) for functions required in verification environment. For low-layer security, we developed a prototype hardware Trojan detection system as a technology for invalid behavior verification at the register-transfer level (RTL) circuits running on field programmable gate arrays (FPGA). We also investigated over 40 models of consumer Wi-Fi routers distributed in Japan, identified vulnerabilities that allow malicious third parties to guess initial Wi-Fi passwords in many models, and reported the vulnerabilities to the router vendors through JPCERT/CC. For usable security, we analyzed potential triggers for behaviors that pose security and privacy risks through user surveys and identified the importance of countermeasures to mitigate the impact of social triggers and prevent their propagation. Furthermore, with a focus on establishing technology for automatically detecting false information, we focused on the modality (expression that represents the judgment and attitude of the information sender) contained in text, which is a linguistic feature of false information, and confirmed that the modality in SNS posts and SNS replies may be effective in identifying false information.

Security Fundamentals Laboratory

Deployment of DeepProtect

DeepProtect enables federated learning while maintaining data confidentiality. We used it to conduct demonstration experiments aimed at creating a system that can automatically identify fraudulent transfers in the financial sector.

We compared an AI model trained separately at individual banks with an AI model trained using federated learning that incorporates data from multiple banks. We found that the AI model trained using federated learning achieves higher accuracy than the separately trained model.

We aim to expand the scope for DeepProtect by leveraging the knowledge gained from demonstration experiments in the financial sector and exploring its application in new fields. Specifically, we have begun research and development to demonstrate the effectiveness of the enhanced DeepProtect for the medical field through demonstration experiments with actual medical data used in healthcare institutions in collaboration with medical schools.

Survey on trends in Post-Quantum Cryptography

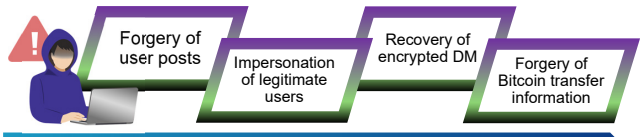
As the CRYPTREC Secretariat, we played a central role in activities aimed at revising the "CRYPTREC Cryptographic Technology Guideline—Post-Quantum Cryptography —." Specifically, recognizing the growing momentum of research, development, and standardization in the field of post-quantum cryptography (PQC), both domestically and internationally, we established the PQC Working Group in 2023. Over a two-year period, the group conducted a comprehensive survey and analysis of technical trends in PQC. Based on the findings of these efforts, we formulated the "CRYPTREC Cryptographic Technology Guideline—Post-Quantum Cryptography—2024 Edition," thereby revising the previous version of the guideline.

Security analysis of a protocol for decentralized social networking services

Through collaborative research with the University of Osaka, NEC Corporation, and the University of Hyogo, we conducted a comprehensive security analysis of Nostr, a protocol for decentralized social networking services. Specifically, we identified several critical vulnerabilities that could lead to serious security risks, including forgery of user posts, impersonation of legitimate users, and recovery of encrypted direct messages by unauthorized third party. We then designed and validated realistic attack scenarios exploiting these vulnerabilities and proposed effective countermeasures to mitigate them. Our findings were reported to both the protocol designers and the application developers implementing Nostr, providing concrete recommendations for improving the overall design of the protocol.

A paper summarizing these findings has been accepted to IEEE European Symposium on Security and Privacy (EuroS&P) 2025, one of the world's leading academic conferences in the field of computer security. In addition, this work was also presented at Black Hat USA 2025 Briefings, one of the world's leading industrial conferences on cybersecurity. These achievements received high recognition from both the academic and industrial communities (Fig. 3).

The world's first comprehensive security analysis of the decentralized social networking protocol Nostr



Identification of vulnerabilities and responsible disclosure to developers along with proposed countermeasures

- Accepted for publication in IEEE EuroS&P 2025
- Presented at Black Hat USA 2025 Briefings

Typical Attacking Scenarios

Attack	Compromised Properties	Target Event
Forgery Attack (Unauthenticated Public Key)	Integrity	Profile, Contact List, Encrypted DM
Forgery Attack (Lack of Signature Verification)	Integrity	Profile, Contact List, Bitcoin Transfer
Encrypted DM Forgery (Lack of Key separate)	Integrity	Encrypted DM
Plaintext Recovery (URL recovery attack & oracle attack via Link Preview)	Confidentiality	Encrypted DM
Inadequate Cache (Bypass signature verification)	Integrity	Profile

Fig.3 : The first comprehensive security analysis of the decentralized social networking protocol Nostr.

Cybersecurity Nexus

In FY2021, the Cybersecurity Nexus was established as a core hub for industry-academia-government collaboration on analyzing information about cybersecurity and developing human resources in the field in Japan. Its mission is to improve the cybersecurity response capabilities of the nation and sustainably cultivate security personnel throughout society (Fig. 4). In FY2023, the CYNEX Alliance was launched, and by the second half of FY2024, 92 organizations had joined in it.

CYXROSS project

The CYXROSS is a pilot project for collecting and analyzing cybersecurity information obtained from government terminals. As part of this project, we developed a domestically manufactured sensor called CYXROSS Agent based on proven domestically manufactured behavioral sensing software. The CYXROSS Agent, which is capable of verifying safety and transparency, fundamentally strengthens Japan's autonomous cybersecurity capabilities using domestically developed technologies. Furthermore, we verified the feasibility and effectiveness of schemes for collecting and analyzing information about terminals using domestically manufactured technologies and began collecting and analyzing cybersecurity information related to government terminals without relying on foreign security products.

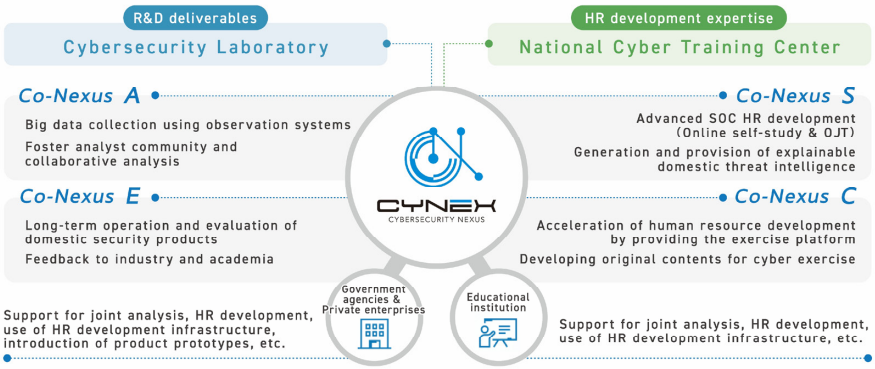


Fig.4 : Missions and activities of the Cybersecurity Nexus

Fig.5 : Activities of the National Cyber Training Center

National Cyber Training Center

The National Cyber Training Center was established to plan and promote practical cybersecurity training. It makes full use of the technical expertise, research outcomes, and research facilities of NICT The Center conducted the practical cyber defense exercise CYDER more than 100 times annually nationwide, with a total of more than 27,000 participants (as of the end of FY2024). It also holds a practical cyber defense exercise called RPCI, which is certified as a specified training course for registered information security specialists (RISS), and the SecHack365 security innovator development program for young ICT professionals. Furthermore, to prepare for Expo 2025 Osaka, Kansai, the Center has been conducting a cyber defense training course called CIDLE since FY2023. CIDLE provides human resource development exercise programs based on CYDER for information system personnel in Expo-related organizations (Fig. 5).

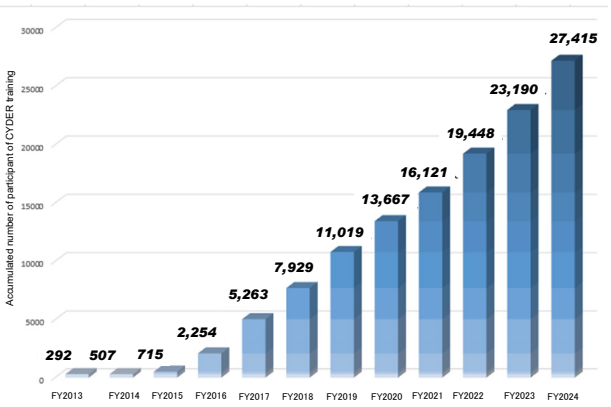


Fig.6 : Increase in the number of participants in CYDER group training

Security operator training program

To date, through CYDER, we have offered group training across all 47 prefectures, primarily targeting personnel responsible for information systems in government agencies, incorporated administrative agencies, and local administrative agencies.

In FY2024, we have fully implemented Pre-CYDER, an online course for security

personnel in small municipalities. It allows them to quickly master the basics required for CSIRT personnel. In addition, we made other efforts to build a scheme that leads to incentives for participation in more training and organizational strengthening.

Security innovator development project

We run SecHack365, a 365-day program for people under the age of 25. It uses an environment in which NICT's research and development know-how and data related to actual cyberattacks are safely available. We have consistently maintained a steady attendance rate of around 40 participants every year, and again provided the program for 40 participants in FY2024. From the start of FY2017 to the end of FY2024, we have produced 328 graduates.

Furthermore, in September 2024, we started a visiting class for junior and senior high school students, titled "SecHack0: SecHack365 Episode 0 (Zero)." Its purpose is to stimulate their interest in security and innovation and to help them gain a more concrete understanding of unresolved issues facing society.

National Cyber Observation Center

In February 2019, the NOTICE initiative was launched to promote security measure improvements for IoT devices. A collaboration of the Ministry of Internal Affairs and Communications, NICT, and ISPs, NOTICE involves investigating vulnerable IoT devices that may be abused for cyberattacks and issuing warnings to the users. The revised NICT Act which was enacted in 2021 set the deadline for NOTICE work practice as the end of FY2023. However, in order to respond to ongoing cyberattacks on IoT devices, the NICT Act was amended to allow work to continue from FY2024 in the form shown in Fig. 7. Taking this opportunity, the content of this business was revamped as the new NOTICE, and NICT's new tasks were positioned as "investigations of devices with firmware vulnerabilities," "investigations of malware-infected devices," and "investigations of devices that could be used as stepping stones for reflection attacks."

The National Cyber Observation Center continues to strengthen public-private collaboration under NOTICE and conduct effective investigations based on the latest technological trends with the aim of strengthening IoT security and creating a safe, secure society.

Center for Research on AI Security and Technology Evolution

Established in February 2025, the AI Security Research Center (CREATE) aims to develop technologies that enable a safe, secure AI-native cyber society. CREATE develops techniques to enhance cybersecurity using AI, secure AI-based solutions, and strengthen trust in AI technologies (Fig. 8).

In its research on AI-based security solutions, CREATE explores AI-driven threat detection, incident response, and cyber defense automation. For example, the center is developing automated vulnerability detection techniques powered by AI. At the same time, it tackles the growing risks of AI misuse and vulnerabilities in AI models, including adversarial attacks, data poisoning, and robust model design. An AI Security Evaluation Platform is also being developed to assess and improve the safety, robustness, and reliability of AI systems. In parallel, research is underway to increase trust in AI by enhancing model interpretability and privacy protection.

CREATE also aspires to serve as a global hub for advancing cybersecurity in Japan and worldwide. Its collaborative initiatives span industry, academia, and government agencies, both domestically and internationally.

Through these activities, CREATE is contributing to the creation of a safe, trustworthy, resilient AI-native cyber society.

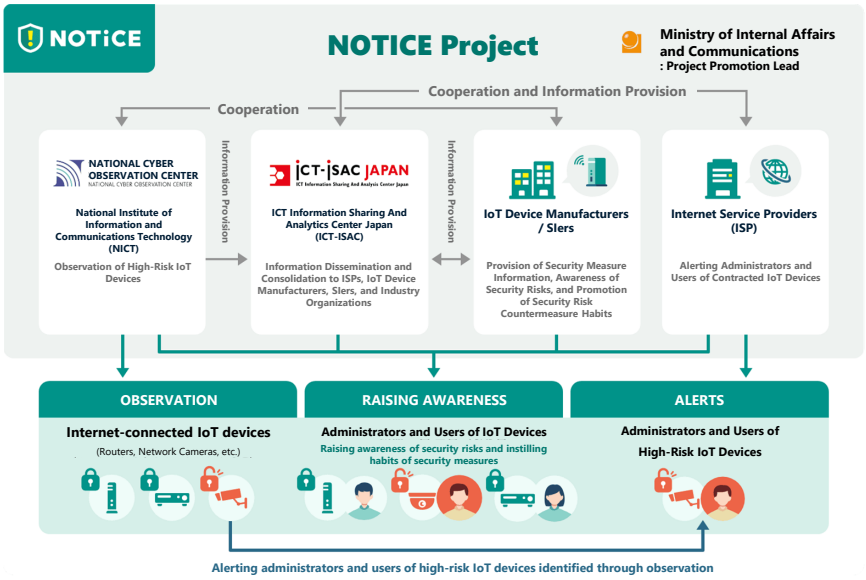


Fig.7 : Overall view of the NOTICE project

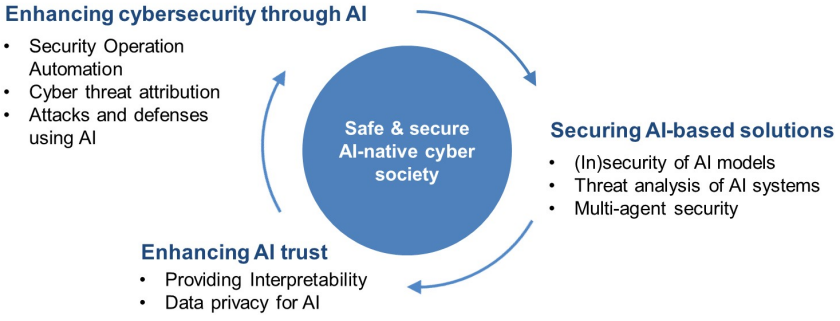


Fig.8 : Domains of R&D in CREATE

Universal Communication Area

Universal Communication Research Institute

Director General UCHIMOTO Kiyotaka

Universal Communication Research Institute (UCRI) aims to realize universal communication in which everyone understands each other, and is conducting R&D on multilingual communication, social intelligence communication, and fundamental technologies for smart data utilization, by utilizing advanced technologies such as deep learning technology based on large-scale datasets including voice, text, and sensory data. Furthermore, UCRI works to promote social implementation of systems that support diverse user interfaces. Through these efforts, UCRI aims to contribute to solving diverse social issues, create new values, by utilizing ICT to address the Beyond 5G age.

ASTREC

The Advanced Speech Translation Research and Development Promotion Center (ASTREC) has been engaged in R&D and social implementation of multilingual speech translation technology based on the Global Communication (GC) Plan, which was launched to eliminate "language barriers" worldwide and enable seamless global communication. In the 5th Medium-to-Long-Term Plan that started in fiscal year 2021, based on the GC Plan 2025 announced in 2020, ASTREC has conducted R&D on multilingual communication technology that utilizes diverse sources such as context, speakers' intentions, and surrounding circumstances, and enables practical-level automatic simultaneous interpretation for business meetings and international conferences. At the 2025 Osaka-Kansai World Expo, NICT's technologies have been adopted by private companies to deliver their services.

Data-driven Intelligent System Research Center

The Data-driven Intelligence System Research Center (hereinafter DIRECT) is engaged in R&D on two technologies: The first focuses on acquiring knowledge (social knowledge) from sources such as the internet in a way that is easily understandable to people and infers hypotheses obtained through a combination of such knowledge and analogies. The second is a social knowledge communication technology, in which a virtual-like personality with objectives and policies, utilizes social knowledge acquired through deep learning techniques and hypotheses derived from it, to engage in dialogue tailored to the user's interests, background, and context. In recent years, we have focused on enhancing technologies related to large language models (LLMs) and creating social value.

1. Establishing the world's largest Japanese pre-training data at 44.3 TB

To prepare Japanese pre-training data for LLMs, a large amount of high-quality data for LLM training is extremely important. Over the past 15 years, NICT has collected over 70 billion web pages, primarily in Japanese, and used them to construct large-scale Japanese pre-training data. Specifically, based on the assumption that the text appropriate for inclusion in the pre-training data is typically found in paperbacks and recently published books, NICT manually prepared training data (2.75 million sentences) by exclusively extracting

Fig.1 : Simultaneous interpretation demonstration at CEATEC 2024

such text from web pages and constructed a deep learning model trained on this data. This model enabled users to extract blocks of text appropriate for training data from any web page. These blocks of text were combined with NICT's own proprietary duplicate removal process and applied to over 70 billion web pages. In August 2025, Japanese pre-training data containing 44.3 TB was constructed, which is the world's largest, to our knowledge.

2. Exploring LLM training hyper-parameters and prototyping many diverse LLMs

To construct LLMs with an improved ability to generate long-form text, NICT explored the optimal values for hyper-parameters (such as setting values for a learning rate, etc.) while the LLMs were being trained. Specifically, an LLM with 1 billion parameters was trained using more than 25 types of hyper-parameter settings and subsequently evaluated. The model was selected for the ABCI-related "Large-Scale Foundation Model Creation Support Program 2024," held by AIST. In the program, 4 types of hyper-parameter settings for a 13-billion-parameter model were explored.Additionally, to increase the maximum token length (the maximum number of words that can be input or output, which determines the length of text that can be input or output to LLMs), more than 10 types of small-scale models were prototyped with diverse token length settings, aiming to exceed the token length of previous prototype models. Furthermore, the training environment improved, resulting in an approximately 1.3- to 1.7-fold increase in training speed.

3. Establishing an LLM evaluation system

To evaluate LLMs, NICT constructed its own benchmark datasets containing 1,000 items each (7,000 items in total) for seven types of tasks (question answering, chatting, hypotheses generation, refutation, agreement, summarization, and question answering with context), and established a system to compare LLM performance.

4. Providing collaboratively researched and prototyped LLMs and their training data to private companies

NICT addressed legal issues related to the utilization of prototyped LLMs and their training data by private companies in FY2023 and established a framework through collaborative research, which took shape in FY2024, starting with KDDI in July 2024. The response was significant, with numerous media reports published. As a result, in FY2024, at the request of various organizations, we gave 13 invited talks on NICT's R&D of LLMs.

5. Developing the general-purpose software platform WISDOM-LLM

NICT believes that the LLMs have three fundamental weaknesses: lack of output reliability, creativity, and diversity. To address these issues, we developed WISDOM-LLM, an unprecedented software platform that can flexibly combine multiple LLMs with diverse perspectives and characteristics, integrate with different types of AI such as WISDOM X, and pool their wisdom. It enables parallel and asynchronous operation of each AI, such as LLMs, to efficiently generate various outputs. Processing on WISDOM-LLM, that is, the processing achieved by combining various AIs, is structured in accordance with a concise description method called "thinking pattern." NICT confirmed that constructing these thinking patterns enables the generation of text suitable for numerous and diverse applications, while allowing low-cost development. For example, Fig. 2 shows an example of WISDOM-LLM demonstrating various health-related chats, along with implementation of basic virtual personalities.

Big Data Integration Research Center

To continuously understand various real-world situations and provide optimized behavioral support, NICT is conducting R&D on data integration analysis technology that collects diverse real-world event data and discovers, learns, and predicts cross-sectoral correlations. It is also conducting R&D on integrated AI technology that constructs common predictive models for situational understanding and behavioral support without sharing individual private data. NICT also constructs xData Platform, with these fundamental technologies implemented, and provides APIs and user development environments, promoting co-creation-based problem-solving using the data and know-how from local governments and service providers. In

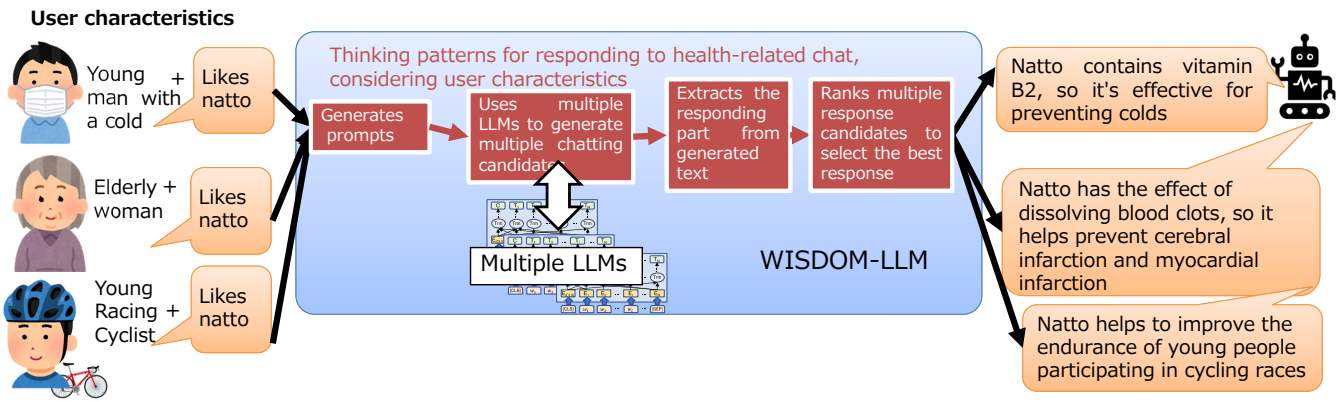


Fig.2 : Behavior examples of basic virtual personalities on WISDOM-LLM

Fig.3 : DriveCoach: A driving behavior recommendation system with MM sensing (Won the Best Industry Demo Award at ACM Multimedia 2024, the top conference in the multimedia field)

FY2024, NICT implemented MM sensing, which applies data integration analysis technology to driving risk prediction, along with previously developed distributed federated machine learning technology, in a smart driving support demonstration system for transportation companies and other organizations, and worked to improve performance through social demonstration (Fig.3). Furthermore, to promote performance improvement with researchers and engineers, NICT established environments used for a previously developed distributed federated machine learning simulation experiment system, enabling the provision of experimental services.

Advanced Reality Technology

Aiming to achieve communication that transcends the constraints of space, time, and the physical body, NICT is promoting R&D on technologies that digitize real-world people and environments, reconstruct them in cyberspace, and convey nonverbal and multisensory information to remote individuals to deepen mutual understanding. In particular, NICT is: 1. Exploring the essence of "reality" (the sense of presence) humans perceive from multisensory information, using human behavior analysis and brain function imaging; 2. Developing artificial intelligence (AI) technologies to digitize and understand real-world people, objects, and environments; and 3. Developing XR (VR/AR/MR) interface technologies that can convey such information realistically and naturally to remote individuals through visual, auditory, and haptic sensations. Implementing these technologies in society will contribute toward realizing the future society envisioned by Beyond 5G / 6G. To this end, NICT aims to promote social deployment of our research outcomes through collaborations with organizations such as the Ultra-Realistic Communications Forum (URCF).

Fig.4 : Mixed reality (MR) Experience of REXR communication

Advancing REXR technology

REXR is a technology that creates a person's photorealistic 3D avatar using only 2D images captured by a single ordinary webcam, enabling reproduction of that person's subtle facial expressions and movements in 3D in real time. In FY2024, a remote live demo of the "REXR Communication System" was presented at NICT Open House (June 2024). This live demo enabled a real-time conversation between the 3D avatars of two persons located in remote locations (Keihanna area) and visitors at the event venue (Tokyo). Two types of shared 3D spaces were developed for this demo: one system that uses a 3D digital twin of the exhibition booth, and another system that overlays the 3D avatars onto the real space using mixed reality (MR) (Fig. 4). Additionally, REXR was integrated

with NICT's speech interpretation system, enabling users' voices to be translated into multiple languages and displayed as subtitles above the speaking 3D avatars. We plan to continue conducting proof-of-concept experiments to improve the system's accuracy, robustness, and usability.

Developing 3D digitalization and interaction technologies for real environments

Regarding 3D digitization of environments, we developed AI technology to construct 3D digital twins of real environments only from 2D images. Conventional digitization methods typically rely on existing CAD data for buildings and objects, or point cloud data measured with 3D scanners, which require extensive manual efforts for measurement and shape visualization, and their accuracy is often insufficient. Therefore, our laboratory developed a machine-learning-based method that automatically constructs 3D digital twins from multi-view 2D images, enabling high-resolution rendering from arbitrary viewpoint. In particular, by walking through a room with a handheld 360-degree camera to capture video the system can automatically constructs a 3D digital twin from 2D data in a short time , and generate images from any viewpoint (Fig. 5). In the future, we plan to develop technologies that allow manipulation and utilization of real-world 3D digital twins for remote collaboration and robot teleoperation.

Fig.5 : Constructing 3D digital twins using 360-degree 2D videos and image generation from arbitrary viewpoints

Frontier Science Area
Advanced ICT Research Institute

Director General WADA Naoya

At the beginning of NICT's current Medium to Long-term Plan, the Advanced ICT Research Institute was envisioned 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 unexplored frontier fields with the plow of science without fear of failure." With this mind, we will conduct cutting-edge and fundamental R&D backed by advanced academic knowledge.

Kobe Frontier Research Center

Superconductive ICT device technology

We conducted research and development focused on operational demonstrations of multilayer SSPD (Superconducting Single Photon Detector) modules that are technologically important for scaling up SSPD arrays. A multilayer SSPD module consists of a lower SSPD layer and an upper SSPD layer separated by an insulating layer. When a photon enters either SSPD layer and is absorbed, Joule heat is generated within it and transmitted to the other layer. By utilizing the series of reactions to form a matrix structure, responsive locations can be identified by measuring row and column signals output simultaneously, making it possible to read out an NxN pixel array with 2-N strips. We demonstrated the generation of simultaneous outputs from the upper and lower SSPD layers, as shown in Fig. 1, and successfully developed an important technology for the development of large-scale SSPD arrays.

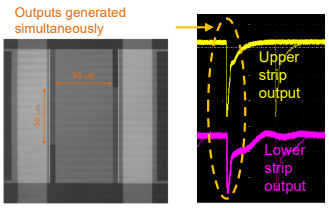


Fig.1 : Multilayer SSPD module by the Superconductive ICT Device Laboratory and confirmation of simultaneous outputs from the layers

Organic-inorganic hybrid device technology

Regarding fundamental technologies for ultrafast optical control devices, we have prototyped a semiconductor/organic EO polymer hybrid optical modulator to achieve ultrafast and low-voltage operation of compact optical modulators and a surface-emitting optical phased array (OPA) for two-dimensional optical manipulation on an OPA, and confirmed the basic operation of these prototypes based on their design values. Regarding fundamental technologies for ultra-wideband electromagnetic wave control devices for applications such as wireless optical modulation elements and electric field sensors, we demonstrated analog radio-over-fiber transmission of 10-Gbps QPSK signals in the world's highest frequency band, 150 GHz, through a direct THz-to-optical converter with a structure suitable for mass-producible devices using an EO polymer optical modulator as a THz receiver (Fig. 2). Furthermore, we successfully fabricated a 15 mm x 15 mm poled EO polymer freestanding film and carrier film structure to enable larger EO polymer freestanding films and lamination.

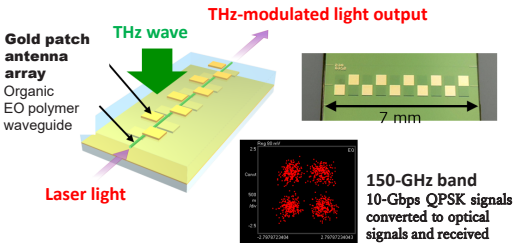


Fig.2 : 150-GHz RoF with an antenna-coupled organic EO polymer optical modulator used as a THz receiver

Biomaterial technology

Regarding identification of chemical substances using biomaterials, we previously developed a system for chemical substance identification using bacteria and we successfully achieved significant miniaturization of the system last year. Even after this success, we have been trying to simplify the configuration of the system and improve its identification capabilities. To improve the system configuration, we prototyped a hydrophilic PDMS micro-channel chamber, optimized it, and developed a process that does not require plasma treatment (Fig. 3).

In order to prototype a component that is part of the biomaterial-based system, we developed a new, smaller elastic element (digital force sensor) that can reversibly convert the magnitude of a mechanical signal into an optical readout (brightness) by improving an elastic molecular element (nanospring) that we developed last year. Among the components of the system, we addressed the energy conversion mechanism of molecular motors. Through the reconstitution of the molecular motor kinesin, we propose a novel mechanism by which molecular motors convert chemical energy into mechanical work.

New ICT technology as learned from an insect' brain

We recorded the neuronal activity of Drosophila flies when they communicate with each other, investigated the behavior of genes in their communications, and modeled a mechanism for neural circuits that control this behavior. Then, based on this model, we explored mechanisms for how Drosophila's behavior changes through social experience and evolutionary diversification. We first constructed a system that automatically quantifies the positions and postures of individual Drosophila flies based on video recordings of their behavior (Fig. 4). Using an automated behavioral analysis system, we quantified the behavior of mutual pursuit between males and how this behavior changes through social experience. From the data obtained with this system, we found that wild-type males rarely pursue other males in the absence of competition for food, whereas fruitless (fru) mutant males, in which sexual differentiation of certain brain neurons is inhibited, aggressively pursue other males in an attempt to court them. We also trained Drosophila flies to remember that they would receive food when they let go of a stick and elucidated the molecular mechanism behind this phenomenon.

Apart from brain functions, which undergo plastic changes throughout the lifetime of an individual, there are also neurobehavioral traits that change over long periods of time. This includes diversification of behaviors resulting from evolution, which is based on species-specific differences in brain structure and function. We focused on Drosophila subobscura, a distant relative of the model organism Drosophila melanogaster, to study the neural mechanisms involved in their courtship behavior and nuptial gifting exhibited exclusively in this species. Nuptial gifting refers to male feeding of nutrients to a female by mouth. This behavior is a prerequisite for the female's acceptance of the male and is not observed with other Drosophila species. Using a technique to forcibly activate a small number of neurons in the brain, we identified neurons that play an important role in nuptial gifting.

DUV device technology

Leveraging NICT's technologies for high-intensity deep-UV LEDs that are comparable to mercury lamps, we jointly developed with Asahi Kasei a low-environmental-impact, energy-saving high-intensity deep-UV LED air sterilization module for railroad vehicles. To verify the effectiveness of our newly developed high-intensity deep-UV LED air sterilization module, we evaluated its performance in inactivating airborne viruses. Through our evaluation, we confirmed that the high-intensity deep-UV LED air sterilization module was able to reduce the power consumption required for 99.9% virus inactivation by 40.7% compared to a mercury lamp module. The new module was installed in in-service Shizuoka Railway passenger cars and a one-month test run confirmed its safe and stable operation.

Koganei Frontier Research Center

Quantum ICT technology

We conducted research focused on enhancing the value of quantum secure networks. As a result of this research, we have achieved the following outcomes: 1) Development and operational verification of an application that enables third parties to guarantee data integrity on the Tokyo QKD network. 2) Patent application for an information-theoretically secure tamper-prevention technology to encrypt timestamps containing high-precision spatial information with a quantum key (Patent Application No. 2024-068687). 3) Patent application for an information-theoretically secure personal authentication technology for intermediate nodes in entanglement swapping between two parties with quantum entanglement light sources (Patent Application No. 2024-083210). 4) Patent application for a technology that enables information-theoretically secure transmission of authentication information using a card equipped with post-quantum cryptography (PQC) on a smartphone by integrating PQC with a quantum key distribution network (Patent Application No. 2024-214678). 5) By applying a protocol that enables information-theoretically secure single-password identity authentication, we successfully conducted an experiment for information-theoretically secure data relays over a 100 km radius. This approach relaxes the security requirements for "trusted stations." The results were published in IEEE access (DOI: 10.1109/ACCESS.2024.3468442). 6) Patent application for a key relay path discovery technology designed to resolve a bottleneck in the protocol and improve throughput without compromising security (Patent Application No. 2023-172625).

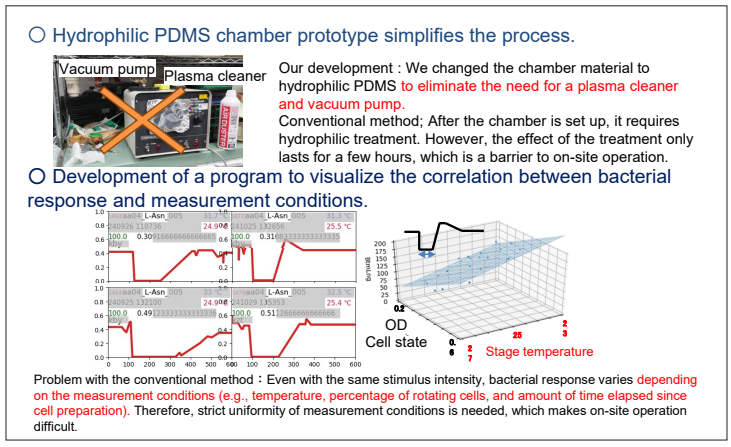


Fig.3 : Improvement of chemical biosensor usability

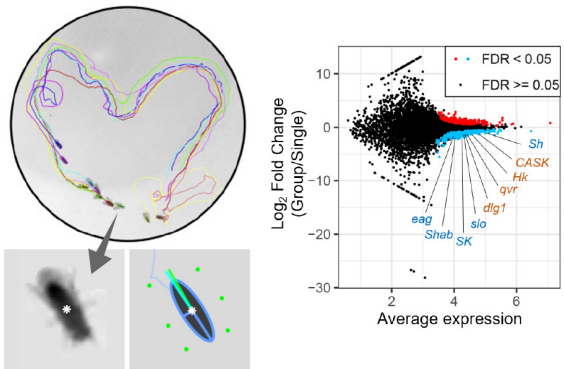


Fig.4 : Automated quantification of free-roaming movements through image analysis (left) and changes in gene expression profiles accompanying changes in pursuit behavior due to differences in social experience (right)

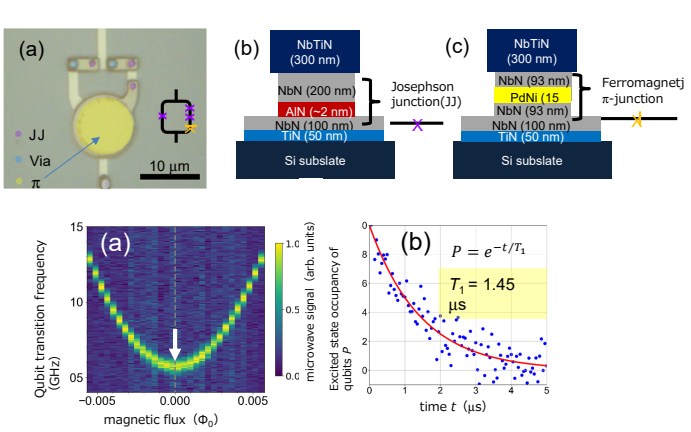


Fig.5 : New superconducting flux qubit that does not require an external magnetic field

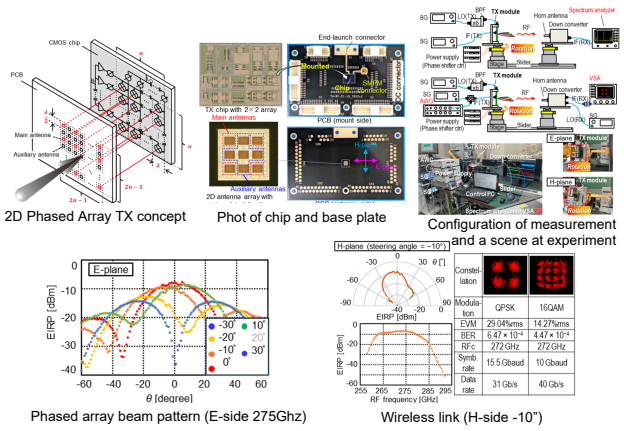


Fig.6 : 300-GHz-band phased-array 2D beam-steering CMOS transmitter

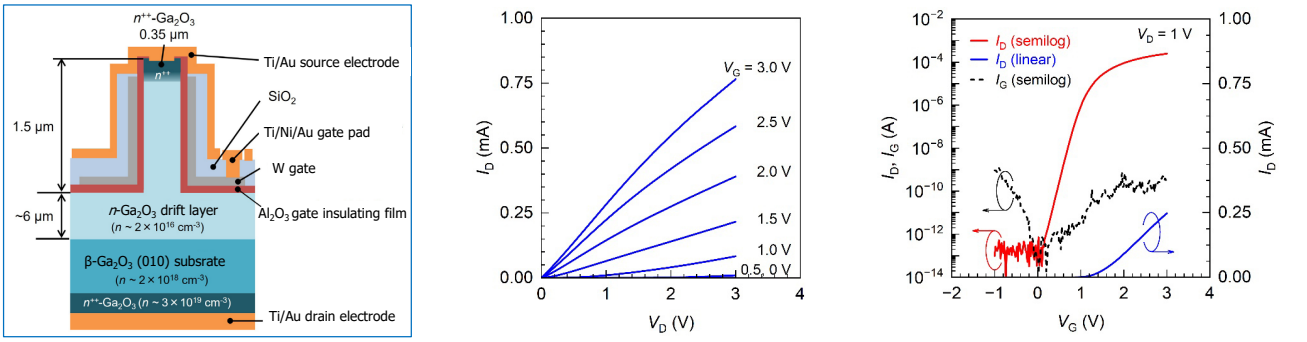


Fig.7 : (a) Schematic cross-sectional view of the vertical Ga_2O_3 fin transistor (fin width: 400 nm)
(b) Drain current-voltage output characteristics of the vertical Ga_2O_3 fin transistor, (c) Transfer characteristics

In the field of quantum node technology, we also made progress in research on qubits realized using superconductors. Specifically, we demonstrated superconducting flux qubits (Fig. 5) that operate in a zero magnetic field using superconducting qubits and an epitaxially grown nitride ferromagnetic Josephson π-junction.

Ultra-high frequency device technology

As part of the development of elemental technologies for terahertz-band transceivers for establishing high-speed and high-capacity wireless communication technologies, we developed a 300 GHz-band phased-array beam-steering transmitter with silicon complementary metal-oxide semiconductor (CMOS) technology, which enables two-dimensional antenna directivity control. To realize a phased-array system using multi-element antennas, the antennas must be spaced at intervals of half the wavelength of the carrier frequency to suppress grating lobes. This has been difficult to achieve in the terahertz-band due to the shorter wavelengths, which poses limitations on circuit size. To overcome this challenge, we combined a silicon CMOS chip equipped with 2x2 array of 300 GHz-band up-conversion mixers with a printed circuit board (PCB) equipped with a 3x3 array of complementary feed antenna elements, achieving the world's first 2D phased array in the 300 GHz-band using only silicon CMOS technology (Fig. 6). The proposed transmitter achieved wireless communication performance of up to 40 Gbps and a two-dimensional steering angle of ±30°.

Ga_2O_3 technology

Development of vertical Ga_2O_3 power transistors

To solve problems that we had previously identified in our prototype vertical Ga_2O_3 fin transistors, we first optimized the device structure and process to reduce the current. We then fabricated vertical Ga_2O_3 fin transistors equipped with the optimized structure and process, and evaluated their device characteristics. Figure 7(a) shows a schematic cross-sectional view of the vertical Ga_2O_3 fin transistor. Figure 7(b) and (c) show the drain current-voltage output characteristics and transfer characteristics, respectively.

Center for Information and Neural Networks

Established in 2011, the Center for Information and Neural Networks (CiNet) applies cutting-edge research on human brain functions to information and communication technology, aiming to realize a human-centric ICT society. Based on the three research pillars of CiNet's Fifth Medium- to Long-Term Plan of a) Build an Artificial Brain Model, b) Increase Brain Information and Communication Technology Applications, and c) Improve Social Acceptability of Brain Information and Communication Technology, CiNet has produced achievements of high academic and social value toward the construction

of a brain-inspired AI model called CiNet Brain.

Brain networks and communication research

Aiming to research technologies for advanced and multifaceted measurement and analysis of brain activity related to human cognition, sensation, and movement, and to develop brain information and communication technologies that help to improve human brain functions, we as CiNet researchers have set the following two sub-goals. The first is research on brain function measurement and analysis for the construction of an artificial brain model. In our project for spatiotemporal sensory manipulation, which is related to this research, we discovered for the first time that, regarding the concept of "numbers," which are essential for human social life, they are represented as absolute values in areas close to an input source (such as the visual cortex) in the human brain, and numbers are represented as relative values in higher-level areas (e.g., the parietal lobe and frontal lobe). The second sub-goal we set is research into the applications of brain information and communication technology. In a project for brain-inspired ICT, which is related to this research, we found that the context of decision-making without doubt and the context of decision-making with doubt are not independent of the motor learning process, and the brain includes such contexts in this process. In a next-generation BMI project in collaboration with Osaka University, we developed a multipoint sequential mechanical stimulation device for the fingers and palm and demonstrated the performance of its multipoint high-density neural electrodes. In a project on human function improvement, we devised a new technique for bilateral proprioceptive-motor coupling that could be effective in restoring finger motor function after a stroke, and elucidated a mechanism in the brain supporting its effectiveness (Fig. 8).

Brain function analysis research

We are conducting research into advanced brain activity measurement technologies, applying them to neuroscientific research using advanced brain activity measurement, and developing technologies to measure brain activity and mood in everyday environments. Through our research, we have successfully measured brain activity related to odor preferences and emotional arousal using functional magnetic resonance imaging (fMRI) and intra-brain information decoding technology. Humans process sensory information from the outside world through the five senses such as sight, hearing, and smelling. However, brain regions involved in evoking emotional responses and the brain information processing that is involved remain unknown. Through fMRI experiments, we collected brain activity data during video viewing and analyzed it using intra-brain decoding technology to investigate brain activity related to emotional arousal (Fig.9).

Neural information engineering

We conducted research to clarify a mechanism for decision-making in a virtual space, as well as to discover similarities and differences between information processing in the human brain and information processing in AI, with the aim of establishing new Neuro-AI. We used fMRI to measure the brain activity of a person watching various types of videos, such as dramas and movies, and linguistically described the video content as multilayered data consisting of layers for speech, situation, story, and other items. We then applied a large-scale language model (LLM) to the data to extract various features and constructed a brain activity prediction model. The model demonstrated that brain activity could be quantitatively predicted through internal representation of the LLM, and that respective data layers correspond to specific brain regions (Fig. 10).

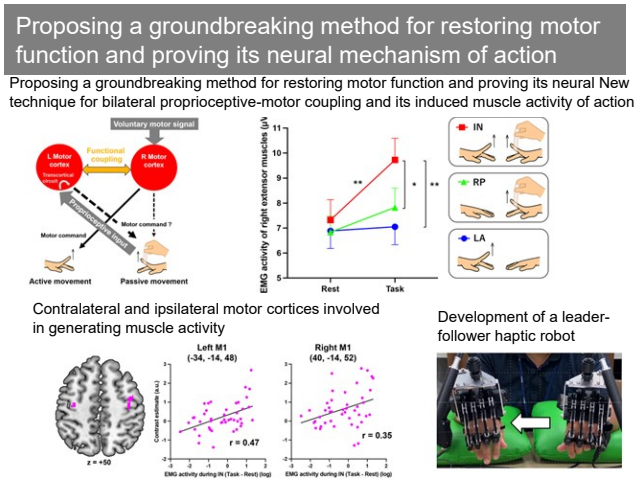


Fig.8 : Totally new technique for restoration of finger motor function, and revealing the brain mechanism behind it

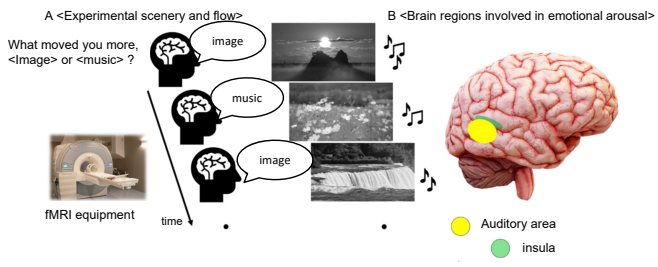


Fig.9 : Experiments on brain activity related to emotional arousal

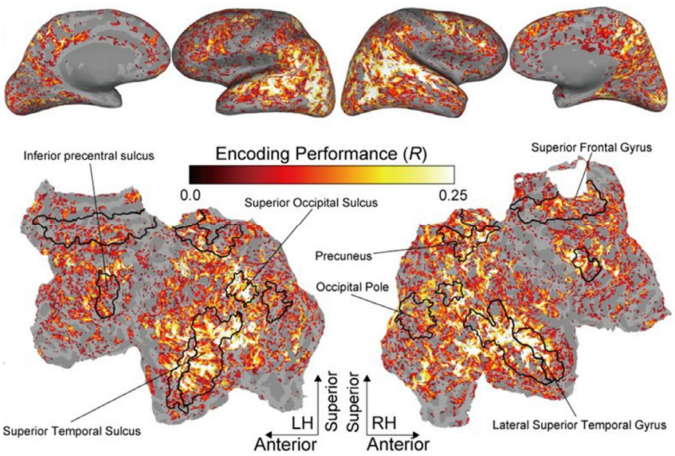


Fig.10 : Prediction through internal representation of the LLM

B5G Field

Beyond 5G Research and Development Promotion Unit

Executive Director of Unit HOSAKO Iwao

The Beyond 5G R&D Promotion Unit serves as the in-company command center for R&D toward the realization of Beyond 5G, vigorously advancing R&D on cutting-edge elemental technologies within NICT, while also functioning as a space where communities from different fields, which were fragmented physically and socially in the past, can collaborate and co-create with each other, aiming to enable all individuals to freely create new value themselves and establish Beyond 5G as social infrastructure that contributes to achieving the SDGs and Society 5.0.

Beyond 5G Design Initiative

To vigorously promote R&D on cutting-edge elemental technologies within NICT in order to realize Beyond 5G/6G, the Beyond 5G Design Initiative advances strategic planning for internal collaboration frameworks, shared awareness, and external partnership policies, alongside effective information dissemination through branding and system demonstrations. Concurrently, it conducts R&D on Beyond 5G / 6G concepts and architectures that connect diverse industries to create new value. In fiscal year 2024, the fourth year since its establishment, the initiative advanced architecture concretization and construction of proof-of-concept (PoC) systems in collaboration with domestic and international universities and research institutions.

Furthermore, through joint research with countries such as Germany and joint participation in international exhibitions, NICT accelerated expansion of its research globally and standardization activities. At MWC Barcelona 2025, NICT secured its own booth for the first time and exhibited some of the results from its collaborative research (Fig. 1). Leveraging a series of these successful international collaboration models, NICT also produced concrete joint research projects by concluding Memorandums of Understanding (MoUs) and holding workshops with countries such as France, Singapore, the U.S., and the UK. Domestically, NICT drives collaboration with industries and other fields through forums and other activities, while also focusing on nurturing young talent. Furthermore, to build a framework to accelerate the accumulation of knowledge and its social implementation, NICT will establish "Innovation Bridge @TOKYO" in March 2026.

Terahertz Technology Research Center

The Terahertz Technology Research Center engages in the following efforts on Terahertz Wave ICT Platform Technology.

1. Realize the future information and communications infrastructure expected to deliver even faster speeds and greater capacity in the Beyond 5G era

NICT will conduct R&D on platform technologies for measurement, evaluation, implementation, and utilization that support terahertz wave ICT and sensing technology. NICT will contribute to advancing international standardization activities, including frequency allocation, for social implementation of terahertz wave ICT systems.

In its international standardization activities, NICT has continuously worked on spectrum standardization in frequency ranges above 275 GHz at ITU-R, etc. In fiscal year 2024, it achieved the publication of new Reports M.2548 and M.2541, as well as a revised version of Report F.2416-1. At the request of the IEEE 802.15 chairman, NICT made a proposal to the session program for the Wireless Next Generation, including presenting unprecedented live demonstrations. With the approval of the IEEE 802.15 Working Group and the IEEE 802 LAN/MAN Standards Committee, presentations and exhibitions were conducted on the current state of THz wireless development based on IEEE 802.15.3e compliant SoCs and new use cases, which greatly attracted the interest of IEEE 802 participants.

2. Terahertz wave measurement and evaluation fundamental ICT

NICT will develop a measurement and evaluation technology for terahertz band radio wave characteristics and device frequency characteristics, etc., and construct measurement and evaluation infrastructure for various systems utilizing terahertz band radio waves and promote their use for accelerating the establishment of terahertz wave ICT and sensing technology.

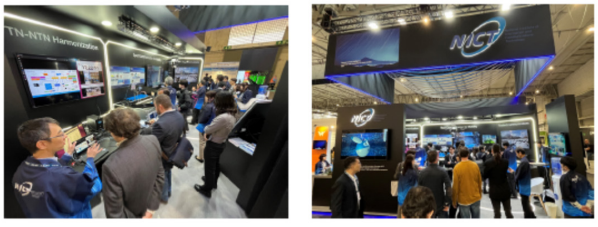


Fig.1 : NICT's first independent exhibition at Mobile World Congress (MWC) Barcelona 2025 (March 3-6, 2025)

In fiscal year 2024, NICT conducted R&D on the Radio-on-Terahertz-over-Fiber system that applies optical fiber wireless (Radio-over-Fiber: RoF) technology, focusing on reducing noise during down-conversion from the 300 GHz band to lower frequencies. This enables down-conversion to lower frequencies and also allows for generation of low-noise optical two-tone signals. This approach is considered as a potential technology applicable to terahertz communications in the Beyond 5G era.

To achieve high-accuracy spectrum measurement in terahertz bands, NICT is conducting R&D on advanced methods for high-accuracy terahertz light generation, control, and measurement utilizing mutual wavelength conversion with the optical band (near-infrared light), where fundamental technologies such as generation, control, and measurement have already been established. A spectral drill resonator was introduced using amplified single longitudinal mode laser light as the optical frequency reference and excitation light. This resonator employs a narrow-linewidth wavelength-tunable light source, enabling measurement of optical frequency changes at any frequency as changes in transmitted light intensity. This light serves as the frequency control light that determines the terahertz optical frequency. The upper part of the figure (Fig. 3) shows an overview of the device, while the lower section shows photographs of the terahertz light detection signals along with indications of the presence or absence of the incident terahertz light being measured. Since the reference light, terahertz light, and detection signal light satisfy non-coaxial phase-matching conditions, the presence or absence of the target terahertz light input enables detection of the presence or absence of the signal to be observed at a position different from that of the reference light. Since the spectrum of this detection signal light reflects the spectrum of the incident terahertz light, performing optical measurements together with the reference light signal enables highly accurate terahertz optical measurements traceable to national standards, corresponding to the accuracy of the light.

3. Space utilization technology for ultra-high-frequency electromagnetic waves

To contribute to future space industrialization, NICT will conduct R&D and implementation/operational testing of foundational technologies, ultra-compact lightweight satellite sensors, and electromagnetic wave propagation models, for utilizing terahertz wave sensing and communications in space. Furthermore, to advance and promote utilization of satellite observation data from ultra-high-frequency electromagnetic waves, NICT will work on satellite data information processing, etc., using new data mathematical algorithms.

As a specific example, focusing on lunar water resource exploration, NICT demonstrated through laboratory experiments and radiative transfer modeling that terahertz wave remote sensing can estimate regions on the lunar surface that are rich in water ice and mineral resources. Additionally, leveraging the advantages of terahertz waves, NICT also succeeded in developing an ultra-compact sensor weighing around 10 kg compared to a sensor weight of approximately 324 kg in the microwave band (Fig. 4).

Furthermore, the "Submillimeter Wave Instrument (SWI)" aboard the Jupiter Icy Moons Explorer (JUICE), a major mission of the European Space Agency's (ESA), completed its performance verification in the space environment during the lunar and Earth flybys in August 2024 after its launch in April 2023, successfully observing the Earth's atmosphere and the Moon. As a member of the international team, NICT contributed to R&D of the primary and secondary mirrors, actuators, and observation data analysis algorithms.

In air pollution monitoring, to realize the concept that "Anyone can monitor air pollution with just a smartphone," NICT developed a simplified aerosol concentration estimation mathematical algorithm (SNAP-CII) utilizing camera images and ICT. This development achieved an accuracy rate of 76%, which is equivalent to that of weather forecasts, in the three-class classification of atmospheric aerosol concentrations such as PM2.5. Furthermore, aiming for expansion into Europe where air pollution monitoring is now being commercialized, NICT exhibited at the trade show "Pollutec Paris" held in Paris in 2024 with the cooperation of IDI-PoCC, conducting various activities toward social implementation.

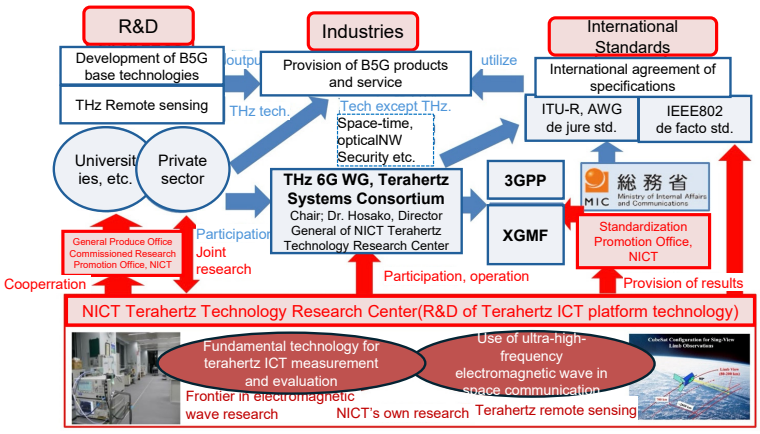


Fig.2 : Overview of Terahertz Research Center

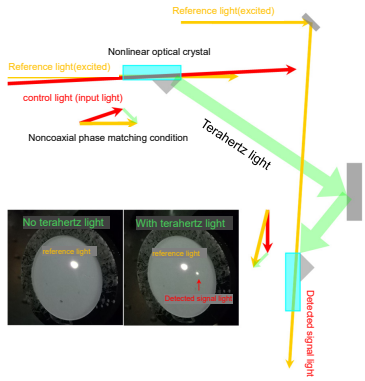


Fig.3 : Overview of terahertz spectrum experiment device and photographs of detection signal light; Absence of incident terahertz light (lower left) and presence of incident terahertz light (lower right)

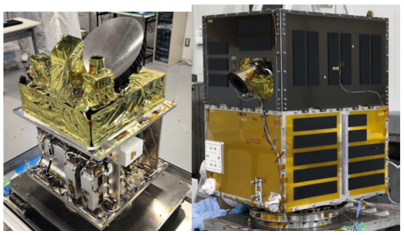


Fig.4 : The sensor unit (left) and overall configuration (right) of the developed lunar orbiting terahertz remote sensing instrument (EM)

AI Field

AI Research and Development Promotion Unit

Executive Director of Unit OIWA Kazuhiro

NICT has positioned "AI" as one of the four research areas to strategically advance in its fifth Mid- to Long-term Plan, aiming to accelerate R&D and social implementation. In response to this strategy, the AI Research and Development Promotion Unit was established in September 2024. This unit has taken over the activities of the AI R&D Headquarters of the Universal Communication Research Institute, and works cross-sectionally to coordinate and support R&D activities related to AI across NICT. Its organizational structure is designed to facilitate timely decision making and cross-sectoral cooperation in order to flexibly respond to the accelerating evolution of AI technology and the increasingly complex scientific, social, and policy issues associated with it. Two offices—the General Planning Office and AI Research and Development Design Initiative Office—were established to operate under the Vice President in charge and welcome department director and center director-level researchers from each research institute as senior researchers. Taking an overview of the entirety of NICT, the departments support the formulation and promotion of AI R&D policies and contribute to promoting collaboration and strategic activities between research institutes inside NICT. In the recent AI field, the emergence of generative AI in particular has had a huge impact on technology and society, and the existing AI application areas have greatly expanded. Generative AI, which assumes large-scale pre-learning, has been applied in a wide range of fields such as natural language processing, image generation, simulation, and design support, and has formed a huge global market. In response to these trends, NICT is exploring and encouraging research on a range of intellectual concepts related to generative AI including, for example, physical intelligence, swarm intelligence, studies inspired by insect and human brains, affordance, and symbol grounding. NICT is advancing efforts toward AI for Science by utilizing unique AI assets such as Japanese language data as well as the space, weather, and environmental measurement data that NICT has accumulated and developed over many years, with the aim of contributing to the development of basic AI technologies (AI for ICT) that may help address social challenges and enhance Japan's international competitiveness. The AI Research and Development Promotion Unit supports these research activities.

Activity for Policies and Organization Development of the AI R&D Promotion Unit

The AI R&D Promotion Unit is developing activities centered on the following three pillars. In the Examination of AI R&D Strategies and Knowledge Accumulation, we are continuously investigating and analyzing AI technology trends, market needs, standardization, and regulatory movements in Japan and overseas, working to accumulate knowledge related to AI research. We share survey results with related organizations inside and outside NICT (such as the Ministry of Internal Affairs and Communications, universities, and companies), and they are shared as reference materials for discussions on policy formulation and research project design. Next, in the Support for AI Research within NICT and Acceleration of Social Implementation, we are strengthening support for the AI application research conducted by each NICT research institute and building a framework to guide the results toward social implementation. In particular, we support efforts toward the deployment of AI technology using NICT's own highly reliable data and support the demonstration of AI applications in multiple fields such as disaster response, network control, multilingual translations, and space communications. In the third pillar, Promotion of External Collaboration and International Cooperation, we are engaging with AI-related organizations in Japan and overseas, such as the AI Safety Institute, the GPAI Tokyo Expert Support Center, and the AI Japan R&D Network. We are actively involved in discussions on international standardization, governance, and social implementation, and serve as one of the contact points for collecting and disseminating information on AI.

Response to Trends in Generative AI and to Issues Related to it

Generative AI has made a breakthrough compared to previous forms of AI due to its high response capacity and wide range of applications. However, it also highlights the following challenges. On the scientific front, the bias caused by training data, lack of explainability, and opaque processing

are problematic. On the social front, the spread of disinformation, its impact on the labor market, and the widening of digital divides are issues. On the policy front, there is a gap between ethics, legal systems, and regulations on the one hand, and technological innovation on the other. To address these safety-related issues, this unit promotes activities aimed at the well-balanced integration of AI into society through dialogue with various stakeholders, strengthens the survey and information dissemination system, and maintains an awareness of AI governance and consistency with policies in order to fulfill its role as a national research institute.

Start of Cross-organizational Research Support (SAIL fund)

In FY 2024, the AI R&D Promotion Unit launched the Strategic AI Initiative for Linkage (SAIL) Fund, which encourages collaboration among different sectors and organizations within NICT. The fund focuses on supporting budding AI research through collaboration across sectors and organizations; promoting open collaboration with research institutions, universities, and companies in Japan and overseas; and promoting research on the security, ethics, and explainability of AI. In addition to supporting the advancement of AI technology, SAIL is intended to contribute to the development of a social infrastructure that allows AI to be used safely and reliably. It is fostering the emergence of challenging proposals that are not bound by conventional frameworks (Fig.2).

For Future Development: Exploration of Next-generation Intelligence

AI is rapidly becoming more sophisticated, as evidenced by generative AI. In the future, it will be required to evolve from mere information processing to "AI that understands meaning." An important problem in this context is the symbol grounding problem. It encompasses how the language and symbols used by AI are connected to the real world and come to have meaning. Research on intelligence based on physicality, interactions with environments, and behavior will be key. This unit is exploring research directions toward what may be described as "intelligence beyond generative AI." We will support the exploration of various intelligent systems, such as swarm intelligence, affordance, bodily intelligence, the brains of insects, and human brain models. In addition, by combining it with NICT's original data collection, management, and analysis technology, we will bring about "AI for Science" and "AI for ICT," which utilize AI in the fields of science and engineering. In the future, as a bridge between AI technology and society, this unit will organically connect NICT's research assets and contribute to the creation of new intelligence and the achievement of a sustainable information and communication society.

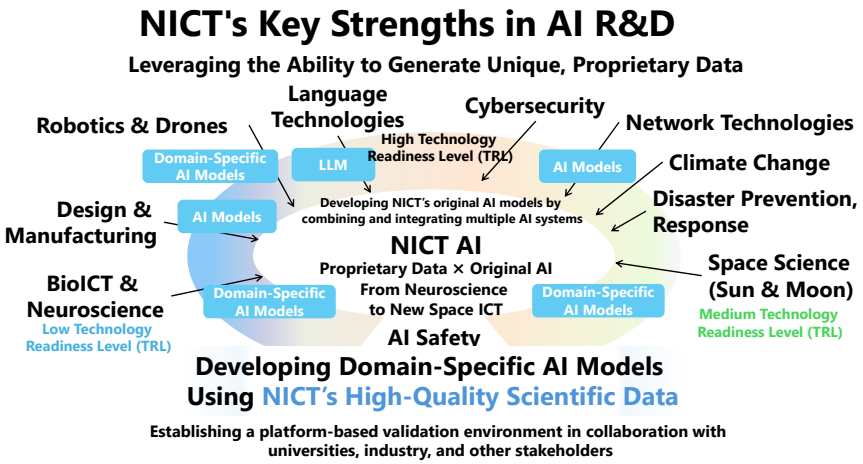


Fig.1 : Strength of NICT's AI Research and Development

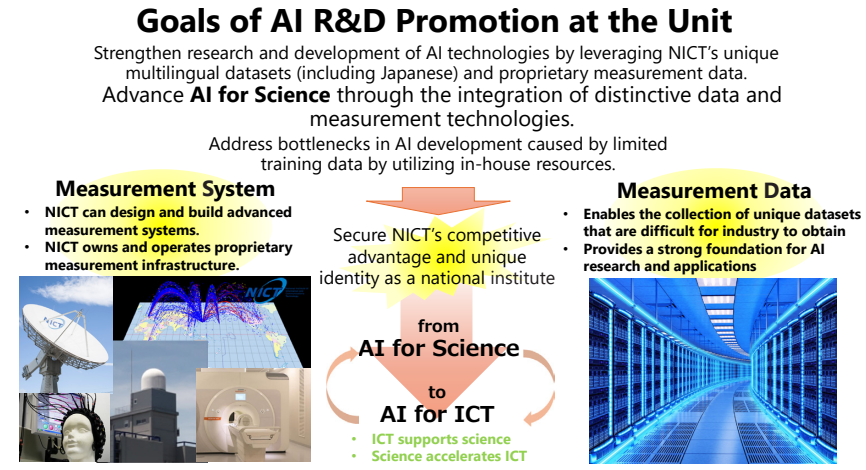


Fig.2 : Goals of AI Research and Development Promotion

Quantum ICT Field
Quantum ICT Collaboration Center

Director General FUJIWARA Mikio

The Quantum ICT Collaboration Center was established in 2021 as the core organization for operating the Quantum Security Innovation Hub, which is one of 8 Quantum Technology Innovation Hubs (currently 12) in Japan. Its purpose is to (1) develop and demonstrate the quantum security field, which is a new academic domain that merges quantum cryptography and quantum communication combining with present cryptography, information theory, network technology, etc., and implement it in systems; and (2) aim to merge the quantum secure communication field, quantum computing field, and quantum measurement/sensing field, define the quantum internet (Fig. 1) as new infrastructure for providing advanced functions that can only be achieved using quantum technology including computation processing, measurement, sensing, communication, and cryptography, create an industry-academia-government collaborative creation environment in cooperation with parties inside/outside NICT, and make efforts in R&D, implementation and testing on open test beds, social deployment, and human resource development in a unified manner.

Expansion of the Tokyo QKD Network

To build next-generation secure cryptography infrastructure, the Quantum ICT Collaboration Center developed quantum key distribution equipment, high-speed covert communication and secret distribution software, and quantum-classical hybrid information processing equipment to expand and build the quantum key distribution network (Tokyo QKD Network) and demonstrate the quantum secure cloud. In 2024, we developed functions for conducting R&D on the elemental technology of the quantum internet on the Tokyo QKD Network, and carried out performance tests chiefly of the quantum key distribution. In addition, aiming for social implementation of quantum cryptography communications

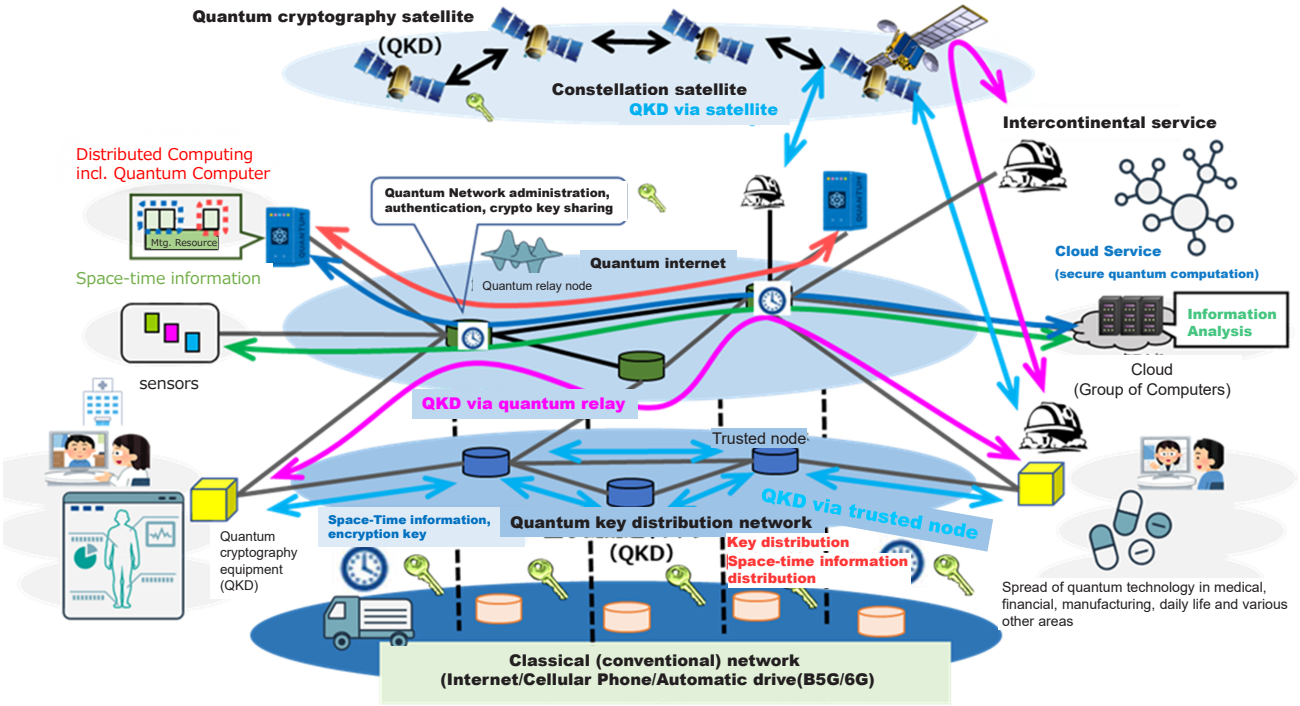


Fig.1 : Conceptual diagram of quantum internet

networks, we held demonstrations of an application that utilizes the QKD network for new companies and presented achievements through demonstrations at the Quantum Cryptography Technology Seminar (held online by the Quantum Forum), thus seeking out new users.

Satellite Quantum Cryptography Technology

In addition to developing QKD between satellites and ground stations, we have been taking advantage of line-of-sight communications to theoretically formulate a quantum eavesdropping channel model for cases where the received optical power level is in a quantum state. Furthermore, we successfully conducted a secret key sharing experiment between the International Space Station (ISS) and a mobile ground station using physical layer cryptography (Fig. 2). The experiment was conducted using a key distillation board that was developed by NICT and made up of commercial off-the-shelf (COTS) products. The board has functioned properly in a low-orbit satellite environment for more than a year. In addition, Vernam's one-time pad (OTP) cryptography function was incorporated into equipment installed in the ISS and successfully carried out OTP cryptography transmission using a shared key. The key distillation equipment and optical signal generation equipment are resistant to the heat, vacuum, vibration, and radiation of the ISS orbit, which is necessary for future quantum key distribution, and require complex computation processing. We verified that the equipment had worked properly for one year.

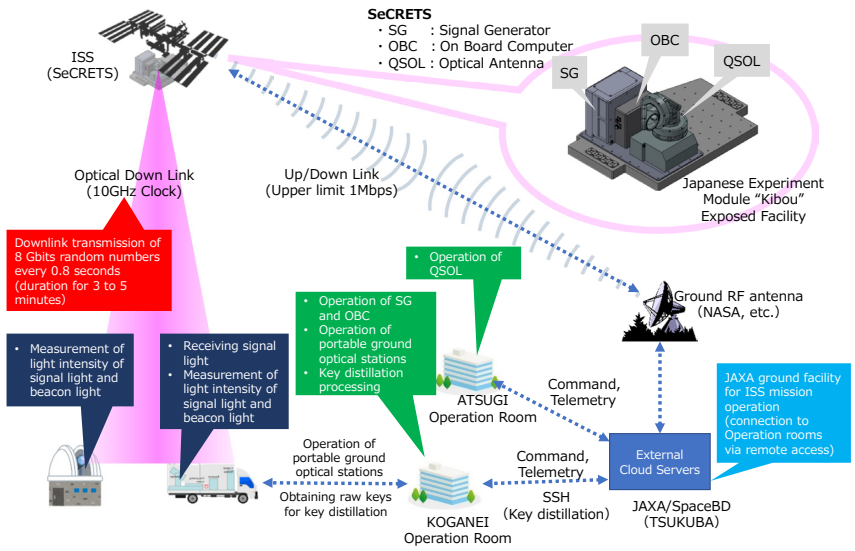


Fig.2 : Conceptual diagram of a demonstration on information-theoretical safe key sharing between the ISS and a portable ground station

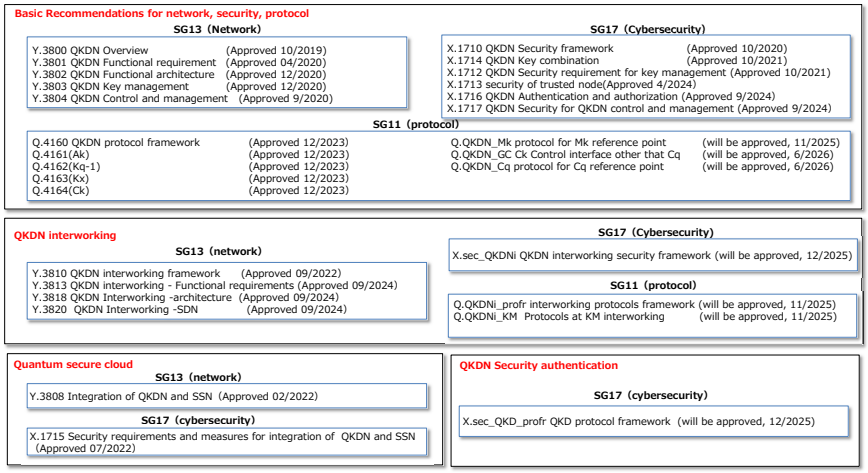


Fig.3 : Overview of ITU-T standardization activities

Standardization Activities

We attended the ITU-T, ETSI, and IOWN and proposed various contributions, including 21 contributions addressed to the ITU-T, leading to the issuance of three recommendations, including approval and authentication of a QKD network in ITU-T SG17 (Fig. 3). In addition, NICT took the initiative in creating a Japan-specific Protection Profile (PP) and a Support Document (SD) concerning evaluation and examination methods for quantum cryptography modules, and the Quantum Forum submitted their applications to the Information-technology Promotion Agency (IPA).

Human Resource Development

We continued implementing the quantum native human resource development program NICT Quantum Camp (NQC) in FY2024 (Fig. 4). We held the following: (1) seminars for the public, (2) hands-on programs in which lectures and training were provided by specialists to chosen members, (3) exploratory programs in which participants conducted research under the guidance of supervisors and online exchange meetings were held among participants. There were 113 participants (an increase of 18 participants compared to the previous year) in (1), 66 participants in (2), and 5 sessions (8 participants) in (3).

Fig.4 : Photo of the NQC program

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General NAGANO Hidehisa

During the fifth mid-to-long-term plan period, anticipating advances in new technologies such as Beyond 5G toward the realization of Society 5.0, ICT Testbed Research and Development Promotion Center has been constructing "Beyond 5G/IoT Testbed with High-reliability and High-elasticity" (Fig. 1) and is carrying the followings.

Construction and Promotion of Utilization of Beyond 5G/IoT Testbed with High-reliability and High-elasticity and Its Promotion, and Its Current Usage Status

While proceeding as planned with construction of Beyond 5G/IoT Testbed with High-reliability and High-elasticity, which will serve as a technical verification environment for Beyond 5G networks, as a part of functional improvements to meet user needs, we accelerated the implementation of a linking function between Beyond 5G Reliable Virtualization Infrastructure and DCCS (Data Centric Cloud Service), which we had been considering in order to make effective use of the hardware resources of the next-generation testbed. Consequently, a use case was achieved where B5G Reliable Virtualization Environment and DCCS are interconnected and utilized together.

To further promote utilization of Beyond 5G/IoT Testbed with High-reliability and High-elasticity, we have strengthened the provision of information on new functions related to Beyond 5G (Reliable Virtualization Infrastructure, Mobile Environment, DCCS), CPS (Cyber-Physical System), and utilization examples for research and development of upper layer services (the number of utilization examples introduced on the website has increased from 25 to 30).

Improvements were also made to the use application process, such as the use of electronic contracts for joint research agreements and making application procedures entirely online. Furthermore, the brochure of NICT Integrated Testbed was revised to include new functions related to Beyond 5G and enhance the overall content, making it available on the website.

As a result of the efforts to promote cyclical evolution of the testbed, including the items mentioned above, as of the end of fiscal 2024, the number of projects using "NICT Integrated Testbed" reached 131 (64 internal projects and 67 external projects), and the number of external user organizations totaled 121. In terms of use by function, the new functions that began to be provided in October 2022 have been steadily used, and the expansion of functions has led to an increase in DCCS use (Fig. 2) and an increase in the number of service and application development cases.

Research and Development, Construction, and Operation of Platform Layer Testbed (DCCS)

In DCCS, a data analysis function is implemented using federated learning

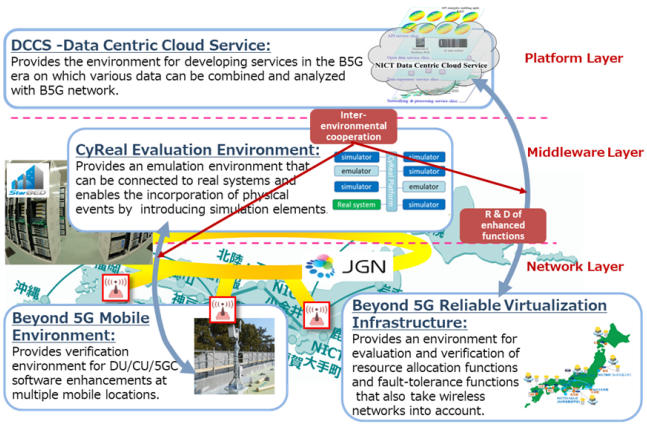


Fig.1 : Overview of functional collaboration in Beyond 5G/IoT Testbed with High-reliability and High-elasticity

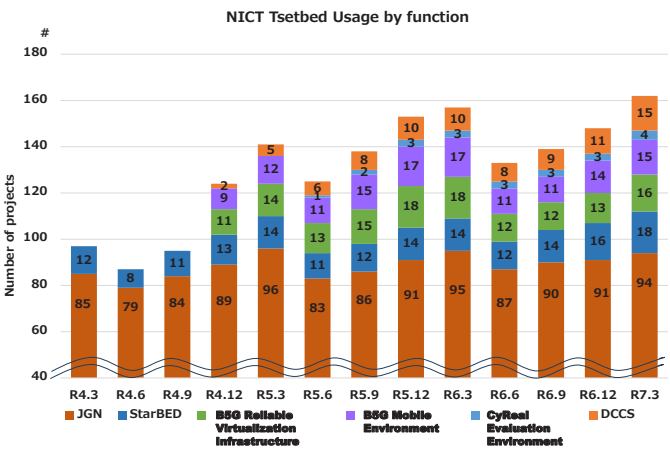


Fig.2 : Changes in the number of uses by each Testbed function

and offered to pilot users. By incorporating other users' research results (behavioral navigation software), synergistic effects are being created by sharing results.

Construction of a CPS architecture demonstration system is also underway based on the "Beyond 5G/6G White Paper version 3.0."

While preparing to provide "Himawari Satellite Data," "Solar Radiation Consortium Data," and "High-Resolution Precipitation Nowcast Data," we are also expanding its API and have begun offering the data to the general public. The data is also being used for research and development of NTN and the Expo 2025 Osaka, Kansai, Japan project.

We implemented a dictionary customization API for the multilingual speech translation platform and offered it to pilot users.

While we provide a development environment for distributed computing and edge computing, we support research and development of cutting-edge application development. Additionally, we have also started providing a Jupyter Hub-based "DCCS Trial" to improve usability and service quality.

Research and Development, Construction, and Operation of Middleware Layer Testbed

The CyReal Evaluation Environment, a testbed for the middleware layer, is constructed on StarBED and continuously supports development from the idea stage to implementation in a real environment by connecting simulation, emulation, and real systems.

To support construction of the CyReal Evaluation Environment on StarBED, we implemented the middleware TENTOU as a control platform that enables exchange of information between each element (Fig. 3). By providing a unified user interface for using and managing StarBED through TENTOU, we have achieved efficiency of use, ease of operation, and operational stability.

International Collaboration Utilizing CyReal Technology in ASEAN IVO

As a new project of ASEAN IVO (a virtual organization for NICT to promote global international collaboration between ICT R&D institutes and universities in the ASEAN region and Japan), we proposed the Cyber to Real World Integrated Testbed for Dam Safety Management and Water Governance System (Fig. 4), utilizing CyReal technology, in collaboration with organizations from Laos, Thailand, Myanmar, Cambodia, and the Philippines, and the proposal was successfully accepted. The new project is expected to become an international and practical use case for StarBED/CyReal in the future.

Research and Development, Construction, and Operation of the Network Layer Testbed

Based on the functional architecture described in the "Beyond 5G/6G White Paper version 3.0." published by NICT, we implemented and verified an interface and orchestrator for collaboration among the testbed services that enable the combination of heterogeneous network functions, provided resources, functions, data, etc. (Fig. 5). This was done by connecting the services that constitute the Beyond 5G/IoT Testbed with High-reliability and High-elasticity, such as "DCCS," "CyReal," "B5G Reliable Virtualization Infrastructure," and "B5G Mobile Environment," via virtual network technology. These functions are scheduled to begin operations as testbed functions in fiscal 2025. Furthermore, we have improved the stability and completeness of the large-scale verification platform (massive device emulation function) that enables the reproduction of an environment in which a large number of terminals and base stations are interconnected, which we had been researching and developing since previous fiscal year. We have begun offering it to general users. In addition to the above, for B5G Mobile Environment, combining 5G-SA (Stand Alone) system and B5G Reliable Virtualization Infrastructure, we verified a circular cycle of development and verification for Beyond 5G systems using actual equipment and a RAN/UE simulation environment.

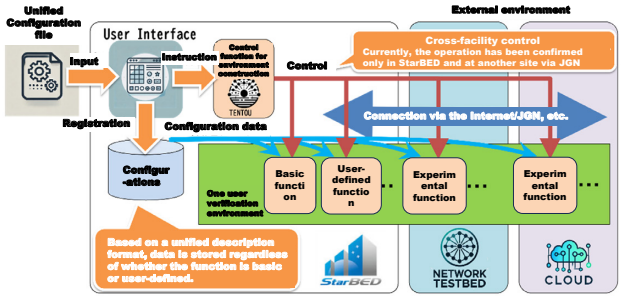


Fig.3 : Architecture of TENTOU Controlling StarBED/CyReal

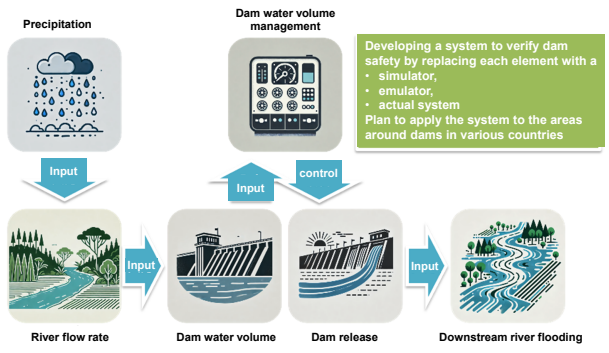


Fig.4 : ASEAN Project utilizing CyReal;
Cyber to Real World Integrated Testbed for the Dam Safety Management and Water Governance System

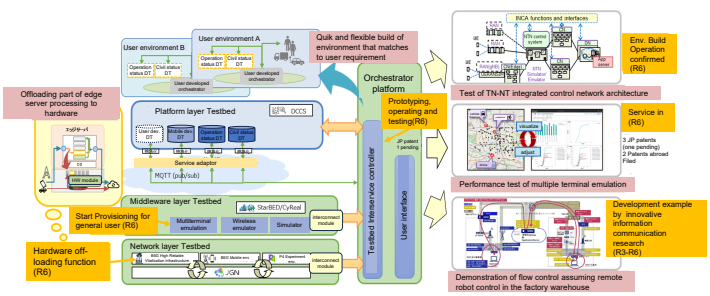


Fig.5 : Implementation of an interface and orchestrator for collaboration among services

Open Innovation

Innovation Promotion Department

Executive Director SAITO Hisashi

The Innovation Promotion Department works on the following missions in collaboration with organizations within and outside NICT to maximize the Institute's research and development outcomes

Promotion of Collaborative Research and Researcher Exchange

In FY2024, the number of joint research contracts reached 600, including ongoing contracts from the previous year as well as the 110 new ones signed in FY2024 (Fig.1). Additionally, NICT entered into 318 non-disclosure agreements. To promote researcher exchanges, we dispatched and accepted researchers and contributed to strengthening industry-academia-government collaboration with a focus on advancing mutual cooperation in the field of information and communications. NICT also promoted research exchanges with universities through a cooperative graduate school system by dispatching NICT researchers to give lectures at graduate schools and providing research guidance through the acceptance of research trainees.

Promotion of Commissioned Research

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

In FY2024, we initiated five new R&D projects in addition to 12 projects continuing from the previous year.

Our efforts resulted in 76 papers, 234 oral presentations, 194 standardization proposals, and 12 applications for industrial property rights (10 domestic and two foreign).

2. Promotion of commissioned research on R&D of innovative information and communication technology

In FY2024, in addition to 33 ongoing projects from the previous year, we launched 12 new projects under the Program for Elemental Technologies and Seeds Creation and one new project under the Strategic Program for Social Implementation and Global Deployment (Common Network Infrastructure Technology Establishment Type).

Research results in FY2024 came to 381 papers, 891 oral presentations, 446 standardization proposals, 35 standardization adoptions, and 604 applications for industrial property rights (288 domestic and 316 foreign).

Promotion of Acquisition and Appropriate Implementation of External Funding

The department investigated various research funding programs for their content and rules in order to provide NICT researchers with relevant information, checked and offered advice on over 100 application documents, and supported the researchers' administrative tasks incidental to applications, thereby helping researchers access external funding. To motivate NICT researchers to acquire external funding, the department held briefings on application guidelines and seminars to successfully acquire scientific research grants, and implements an external funds acquisition program. An overview of the external funds acquired in FY2024 is shown in Fig.2.

Proactive Acquisition and use of Intellectual Properties

In FY2024, the number of patent applications came to 155 (74 domestic and 81 foreign [including two utility model patents]), while the number of registered patents held by NICT was 905 (558 domestic and 347 foreign) as of the end of FY2024 (Fig.3). Compared to the previous year, the number of domestic patent applications increased, while that of foreign patent applications decreased slightly.

To comply with Japan's System for Non-Disclosure of Patent Applications introduced in May 2024, we streamlined the operational procedures for appropriately meeting requirements regarding the prohibition of foreign applications and the non-disclosure

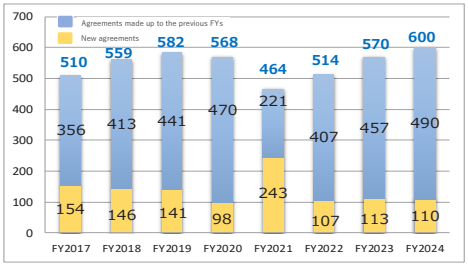


Fig.1 : Trends in the number of joint research contracts

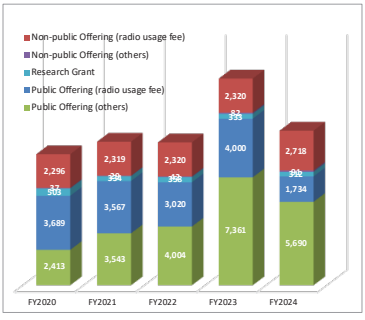


Fig.2 : Annual progress in external funds acquisition

of patent applications, and shared this new procedure with our research sites.

To introduce NICT's intellectual property (IP) right-protected seeds to industry and other sectors, we actively provided information about our IPs and technology use cases to industry and other sectors through our website, and took opportunities to explain and introduce the technologies. Jointly with the Japan Science and Technology Agency, NICT organized the "NICT New Technology Presentation Meeting" (held online on October 2, 2025) as an event for an external audience. Researchers themselves presented their latest achievements to companies interested in industry-academia collaboration. At Interop Tokyo 2025 (June 11–13, 2025, Makuhari), we worked with technology transfer recipient companies to showcase our technology transfer efforts and use cases. We introduced, in particular, NIRVANA Kai and DAEDALUS.

The number of new technology transfer agreements in FY2024 was 12, with the number of technology transfer agreements in force at the end of the fiscal year stood at 122. The revenue from technology transfers for FY2024 totaled 132 million yen. Compared to the previous year, the revenue increased (Fig.4), despite a decrease in the number of agreements.

Promotion of Standardization Activities

NICT was represented by a total of 579 researchers from its research institutes and centers at meetings of international standardization organizations, and submitted 232 contribution documents (including 159 related to Beyond 5G). This led to the establishment of 24 international standards (including 21 related to Beyond 5G) based on NICT's R&D results.

The main outcomes of NICT's standardization activities based on its research results are as follows.

· At ITU-T SG13, we contributed to the approval of a recommendation concerning the integrated network control system architecture for terrestrial network (TN) and non-terrestrial network (NTN) convergence. This enables the construction of NTN networks with interconnectivity between different communication providers.

· ITU-T SG17 approved our recommendations to define "authentication and authorization," "control and management security", and other requirements necessary for constructing quantum key distribution networks (QKDNs). Based on the security technologies implemented for the Tokyo QKDN, we proposed activities which led to the completion of these recommendations.

· At the International Electrotechnical Commission (IEC), we contributed to the development and establishment of a method for measuring a common mode rejection ratio of coherent photodetectors and that for measuring the nonlinear response of photoelectric converting devices, enabling highly accurate, unified measurement and evaluation methods.

· At the Internet Engineering Task Force (IETF), we contributed to the establishment of a telemetry specification for measuring multicast communication quality as a proposed standard. The standard was jointly proposed with European and American telecommunications carriers and manufacturers. This enables the maintenance and monitoring of multicast communication quality independent of vendors and network equipment.

· At the IOWN Global Forum, we contributed to the creation and establishment of a PET architecture for protecting data during processing and an MFS architecture for protecting data during transmission. This became the first security architecture document for the IOWN Global Forum.

At international standardization conferences and meetings, 27 NICT members served on a total of 75 key posts, including the chairmanship of ITU-T Study Group 13, where they led discussions and coordinated outcomes. Additionally, 41 NICT members held a total of 80 principal positions at domestic committees and other forums responsible for discussing domestic standards and formulating Japan's policy for activities at international standardization meetings, to provide their expertise in deliberations. At the ITU World Telecommunication Standardization Assembly (WTSA-24) held in October 2024, NICT members were appointed as the Chair of SG13 and Vice Chair of SG11. Key activities at international standardization conferences and meetings are as follows.

ITU-R WP5D, following the approval of the recommendation framework for IMT-2030 in November 2023, began developing minimum requirements for wireless interface technologies and evaluation methodology. NICT has been submitting contributions on minimum performance requirements for positioning technology that utilizes compact atomic clocks under development at NICT, with a focus on its social implementation (Fig.5).

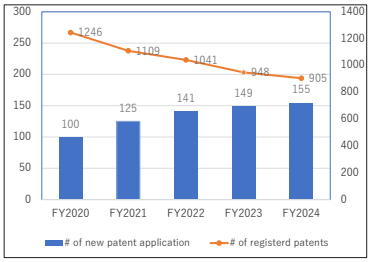


Fig.3 : Trends in Patent application and registered patents

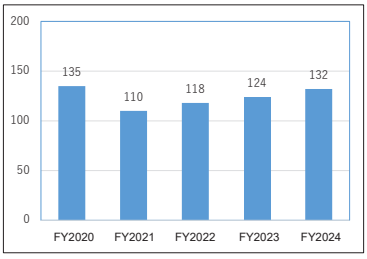


Fig.4 : Trends in revenue from Intellectual Properties (unit:million yen)

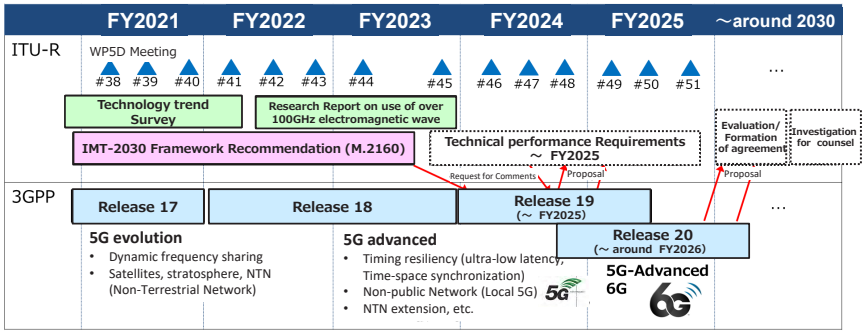


Fig.5 : Schedule for IMT2030

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Global Alliance Department

Executive Director NAGATA Kazuyuki

Collaboration with leading international research institutions and universities is crucial for achieving significant results in research and development into information and communication technology, as well as the deployment of its outcomes. Therefore, the Global Alliance Department aims to maximize research and development outcomes and promote their global dissemination by enhancing international collaboration in research and development activities of the National Institute of Information and Communications Technology (NICT) and facilitating the international deployment of these outcomes.

Establishing and Promoting International Collaborative Relationships

NICT concluded 11 memorandums of understanding (MOUs) with overseas universities and research institutions in FY2024, which included five new agreements and six renewals. In the first half of FY2025, NICT entered into five additional MOUs, comprising one new agreement and four renewals. As of the end of the first half of FY2025, NICT has a total of 77 MOUs with 76 institutions across 24 countries (Fig. 1). Based on these MOUs, during the first half of FY2025, NICT organized three joint workshops: the Japan-France Joint Workshop 2025 in France, the TASA/NIAR-NICT Joint Workshop in Taiwan, and the NECTEC-NICT Joint Workshop 2025 in Thailand, enhancing collaboration with these institutions.

NICT also seizes opportunities presented by visits from overseas government officials and university representatives seeking research collaboration (Fig. 2), thereby contributing to the advancement of relationship-building for international partnerships.

Promoting International Collaborative Research with the U.S. and Europe

Under the Japan-U.S. Network Opportunity 3 (JUNO3), an international collaborative research program in the network domain jointly operated with the U.S. National Science Foundation (NSF), a final Principal Investigator (PI) meeting was held in August 2025. This meeting focused on five Japan-U.S. collaborative research projects—four commissioned externally and one internal to NICT—centered on the theme of R&D for Programmable Networking for Next Generation Core and Beyond 5G / 6G Networks. Each project presented its research findings, and the program, which began in 2022, concluded that month, having achieved significant results.

In the field of computational neuroscience, the international collaborative research program known as Collaborative Research in Computational Neuroscience (CRCNS) includes participation from the U.S., Germany, France, Israel, Spain, and Japan (NICT). In this research program, a collaborative research project initiated in September 2022 was concluded at the end of August 2025. Additionally, a new

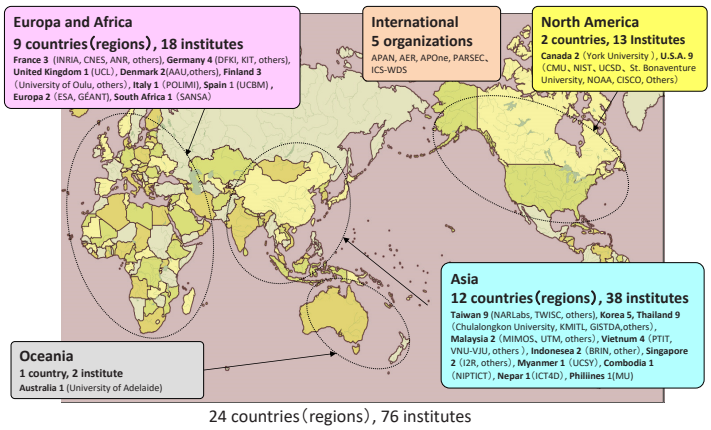

Fig.1 : Overseas institutions with which MOU have been exchanged

Fig.2 : Visit by Luxembourg's Minister for Digitalization, Research and Higher Education (September 2025, NICT Headquarter)

international collaborative research project involving Japan, the U.S. and Germany began in September 2025.

Furthermore, through the B5G Collaboration Fund, which promotes international joint research in the Beyond 5G domain, NICT has supported nine collaborative research projects with research organizations in Germany, France, and other countries, which were initiated in January 2025.

Continuous Advancement of International Joint Research and Development with Asian Countries and the Deployment of Outcomes

The ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO) is a research collaboration organization jointly operated by NICT, research institutes, universities, and other entities across the ASEAN region. Over time, it has evolved into a collaborative research body comprising 102 participating institutions. The organization has a significant presence in the ASEAN region by implementing 52 projects to date, engaging 623 researchers (Fig. 3).

In November 2024, NICT hosted the ASEAN IVO Forum 2024 in Phnom Penh, Cambodia, to establish international research collaboration projects. The forum featured 24 research presentations from the 10 ASEAN countries, including Japan, encouraging active discussions and the exchange of ideas. Additionally, five new projects were selected to commence in FY2025.

As a result, in FY2025, NICT is promoting 14 joint research and development projects that were initiated between FY2022 and FY2025, including ongoing projects, with the theme of addressing common social challenges in the ASEAN region. Multilateral collaborative research is being conducted to address various challenges using information and communication technology (ICT). For example, in the field of safe, secure smart societies, research and development focuses on smart-energy sharing and management devices for low-carbon societies, water quality monitoring systems that account for climate change, and road safety monitoring systems. In the food field, research and development focus on crisis management systems for regional food manufacturers. Additionally, in the fields of environmental protection and disaster prevention, research and development are underway to develop landslide observation and prediction systems.

To celebrate the 10th anniversary of ASEAN IVO's establishment, NICT organized a commemorative event in Bangkok in September 2025. The event was attended by directors of research institutions and university presidents from countries involved in ASEAN IVO. During our discussions, we explored future strategies for enhancing international cooperation and collaboration (Fig. 4).

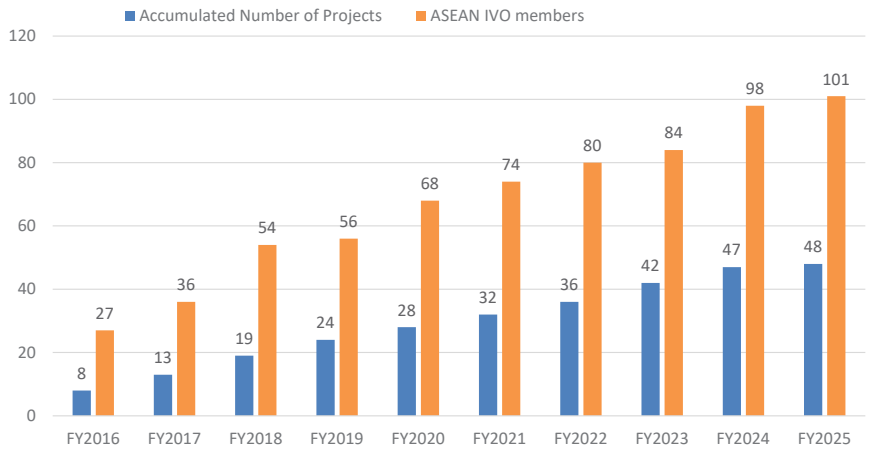

Fig.3 : Number of projects and member institutions in ASEAN IVO

Initiatives to Enhance NICT's International Presence

In March 2025, at Mobile World Congress (MWC) Barcelona 2025 held in Spain, NICT established its own booth for the first time, showcasing its latest research and development achievements, primarily in Beyond 5G (Fig. 5).

The total number of visitors to the NICT's booth reached 1,800. The Institute also fielded interviews from both the domestic and international press, significantly enhancing its global presence.

Fig.4 : Group photo at ASEAN IVO 10th Anniversary

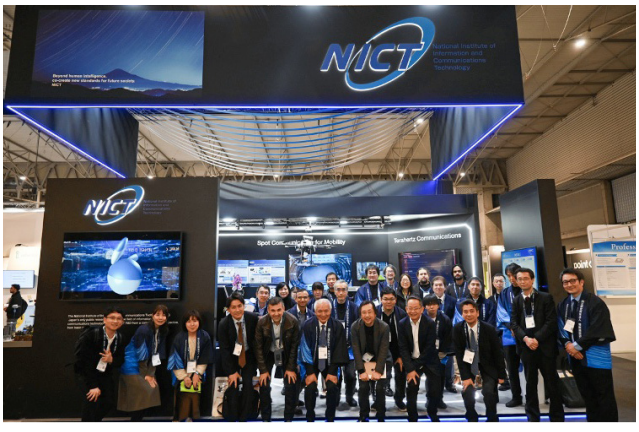

Fig.5 : Snapshot at MWC2025, Barcelona

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director HONMA Yuichi

The ICT Deployment and Industry Promotion Department is responsible for overseeing comprehensive operations to promote the information and communications industry, aiming to revitalize industries, foster an inclusive society where everyone can live safe, secure, and prosperous lives, and support the penetration of information and communications services into people's daily lives through the utilization of information and communications technology, which serves as the foundation of social life and economic activities. Specifically, the department implements initiatives such as supporting the commercialization of information and communications ventures, including the creation of locally-based ICT startups; promoting an information barrier-free environment; encouraging foundational technology research in the private sector; supporting commercialization that contributes to deploying research outcomes from NICT; and facilitating international exchange in research and development of information and communications.

Providing Information and Networking Opportunities for Regional ICT Startups

1. "Kigyouka Koshien"* and "Kigyouka Banpaku"*

On March 13, 2025, NICT hosted the **"Kigyouka Koshien"**, followed by the **"Kigyouka Banpaku"** on March 14 at the Marunouchi Building Hall & Conference Square in Chiyoda-ku, Tokyo. Continuing from FY2023, the event featured the presentation of both the Minister of Internal Affairs and Communications Award and the NICT President's Award. At the **"Kigyouka Koshien"** the Minister of Internal Affairs and Communications Award was won by Kick Space Technologies Inc. and Kyushu Institute of Technology, represented by Co-Founder & CEO SATO Rin, for their presentation titled "Orbital Demonstration Services Utilizing Ultra-Small Satellites." Additionally, Real Touch Inc. and Hokkaido University Graduate School, represented by CEO MAKI Shun, received the NICT President's Award for their presentation "Easy Operation for Everyone with Haptic Senses! General-Purpose Robots Transforming the Fisheries Industry." (Fig. 1).

At the **"Kigyouka Banpaku"** TriOrb Inc., led by CEO ISHIDA Shuichi, which presented the "TriOrb BASE 360° Spherical Mobility Platform that builds the foundation for next-generation industries," received the Minister of Internal Affairs and Communications Award. F.MED Inc., under Co-Founder & CEO SHIMOMURA Keita, which presented the "Development of a Microsurgery Support Robot Contributing to Improving Human Quality of Life," received the NICT President's Award (Fig. 2).

2. Participation in exhibitions

(1) NICT provided exhibition opportunities to 10 participants, including entrepreneurs from **"Kigyouka Koshien"** and **"Kigyouka Banpaku"** as well as startups interested in showcasing their work at CEATEC 2024, which was held in October 2024. Additionally, NICT had a booth to share initiatives such as the **"Kigyouka Koshien"** and **"Kigyouka Banpaku"** and to enhance our brand visibility. Among the 10 exhibitors, three teams consisted of current students.

(2) At the Future Life Experience section of the Expo 2025 Osaka, Kansai, Japan, NICT conducted hands-on exhibitions and stage events as follows:

(i) From September 16 (Tue) to 22 (Mon), 2025, over seven days, the "Colors for Future — The (Very) Near Future that ICT Startups Attaract" exhibition was held within the Future Life Experience. This featured introductions to NICT initiatives by the Entrepreneur Promotion Office and the Universal Communication Research Institute, alongside hands-on exhibitions by nine companies that had previously participated in the **"Kigyouka Banpaku"**.

(ii) On September 16 (Tue), NICT organized

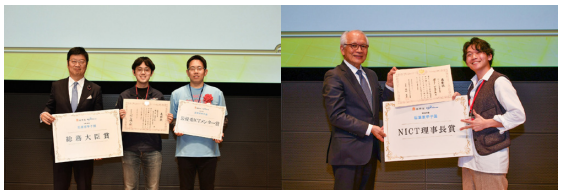

Fig.1 : "Kigyouka Koshien": Recipients of the Minister of Internal Affairs and Communications Award and the NICT President's Award

Fig.2 : "Kigyouka Banpaku": Recipients of the Minister of Internal Affairs and Communications Award and the NICT President's Award

* "Kigyouka Koshien" for studentsand "Kigyouka Banpaku" for young entrepreneurs are the series of business plan contests for ICT startups, beginning from related regional contents with the deep helps by NICT mentors. The Final contests were in March every year.

the "Alumni Network Night".
(iii) On September 17 (Wed), NICT hosted the "NICT Next Entrepreneurs Pitch supported by Startup Challenge Koshien × High School Business Plan Grand Prix" as a collaborative event for the FY2025 **"Kigyouka Koshien"** (Fig. 3).

3. Information provision on the Internet

On the ICT Startup Promotion Center website (https://www.nict.go.jp/venture/index.html), NICT gathers and provides valuable and timely information for regional ICT startups, including introducing NICT's support measures.

Promoting an Information Barrier-free Environment

To promote its efforts to realize an information barrier-free environment where everyone can equally access telecommunications and broadcasting services, NICT receives subsidies from the Ministry of Internal Affairs and Communications. NICT in turn provides grants and barrier-free information for projects such as the production of subtitled, audio-described, and sign language programs that assist persons with visual or hearing impairments in watching television broadcasts, and for the provision and development of services enabling persons with physical disabilities to use telecommunications and broadcasting services smoothly.

1. Facilitating the production of subtitled, sign language, and audio-described programs

(1) NICT provides financial assistance to cover some of the costs of producing subtitled programs for persons who are hard of hearing, as well as sign language and audio description programs for those with visual or hearing impairments in television broadcasting. NICT has awarded grants to 127 broadcasters nationwide, enabling the broadcast of 61,325 programs featuring subtitles, audio descriptions, and sign language.
(2) NICT provides financial assistance to cover some of the costs of producing sign language translation videos that are composited and displayed onto broadcast programs via information reception devices for persons who are hard of hearing (communication support tools). By providing grants to one company, NICT supported the production of 122 sign language translation video programs for compositing onto broadcasts, thereby providing opportunities for persons who are hard of hearing to obtain information from broadcasts.
(3) NICT provides financial assistance to cover some of the costs of maintaining equipment for providing subtitles on live broadcast programs. NICT provided grants to two broadcasters to promote the maintenance of equipment that contributes to the spread of live subtitled programming.

2. Promoting the provision and development of telecommunications and broadcasting services for persons with disabilities

NICT offers financial assistance to cover some of the costs related to projects that develop and provide telecommunications and broadcasting services with significant ripple effects and benefits that enhance the convenience of persons with disabilities. NICT has provided the Grant for Information Barrier-Free Communication and Broadcasting Service Provision and Development Promotion (renamed the Grant for Promoting Information Barrier-Free Service Provision from FY2025) to support four projects (Fig. 4), thereby contributing to the provision of communications and broadcasting services that enhance convenience for persons with physical disabilities. During the application period, NICT publicized the program through press releases, related websites, and email distribution. Grant decisions were made based on evaluations by the Evaluation Committee for the Project to Facilitate Access for Persons with Disabilities.

3. Provision of barrier-free information

NICT offers a wide range of barrier-free information through monthly feature articles on topics directly valuable to persons with disabilities and their supporters, as well as initiatives related to barrier-free information.
https://www.nict.go.jp/info-barrierfree/ (only available in Japanese)

NICT promotes development that addresses the difficulties faced by persons with disabilities and others by offering information on ICT devices and services designed with accessibility in mind, as well as helpful information for those seeking to develop such products and services.
https://www.actnavi.jp/ (only available in Japanese)

Fig.3 : Exhibitions inside the venue (left) and President Tokuda with the recipients of the NICT President's Award (right)

Fig.4 : Example of a grant program: Providing cloud-based information accessibility services (e.g., subtitle guides viewable through glasses) for film, video, and performing arts at the NPO Media Access Support Center

Support for Inviting Overseas Researchers and Hosting International Research Conferences

NICT implements programs inviting overseas researchers to Japanese research institutions (excluding NICT) through its unique International Exchange Program and the *Japan Trust International Research Cooperation Program (Japan Trust) and subsidizes the costs. Japan Trust is funded by public trust assets established by private benefactors. Additionally, the International Exchange Program provides support for hosting international research conferences.

NICT has issued nine invitations to overseas researchers to conduct research at Japanese universities as part of the international exchange program. Additionally, NICT supported 15 international research conferences, including the Optics and Photonics International Congress 2024.

Research Highlights

Researchers

Research Highlights

Researchers

Advanced Electromagnetic Technology Area

Transition to Mission Operation Phase and Release of Level 1 Product of CPR onboard EarthCARE "Hakuryu"

NICT, and JAXA have successfully completed the commissioning and the initial calibration & validation of the Cloud Profiling Radar (CPR), which was jointly developed by JAXA and NICT, onboard Earth Cloud Aerosol and Radiation Explorer (EarthCARE) (Nickname: "Hakuryu"). The operations have moved to the mission operation phase. Also, the European Space Agency (ESA) announced the successful completion of the initial calibration validation verification of the Atmospheric Lidar (ATLID), the Multi-Spectral Imager (MSI), and the Broad-Band Radiometer (BBR).

Accordingly, we are pleased to announce that Level 1 Product releases from all sensors onboard the EarthCARE satellite "Hakuryu" are set to commence.

The EarthCARE satellite "Hakuryu" was launched on May 29, 2024 (Japan Standard Time) and the initial calibration & validation was carried out as follows:

- Verification of on-board sensors: The functional operation and performance of the installed sensors (Cloud Profiling Radar, Atmospheric Lidar, Multi-Spectral Imager, Broad-Band Radiometer) were confirmed as nominally operated.
- Data acquisition and initial analysis: The initial analysis of acquired data validated the performance of the sensors as expected.

On January 14, 2025, we started releasing Level 1 Product from the website of JAXA, which contains engineering values converted from the observation data of individual sensors, following the completion of the initial calibration & validation.

- CPR Data: Data on the vertical distribution and up and down motions of clouds
- ATLID Data: Data on the vertical distribution of clouds and aerosols
- MSI Data: Data on the horizontal

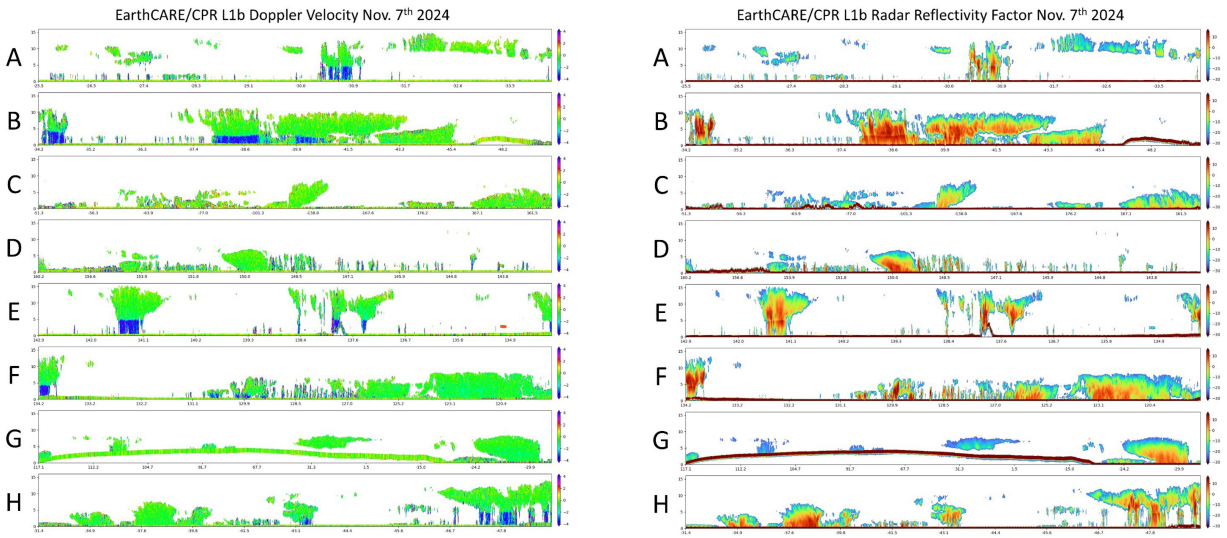

Fig.1 : The vertical distributions of the radar reflectivity (left) and vertical motion (right) of level 1b data are shown for each of the eight scenes A to H which are divided for one orbit. The horizontal axis is longitude (degrees) and the vertical axis is height (km). The rain areas are clearly identified where Doppler velocity is shown in blue. ©JAXA/NICT.

distribution of clouds and aerosols
- BBR Data: Data on the radiative distribution of the Earth

The above data will be converted into Level 2 Product, which is the geophysical values (Cloud water content, Cloud ice content, Optical Thickness, etc.). In addition, data from multiple sensors of the EarthCARE satellite "Hakuryu" will be combined to provide accurate observation data that cannot be obtained from a single sensor alone. This data will be used to improve predictions of future climate change, contributing to studies on adaptation to climate change.

Level 2 products derived from a single sensor and from a combination of two sensors started to be released on March 17, 2025.

Level 2 products derived from a combination of three or four sensor started to be released on December 1, 2025.

The EarthCARE satellite "Hakuryu" will continue to acquire observation data throughout its operation. By analyzing the acquired data, we will contribute to a better understanding of climate change and to the improvement of its prediction accuracy. We deeply appreciate the cooperation and support of the various stakeholders who assisted in the commissioning and initial calibration validation.

Frontier Science Area

Energy-saving Air Sterilization Inside Railroad Cars using High-Intensity Deep-UV LEDs

In collaboration with Asahi Kasei Corporation, a research group led by INOUE Shin' Ichiro, director of the NICT Advanced ICT Research Institute, developed an air sterilization module for railroad cars equipped with high-intensity deep-UV LEDs with an emission wavelength of 265 nm. The group successfully demonstrated it on trains operated by Shizuoka Railway Co., Ltd.

Compared to conventional air sterilization modules equipped with mercury lamps, our newly developed high-intensity deep-UV LED air sterilization module achieved a significant reduction in the power required to inactivate airborne viruses (more than 40% reduction). The new module was installed in passenger cars in service, and a one-month test run confirmed its safe and stable operation.

In recent years, hygiene control on public transportation has become increasingly important. In particular, reducing the risk of aerosol infection is an urgent issue in environments such as railroad cars, where a large number of people spend a long period of time in an enclosed space. Additionally, toward the realization of a sustainable society, the development of sterilization technologies with low environmental impact and low power consumption is anticipated.

Mercury lamps have traditionally been used as the light source for deep-UV sterilization. However, because mercury lamps contain mercury, which is harmful to the human body and the environment, they need to be eliminated as soon as possible. Additionally, mercury lamps are prone to breakage, require bulky light sources and high power consumption, and are therefore unsuitable for installation in railroad cars.

On the other hand, deep-UV LEDs have excellent properties such as compact size, low environmental impact, and long life. However, to date, deep-UV LEDs have been unable to generate a higher light intensity than mercury lamps, posing a challenge to their practical implementation for air sterilization in large spaces such as railway cars.

To respond to this challenge, NICT, which possesses technologies to realize high-intensity deep-UV LEDs that are comparable to mercury lamps, and Asahi Kasei, which has gained achievements in the mass production and application of deep-UV LEDs, have collaborated to develop a high-intensity deep-UV LED air sterilization module for railroad cars that is environmentally friendly as well as

energy-saving.

Figure 1 shows a Shizuoka Railway train equipped with the new high-intensity deep-UV LED air sterilization module. Leveraging the small and lightweight features of deep-UV LEDs, the module is compactly installed inside the upper section of the car's coupling. It sucks in air in the car containing viruses, inactivates them by irradiating them with deep-UV light internally, and then releases clean air (Fig. 1).

To verify the effectiveness of the module, we evaluated its ability to inactivate airborne viruses. We sprayed test viruses (Coliphage MS2) into a 25-m^3 space using a nebulizer (aerosol generator) and measured virus inactivation rates based on the module's power consumption and operating time using the plaque technique.

For comparison, we made a reference module equipped with low-pressure mercury lamps and evaluated its ability to inactivate airborne viruses in the same manner.

Evaluating the power consumption required for virus inactivation, we confirmed that the high-intensity deep-UV LED air sterilization module was able to reduce the power consumption required for 99.9% virus inactivation by 40.7% compared to the mercury lamp module.

We also confirmed that, using another module of the same type equipped with 500-mW deep-UV LEDs, 90%, 99%, and 99.9% of viruses were inactivated after 35, 71, and 106 minutes of operation, respectively. In contrast, the mercury lamp module required 188 minutes to inactivate 99.9% of the viruses. Through the evaluation, we found that the newly developed high-intensity deep-UV LED module can reduce the time to inactivate viruses by 43.6% compared to the mercury lamp module.

Dr. INOUE Shin' Ichiro, director of the DUV ICT Device Laboratory said, "Our achievement demonstrates that NICT's high-intensity deep-UV LED technology can achieve fast, energy-efficient air sterilization in railroad cars. Compared to conventional types of modules equipped with mercury lamps, our newly developed high-intensity deep-UV LED air sterilization module significantly reduces the time required to inactivate airborne viruses and reduces power consumption (by more than 40%). The new module was installed in a passenger car, and a one-month test run confirmed its safe and stable operation. The new module is expected to be a groundbreaking method for suppressing aerosol infection by airborne viruses in environments where many people spend long periods of time in enclosed spaces such as railroad cars."

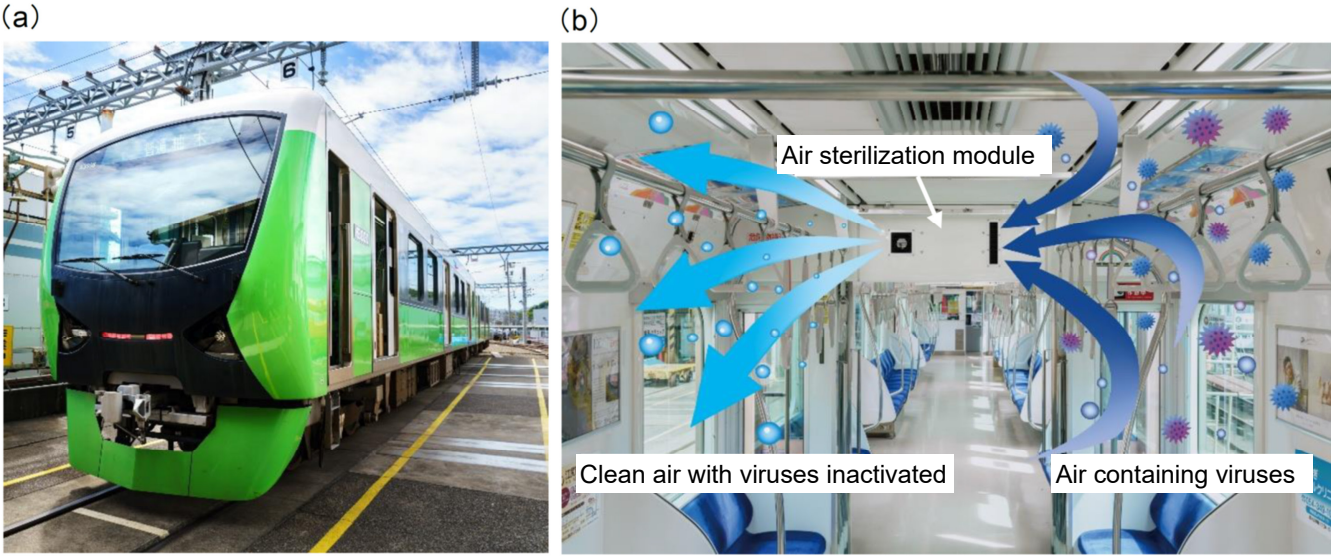

Fig.1 : (a) Train equipped with the high-intensity deep-UV LED air sterilization module
(b) Module installed in a train car

B5G Field

NICT Showcases Latest Technologies for Beyond 5G Society at "MWC Barcelona 2025" One of the World's Largest Mobile Technology Exhibitions

NICT showcased its latest R&D achievements, including those in the Beyond 5G domain, for the first time in its booth at "MWC Barcelona 2025," the world's largest mobile technology exhibition, held in Barcelona, Spain from Monday, March 3 to Thursday, March 6, 2025. At the exhibition, NICT introduced a technology for intercontinental base station control through the integration of terrestrial networks (TN) and non-terrestrial networks (NTN), as well as a technology applicable to wireless transfer of high-capacity files between drones passing each other using 300-GHz band terahertz waves and uncompressed 4K video real-time transmission, presenting ICT technologies that will support people's lives beyond 2030.

Exhibition contents

●Presenting a social vision for Society 5.0

NICT introduced an orchestration function that enables systems across different industries to collaborate based on user requirements. Visitors were able to experience three themes: "solving food loss issues," "reducing CO_2 emissions," and "preventing disaster risks."

●Presenting fundamental technologies and associated services

Aiming to achieve energy savings and optimize communication quality through the terrestrial network (TN) and NTN integration, NICT demonstrated cross-continental base station control between Spain and Singapore in collaboration with Singapore University of Technology and Design (SUTD). Results of this endeavor demonstrated improved energy efficiency through dynamic switching between TN and NTN paths.

NICT conducted its first overseas demonstration of instantaneous wireless transmission of large-capacity files

Fig.1 : View of the NICT booth at MWC 2025

between mobility devices such as drones flying past each other using 300-GHz band terahertz waves, along with a demonstration of uncompressed 4K video real-time transmission.

"NICT's four efforts in expanding its booth, increasing the number of exhibits, implementing pre-event media outreach activities, and conducting on-site visitor acquisition activities attracted significantly more media coverage and booth visitors compared to MWC24 (number of media outlets increased from 2 to 11, and number of visitors from 1,000 to 1,800). This resulted in enhanced effectiveness in boosting NICT's presence in the exhibition at MWC," said Dr. HAMMURA Kiyotaka, Planning Manager of International Research Development Office, "For the next exhibition, MWC2026, the booth will be held adjacent to the Japan Pavilion. NICT believes that uniting under the "Japan" umbrella will enhance the country's overall presence."

"Visitors to NICT's booth comprised not only those from the mobile communications industry, but also those from diverse sectors, as well as students. Through dioramas depicting future societies and hands-on experiences with industrial collaborations by implementing Beyond 5G, the attendees were able to envision an exciting future," said Dr. ISHIZU Kentaro, Director of the Beyond 5G Design Initiative, "Furthermore, the presentation of technologies in the form of services effectively conveyed their appeal. NICT plans to exhibit at MWC again in March 2026, and is looking forward to receiving your feedback from new perspectives at that time as well."

As examples of services utilizing this terahertz wave communication technology and space-time synchronization technology that support next-generation communications, NICT demonstrated images of a multi-view camera shooting service with high-precision wireless space-time synchronization, and images of a high-capacity data transfer service between a moving robot car and a drone that were passing each other using ultra-compact 60-GHz band wireless devices.

The above demonstrations utilized technology to visualize and control physical space entities by using digital twins jointly developed with the University of Tokyo, and technology to visualize wave propagation, developed through joint research with RWTH Aachen University (Germany).

Quantum ICT Field

Demonstration of Interconnection between the Quantum Secure Cloud and a Quantum Computer

Demonstration of Secure Transmission and Storage of High-Value-Added Information Generated by using Quantum Computers

NICT, RIKEN, the Center for Quantum Information and Quantum Biology, University of Osaka (QIQB), and QunaSys Inc. have connected the Quantum Secure Cloud operated by NICT (still under research and development) with a domestically developed gate-type quantum computer developed by RIKEN and its associates, achieving interconnection for secure use of the domestically developed gate-type quantum computer. Through this interconnection, we demonstrated that users of the Quantum Secure Cloud can access the functions of the domestically developed quantum computer and securely transmit and store data generated by it.

Currently, active research and development is underway both domestically and internationally with the aim of using quantum technology to solve various societal challenges. In this situation, the quantum secure

cloud technologies that NICT has been working on and the quantum computer technologies that RIKEN and its associates have been working on are attracting attention as challenges for research and development aimed at social implementation that are beginning to bear fruit through industry-academia-government collaboration. For the quantum technology innovation hubs established based on the Quantum Technology Innovation Strategy formulated by the Japanese government in 2020, NICT is positioned as a quantum security hub, and RIKEN as a quantum computing pioneering hub. NICT and RIKEN are working together on everything from basic quantum technology research to technology demonstrations, open innovation, intellectual property management, and human resource development through industry-academia-government collaboration.

Recently, through collaboration between research and development teams led by NICT and RIKEN, an interconnection was achieved between NICT's Tokyo QKD network, where the Quantum Secure Cloud was built, and RIKEN's quantum computer (Fig.1). This interconnection makes it possible to add information-theoretic security to remote communications with a quantum computer. For example, because an individual's genetic information is personal information that requires extremely high confidentiality, it is extremely important to ensure that it cannot be intercepted by others. When handling such highly confidential data on a quantum computer, it is necessary to prevent eavesdropping on data input and output. Also, if such high-value-added data is stored for an extremely long period of time, it is necessary to store it securely.

With the interconnection in place, users can now operate RIKEN's quantum computers via a completely confidential communication channel using keys provided by a key management system on the Tokyo QKD network.

"Important personal information such as genomic data and clinical data must be strictly protected. At the same time, by aggregating and analyzing such data while protecting personal information, it is expected that it can be applied to drug discovery and other applications," said Dr. FUJIWARA Mikio , Director General of the Quantum ICT Collaboration Center. "To use such sensitive data, we need a platform that can securely transmit data, store data securely for a very long time, and incorporate advanced computing power. Such a platform can be realized by applying quantum secure cloud technologies."

With steady operation of the QKD link between NICT and RIKEN, data securely stored in the Quantum Secure Cloud built on the Tokyo QKD network can be processed using quantum computers, and the processed data can be stored back in the Quantum Secure Cloud, making it impossible to intercept data transmitted during the process. This paves the way for ensuring that sensitive data is never intercepted and enabling high-speed data processing that has not been available with conventional classical computers. Going forward, we will provide quantum computing functions not only to authorized users but also to trial users at all NICT and RIKEN interconnection nodes to allow them to share their quantum computer operation know-how and needs, and encourage interaction among them in order to accelerate the social implementation of quantum technology.

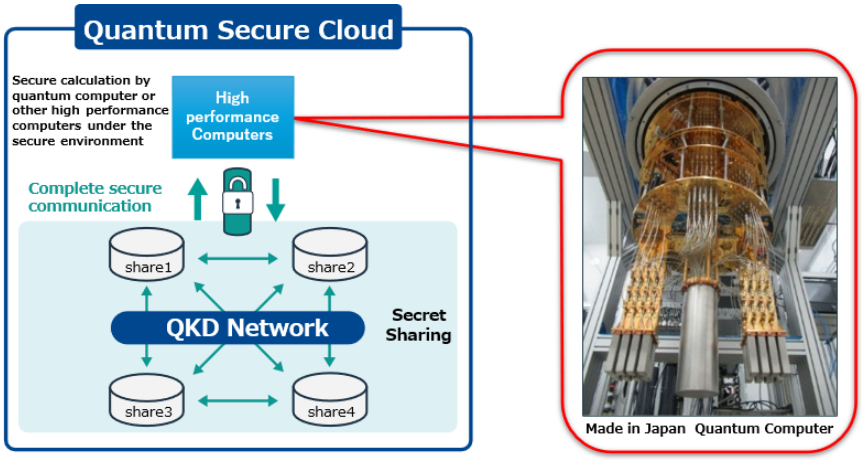

Fig.1 : Integration of the NICT Quantum Secure Cloud (left) and RIKEN's Quantum Computer

Advanced Electromagnetic Technology Area

Continuous High-intensity Terahertz Wave (0.6 THz) Generator Developed

Experimental Research to Ensure the Safety of Terahertz Waves Enabled

NICT and the Research Center for Development of Far-Infrared Region, University of Fukui (FIR-UF), have developed a continuous high-intensity terahertz wave generator that enables experimental research into the safety of terahertz waves, which are expected to be used in next-generation high-speed, high-capacity wireless communication technologies.

To confirm the safety of terahertz waves, it is necessary to investigate the possibility of temperature rise and damage on human skin or eyes exposed to terahertz waves. However, no instruments capable of continuously generating the high-intensity terahertz waves required for experimental research on this possibility existed. To address this challenge, our newly developed instrument makes it possible to continuously generate high-intensity radio waves in the terahertz band (0.6 THz). The instrument is expected to enable reliable data on the safety of these radio waves from the medical and biological perspectives to be obtained and analyzed.

Our instrument was featured in IEEE Electron Device Letters on Saturday, February 1, 2025 [1].

Radio waves in the highest frequency bands (above 0.1 THz) are called "terahertz waves." They are known to possess not only the properties of radio waves, but also the properties of light. Terahertz waves are being used to develop next-generation high-speed, high-capacity wireless communication technologies. The use of terahertz waves is also being considered for security screening at public facilities such as airports. However, in order to ensure the safety of terahertz wave technologies in everyday life, research is needed to clarify the possible effects of terahertz waves on the human body. In particular, detailed investigation is necessary into potential damage resulting from the temperature rise that occurs on skin or eyes continuously irradiated with high-intensity terahertz waves. However, the terahertz frequency (0.6 THz) required for such research is difficult to generate, and no instrument was available to continuously generate high-intensity terahertz waves for several minutes or longer, necessary to raise the temperature of the exposed areas.

Therefore, we focused on gyrotrons, which are used as high-intensity radio wave generators in facilities such as experimental nuclear fusion facilities, to find the conditions under which high-intensity radio waves in the terahertz frequency band (0.6 THz) can be generated, and designed and developed a new gyrotron based on the findings. Our gyrotron is capable of continuously generating high-intensity terahertz waves, making it possible for the first time in the world to conduct experiments on the safety of terahertz waves with high reliability.

Using the gyrotron we developed (Fig. 1), we confirmed that we could continuously generate 0.6-THz radio waves at high intensity (more than 1,000 times that of commercially available instruments that employ semiconductor elements to generate radio waves). We also observed a circular intensity profile, with high intensity at the center of irradiation (red spot on the left photo in Fig. 1). Furthermore, because the instrument can irradiate at the high intensity level required for medical and biological experiments, constantly and continuously for more than 10 minutes, it is now possible to accurately investigate the rise in temperature and the severity of damage caused by terahertz wave irradiation.

"By combining the newly developed gyrotron-based terahertz wave irradiation instrument [2] with a technology for three-dimensionally imaging temperature distribution [3], it is now possible to observe how high-intensity radio waves in the terahertz band cause temperature increases on skin-equivalent and cornea-equivalent phantoms or experimentally assess the relationship between terahertz wave intensity and local temperature increase with high precision," said Dr. MIZUNO Maya, Research manager of Electromagnetic Compatibility Laboratory, "Outcomes of such high-precision evaluations are expected to serve as the basis for revision of international

guidelines on radio wave safety and smooth deployment of next-generation high-speed, high-capacity wireless communication technologies for terahertz waves."

Part of the research was conducted under the commissioned project by the Ministry of Internal Affairs and Communications of Japan, titled "Research on Radio Wave Exposure Assessment Technologies for New Diversified Wireless Systems such as Beyond 5G/6G" (JPMI10001).

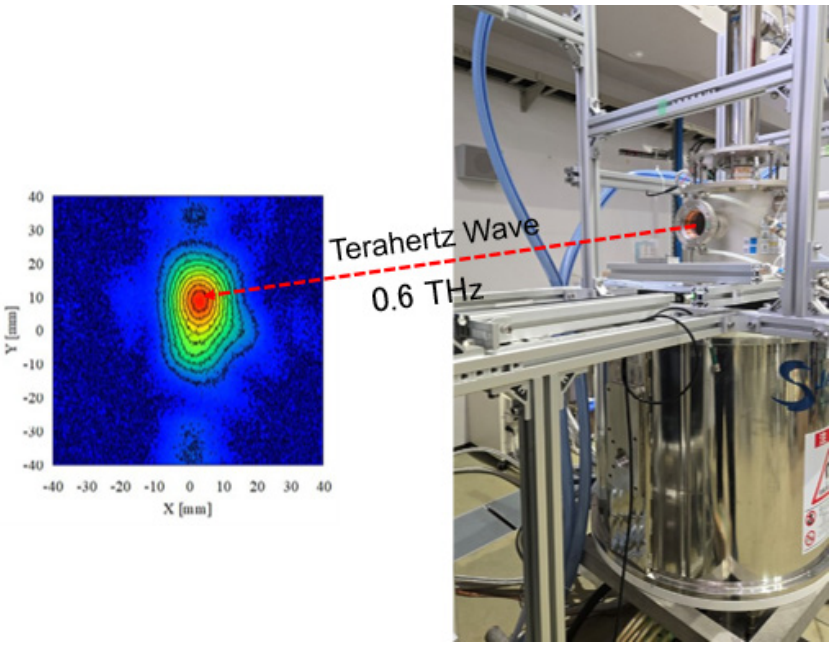

Fig.1 : Observation data of terahertz waves generated by the instrument (left) Exterior of our developed gyrotron (right)

Reference

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Innovative Networks Area

World's First Practical Surface-Emitting Laser for Optical Fiber Communications Developed

Advancing Miniaturization, Energy Efficiency, and Cost Reduction of Light Sources

NICT in collaboration with Sony Semiconductor Solutions Corporation (Sony), has developed the world's first practical surface-emitting laser that employs quantum dot(QD) as the optical gain medium for use in optical fiber communication systems.

This achievement was made possible

by NICT's high-precision crystal growth technology and Sony's advanced semiconductor processing technology. The surface-emitting laser developed in this study incorporates nanoscale semiconductor structures called quantum dots as light-emitting materials. This innovation not only facilitates the miniaturization and reduced power consumption of light sources in optical fiber communications systems but also offers potential cost reductions through mass production and enhanced output via integration.

Modern communication technologies require large-capacity data transmission with minimal power consumption. Vertical-cavity surface-emitting lasers (VCSELs) have attracted significant attention as a key technology that addresses these requirements, particularly in optical communications. However, VCSELs typically operate in the near-infrared region, at wavelengths of 850 or 940 nm. Developing VCSELs that operate at the long wavelength of 1,550 nm—typically used in existing optical fiber communications—presents significant technical challenges.

In a joint research project with Sony, NICT achieved the world's first electrically driven VCSEL operating at 1,550 nm—the standard wavelength for optical fiber communication—using nanoscale semiconductor structures known as quantum dots as the optical gain material.

NICT developed the first core technology: a high-precision crystal growth method for compound semiconductors using molecular beam epitaxy. Fabricating a VCSEL requires growing a highly reflective semiconductor multilayer film (DBR: Distributed Bragg Reflector) to enhance light intensity; however, fabricating DBRs that operate at 1,550 nm has been challenging because the combination of materials that can be grown is limited. In this study, we developed a technology that can precisely grow DBR by strictly controlling the ratio of materials in the crystal growth and realized a semiconductor DBR with a high reflectivity exceeding 99% even at 1,550 nm. In addition, strain-compensation techniques were applied to the VCSEL production to accurately cancel the internal crystal strain (strain generated within the material) that occurs around the quantum dots, thereby significantly increasing the density of the quantum dots and improving the light-emitting performance.

Sony contributed to the second core technology: a device design and fabrication process that enables highly efficient current injection employing a structure called a tunnel junction. VCSELs emit light perpendicular to the wafer surface; therefore, even if quantum dots emit light, conventional electrode placement obstructs light extraction. Sony addressed this by implementing a tunnel junction structure that permits efficient current flow while facilitating light extraction employing a precise device process.

Through the integration of these two technologies, we succeeded in lasing VCSELs using quantum dots at 1,550 nm as a light-emitting material with a small current of 13 mA (low threshold). Furthermore, polarization fluctuations were eliminated, resulting in a stable output.

NICT aim to conduct advanced technical studies on quantum-dot-based VCSEL technology to further enhance the capacity and reduce power consumption in optical fiber communication systems beyond the 5G era. Concurrently, we will undertake efforts to promote social deployment of this technology.

The results of this research were published in Optics Express, a leading international journal in optical technology, published by the OPTICA Publishing Group in the United States, in Vol. 33, Issue 6, on Monday, March 24, 2025.

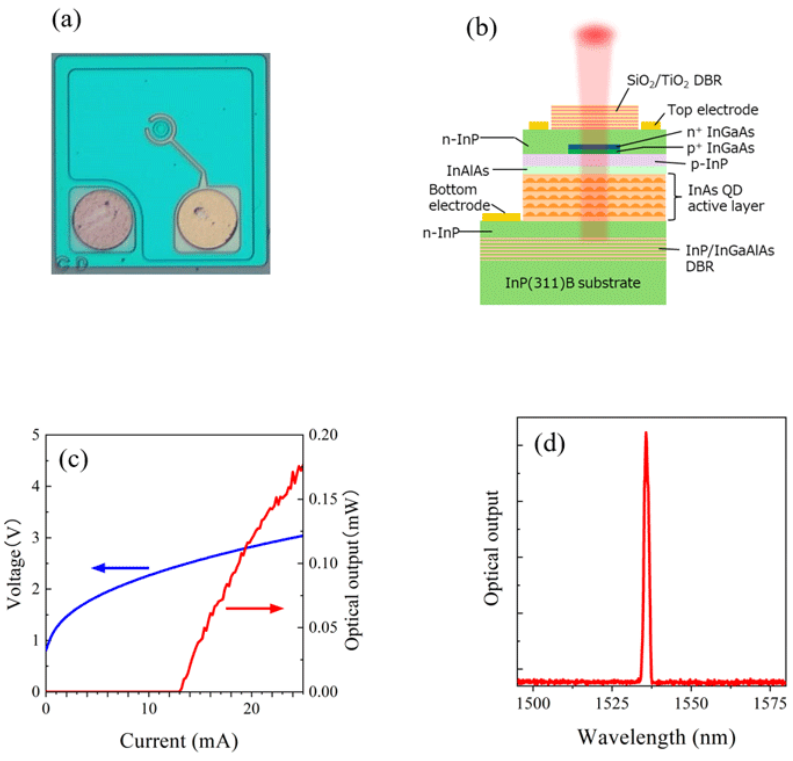

Fig.1 : (a) Micrograph of the quantum dot-based VCSEL that was fabricated, (b) Schematic of the cross-sectional structure of the quantum dot-based VCSEL,(c) Current-light output characteristics (red) and current-voltage characteristics (blue), (d) Laser oscillation spectrum of the VCSEL.

Frontier Science Area

Brain Activity Related to Latent Odor Preferences Discovered

These Findings Could be Applied to Product Development using Scent, Independent of Subjective Evaluation

A research team consisting of CiNet researcher OKUMURA Toshiki, CiNet PI and Associate Director KIDA Ikuhiro, and Lion Corporation analyzed brain responses when participants first smelled odors from three types of fabric softeners they had never used before. The team was able to correctly predict to an accuracy of approximately 60% the preferred fabric softeners selected by the participants after using them multiple times. In contrast, predictions based on subjective preferences when the participants first smelled the odors were only about 50% accurate, comparable to the accuracy of random selection, and failed to correctly predict the fabric softeners actually chosen by the participants. These results reveal that even when people perceive an odor for the first time, latent preferences not reflected in subjective evaluations are manifested in brain activity. These findings represent a crucial step toward comprehensively understanding the brain's mechanism of processing information related to latent odor preferences. Furthermore, by improving the accuracy of prediction based on brain activity analysis, this approach holds promise for application as a more reliable objective indicator in the development and evaluation of scented products, which have traditionally relied on subjective evaluations.

This study was published in the international scientific journal "*NeuroImage*" on March 7, 2025[1].

CiNet researcher Dr. OKUMURA Toshiki and CiNet PI and Associate Director Dr. KIDA Ikuhiro conducted experiments focusing on fabric softener odor in collaboration with Lion Corporation. The participants consisted of 25 females who regularly select and purchase fabric softeners based on their odor preferences and use them daily, but had never used the three types of fabric softeners employed in the study.

On the first day, the participants underwent functional Magnetic Resonance Imaging (fMRI) scans, where brain activity was measured while they perceived the odors of three different fabric softeners, and rated the odors in terms of subjective preferences (whether they liked or disliked the odors). Over the next two weeks, the participants used each of the three fabric softeners twice at home and then selected the one they liked best.

The prediction of fabric softener selection based on subjective preference ratings on brain activity measurement on the first day was approximately 50% accurate, showing no greater accuracy than random selection. In other words, it was not possible to predict fabric softener selections based on self-reported preference ratings.

In contrast, by analyzing brain activity in the nucleus accumbens, a key brain region that is strongly related to rewards (reward system), and the piriform cortex (the primary olfactory cortex) that processes odor information, the team successfully predicted fabric softener selections with an accuracy of approximately 60%. These findings suggest that brain activity in the reward system and the primary olfactory cortex reflects latent preferences not apparent in subjective evaluations, even with novel

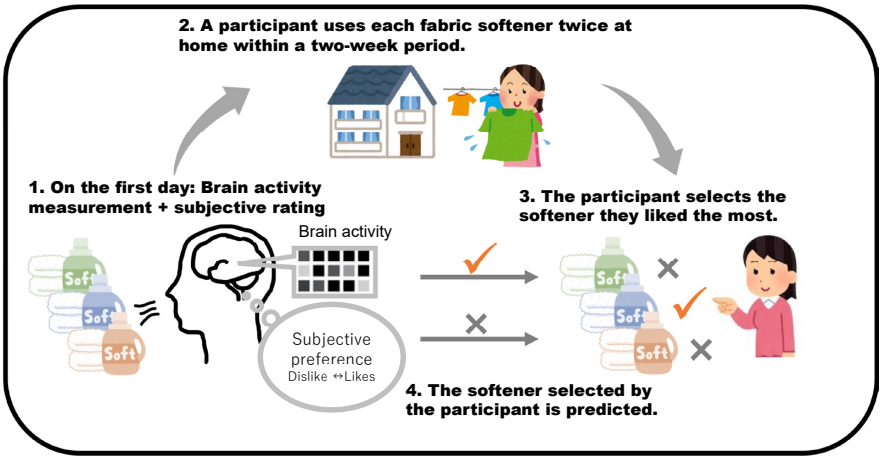

Fig.1 : Experimental procedures for predicting the selection of fabric softeners using brain activity

odors. In other words, it has become clear that activity in the brain regions related to rewards and odor processing reliably reflects latent odor preferences that are not predictable using subjective ratings.

This analysis employed a predictive model based on brain activity data. While it has been a common convention to construct predictive models for each individual, this study integrated brain activity data from 25 participants to build a predictive model applicable to a group as a whole, rather than to individuals. While information about minute brain structural differences is lacking, this approach minimizes variations among individuals, enabling predictions based on large-scale data. This should facilitate the construction of universal models independent of individual characteristics.

"This study demonstrated the potential to predict latent preferences for odors based on brain activity." explained Dr. KIDA Ikuhiro. "These findings suggest brain activity measurements could provide a clue for understanding individual preferences that cannot be fully captured by subjective evaluation alone, with potential applications in the development of products using scent and in personalized scent-based recommendations. Further technological advances, including improvements in prediction accuracy, will be required for future social implementation."

These findings provide insights into the brain's mechanism of processing information related to latent odor preferences. By improving the current 60% prediction accuracy, it is expected that this method will lead to the introduction of objective and reliable indicators in the development and evaluation of scented products, which has traditionally relied on subjective evaluations. Furthermore, if a new brain activity-based evaluation model is established, it could potentially assist in selecting odors better tailored to individuals. Going forward, by refining the experimental design, the brain activity-based approach may enable more elaborate predictions using diverse odor-related indicators.

Reference

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Advanced Electromagnetic Technology Area

New Space Weather Event Alert "SAFIR" and Space Weather Information Usage Guideline Released

For Additional Applications of Space Weather in the Private Sector

In response to the "Study Group on the Advancement of Space Weather Forecasting" hosted by the Ministry of Internal Affairs and Communications in 2022, NICT began providing the "New Space Weather Event Alert : SAFIR (Space Weather Alert for Social Impacts and Risks)" service based on newly determined criteria that take into account societal impacts of space weather from Thursday, June 19, 2025. In conjunction with this endeavor, NICT formulated and published the "Space Weather Information Introductory Guide" and the "Space Weather Information

Usage Guideline." These initiatives provide guidance on how to quickly identify space weather phenomena that have a significant social impact in communications and broadcasting, space system operations, aircraft operations, and other business fields, and how to respond to such phenomena.

It is expected that operators of social infrastructure, such as companies and government agencies, will be able to correctly understand large-scale space weather phenomena more than ever before and take safer and more secure countermeasures by utilizing the information provided through these initiatives (Fig. 1).

When a large-scale phenomenon such as a strong solar flare disturbs the space environment around the Earth, it can impact critical infrastructure related to telecommunications, broadcasting, space system operation, aircraft operation, satellite positioning, and power generation. Such disturbances in the space environment are called "space weather." With the aim of minimizing the impact of space weather, NICT began its space weather forecasting in 1988. Through this endeavor, NICT distributes information on space weather phenomena (space weather events) such as solar flares, along with an overview of space weather and 24-hour forecasts, via its website and email.

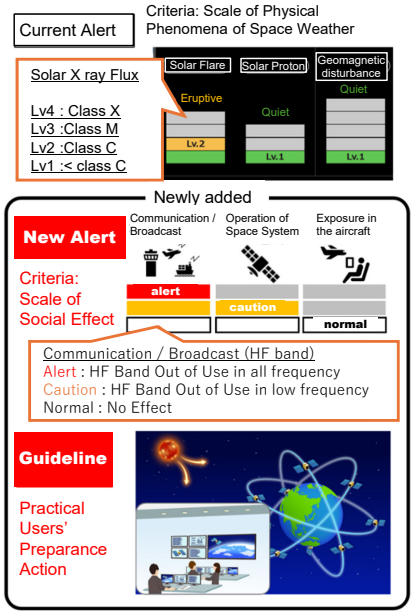

Fig.1 : Alert currently available, SAFIR newly added, and Guidelines for the Use of Space Weather

However, space weather phenomena affect different social infrastructure differently, and forecasts are not directly connected to specific types of impacts, making quantitative assessment of any impact difficult. Additionally, space weather forecasts are still in their maturation stage compared to meteorological forecasts due to an overwhelming lack of observation points. Thus, space weather forecasts are still in the development stage, and information provided by space weather forecasts has not been clearly associated with space weather-caused social impacts. Furthermore, guidelines for how to use such information have not yet been established.

In order to reduce the impacts of space weather phenomena on social infrastructure, on Thursday, June 19, 2025, NICT began providing information on space weather events based on new warning criteria established in light of possible impacts of space weather phenomena. Also, NICT created and released guidelines as well as an introductory guide for how to use space weather information.

1. New Space Weather Event Alert : SAFIR (Space Weather Alert for Social Impacts and Risks)
- Instead of conventional criteria for alerts based on scales of natural phenomena, new alert criteria are adopted in SAFIR based on possible social impacts.
- Types of possible impacts on social infrastructure are clearly defined by industry to allow infrastructure operators to easily use the information provided by SAFIR.
- The criteria used in SAFIR are based on the perspective of the information receiver.
- Industry-specific terminology, rather than scientific terminology, is used in SAFIR.

2. Space Weather Information Usage Guideline
- The guidelines describe how to use information about space weather to enable actions toward disaster prevention and mitigation.
- The guidelines include a summary of impacts and countermeasures by industry, such as telecommunications, broadcasting, space systems operation, and aircraft operation.
- The guidelines are designed to be useful as a reference for disaster prevention and mitigation actions and Business Continuity Plans based on information available from space weather forecasts and information on specific circumstances.

3 . Space Weather Information Introductory Guide
- For those accessing space weather for the first time, the guide explains what space weather is and provides examples of the social impacts of space weather.
- This guide is not intended as a textbook on solar-terrestrial interplanetary physics, but as a primer for space weather users.

You can access information from the following :
https://swc.nict.go.jp/safir/ (in Japanese)

It is expected that private and public infrastructure operators in various fields will be able to use SAFIR while referencing the Space Weather Information Usage Guideline and Space Weather Information Introductory Guide, correctly understand space weather phenomena, and implement appropriate measures, thereby enabling them to take safer and more secure countermeasures against the possible impacts of space weather. NICT is planning to continue advancing the initiatives described in this paper through communication with space weather users. Regarding SAFIR, NICT is also planning to determine criteria in fields where such criteria have not yet been determined, such as positioning, and add such fields to SAFIR coverage. These initiatives are expected to expand the range of applications for space weather and promote the development of human resources and private services related to space weather, making societies safer and more secure.

Frontier Science Area

World's First Demonstration of Entanglement Swapping using Sum-Frequency Generation between Single Photons

NICT has successfully demonstrated entanglement swapping, one of the key quantum communication protocols, using sum-frequency generation (SFG) between single photons for the first time.

Although nonlinear optical effects of single photons have long been theoretically recognized as powerful tools for advancing quantum communication protocols, such effects are extremely weak at the single-photon level and had never been applied for quantum operations. By combining NICT's state-of-the-art technologies including high-speed-clocked entangled photon-pair sources, low-noise superconducting nanowire single-photon detectors, and a high-efficiency nonlinear optical crystal, the research team succeeded in observing SFG between single photons with an unprecedented signal-to-noise ratio. Using this effect, they achieved the first experimental demonstration of entanglement swapping via single-photon SFG.

This achievement is expected to pave the way for miniaturized and efficient photonic quantum information processing circuit, as well as long-distance device independent quantum key distribution.

The results were published in Nature Communications on October 7, 2025 .

In the field of quantum information processing such as quantum communication and quantum computing, two-qubit gate operations are fundamental building blocks. In optical implementations, two-photon interference has been used to realize such operations. While this method allows for a relatively simple experimental setup using only a standard beam splitter and photon detectors, it suffers from a major limitation: Unless the existence of a photon pair obtained through entanglement swapping is confirmed by a measurement (and thus destroyed), the fidelity becomes low, limiting the range of applications.

To overcome this limitation,

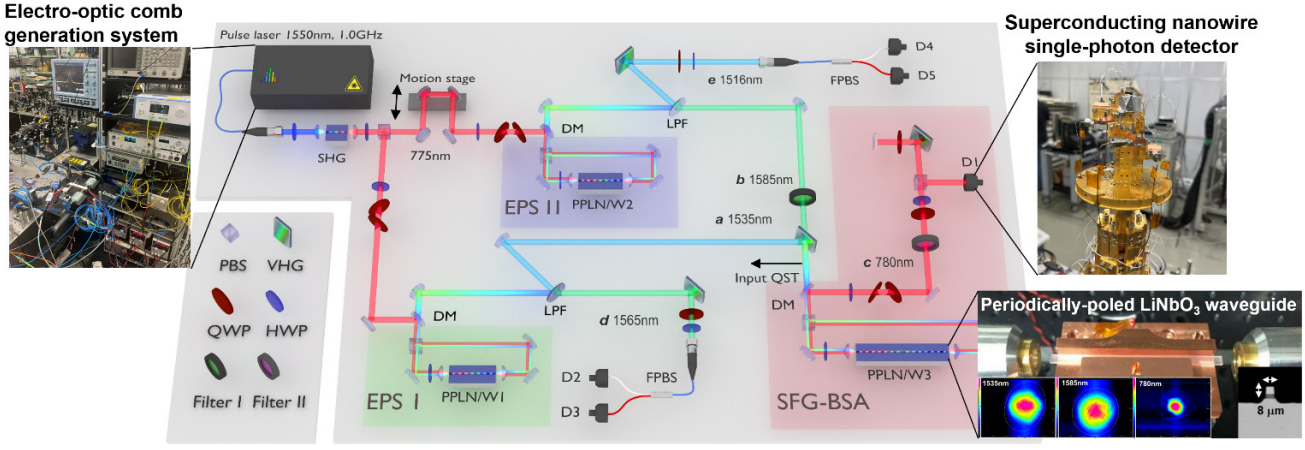

Fig.1 : Experimental setup for the SFG-based entanglement swapping
One entangled photon pair is generated from each of the two sources, EPS I and EPS II, and a gate operation based on sum-frequency generation between single photons is performed using the SFG-based Bell-state analyzer (SFG-BSA).

a theoretical scheme based on entanglement swapping using sum-frequency generation (SFG) between single photons has been proposed [1]. In this approach, by detecting the photon generated via SFG between two single photons (the SFG photon), it becomes possible to perform high-fidelity entanglement swapping without destroying the resulting entangled photon pair. This feature offers significant advantages for loophole-free Bell tests and long-distance device independent quantum key distribution. However, although SFG between single photons was first reported in 2014 [2], the detected signal at that time was extremely weak and buried in noise. Therefore, to apply this effect to entanglement swapping, it was essential to dramatically improve the signal-to-noise ratio (SNR) of the detected SFG signal.

In this study, the research team constructed an experimental setup by combining NICT's state-of-the-art technologies including high-speed-clocked entangled photon-pair sources [3][4], low-noise superconducting nanowire single-photon detectors (SNSPDs) [5][6], and a high-efficiency nonlinear optical crystal [7] (see Fig. 1 for details).

As a result, the SFG photons were detected with a high SNR, achieving nearly an order of magnitude improvement compared with the previous study [2]. Furthermore, the researchers confirmed the presence of strong entanglement in the final state estimating a lower bound of the fidelity to the maximally entangled state as 0.770 ± 0.076.

These results represent the world's first experimental demonstration of entanglement swapping via sum-frequency generation between single photons. This achievement marks a significant step forward in photonic quantum information processing and is expected to serve as an important guideline for the development of next-generation nonlinear optical devices.

To apply the current system to the more advanced quantum information protocols beyond entanglement swapping, further improvement in the SNR will be required. In the future, the research team aims to enhance a nonlinear optical efficiency, leading to the miniaturization and efficiency improvement of photonic quantum information processing circuits and the extension of transmission distance in device independent quantum key distribution.

This work was supported by the Japan Society for the Promotion of Science (JP18K13487, JP20K14393, JP22K03490) and R&D of ICT Priority Technology Project (JPMI00316).

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[4] Y. Tsujimoto et al., "Ultra-fast Hong-Ou-Mandel interferometry via temporal filtering," Opt. Exp. 29, 37150, 2021.
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Innovative Networks Area

World's First Successful Horizontal 2 Tbit/s Free-Space Optical Communication using Small Optical Terminals for Satellites and HAPS

NICT has successfully demonstrated 2 Tbit/s horizontal Free-Space Optical (FSO) communication using small optical communication terminals that can be mounted on satellites and High Altitude Platform Stations (HAPS), marking a world first for this technology.

This experiment involved horizontal free-space optical communication between two types of small portable optical terminals developed by NICT: a high-performance FX (Full Transceiver) installed at NICT Headquarters (Koganei, Tokyo) and a simplified ST (Simple Transponder) installed at an experimental site 7.4 km away (Chofu, Tokyo). Despite the difficult conditions of an urban environment with atmospheric turbulence that disrupts laser beams, the system maintained a stable total communication speed of 2 Tbit/s via Wavelength Division Multiplexing (WDM) transmission of 5 channels (400 Gbit/s each). This is the first time in the world that terabit-class communication has been realized using terminals miniaturized enough to be mounted on satellites or HAPS.

Moving forward, NICT plans to further miniaturize the terminals for implementation onboard a 6U CubeSat. NICT aims to conduct free-space optical communication demonstrations at speeds of up to 10 Gbit/s between a Low Earth Orbit (LEO) satellite (altitude approx. 600 km) and the ground in 2026, and between a satellite and HAPS in 2027. Through these experiments, NICT will demonstrate compact, ultra-high-speed data communication capabilities and pave the way for the realization of Beyond 5G/6G Non-Terrestrial Networks (NTN).

Free-Space Optical (FSO) communication, which transmits laser light through space without optical fibers, is attracting attention as a fundamental technology supporting high-capacity communication between the ground, the sky, and space. While demonstrations of FSO exceeding Tbit/s speeds have been advancing, primarily in Europe, previous experiments utilized large, stationary equipment in laboratory-style configurations. These configurations face challenges in meeting size and weight constraints for mounting on mobile platforms such as satellites or HAPS and in maintaining stable communication in fluctuating environments. Furthermore, in Asia, there have been no reports of FSO demonstrations exceeding the terabit level, with speeds reported to reach at most around 100 Gbit/s.

The terminals used in this demonstration were designed for

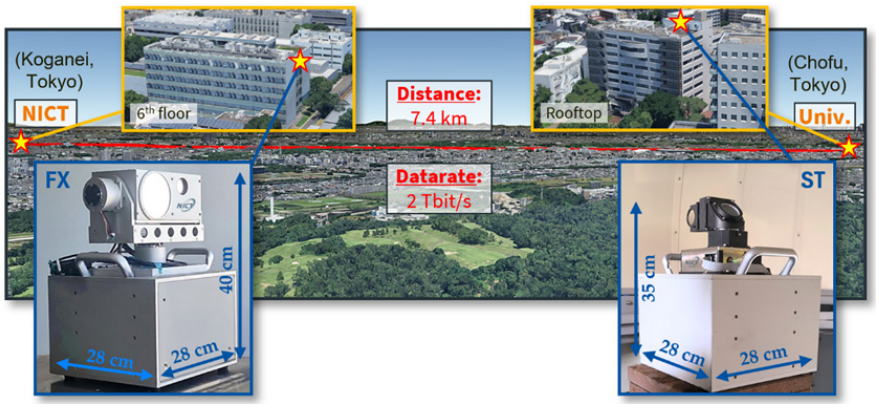

Fig.1 : NICT's 7.4 km, 2 Tbit/s horizontal propagation experiment (April 2025). The ST terminal was used as the transmitter and the FX terminal as the receiver. The terminals exchanged pseudo-random binary sequences (PRBS) to evaluate line quality. A transmission speed of 2 Tbit/s is equivalent to sending approximately 10 full-size 4K UHD movies per second.

integration into microsatellites, including CubeSats. They meet size and weight constraints, distinguishing them from conventional laboratory-style configurations that use large stationary equipment. To achieve miniaturization, NICT strictly adhered to a design policy that fits within the severe Size, Weight, and Power (SWaP) constraints of CubeSats. NICT implemented three approaches:

1. Development of custom-designed components (e.g., a 9 cm-class telescope meeting optical quality requirements for the space environment).
2. Redesign and modification of commercial components (e.g., a miniaturized fine steering mirror improved to handle high-power laser beams in a vacuum).
3. Active utilization of existing components (e.g., repurposing high-speed optical transceivers for data centers and incorporating them into modems).

By implementing these approaches, NICT was able to reduce the size, weight, and power consumption of the entire device while maintaining all the required functions and minimizing the burden on the platform.

Additionally, to handle dynamic environments assumed for mobile operation, NICT implemented high-precision alignment using coarse acquisition and fine tracking. NICT also implemented its proprietary Beam Divergence Control (BDC) technology, which dynamically adjusts the laser beam divergence according to link conditions. This design, enabling stable communication in mobile environments, is a key feature of these terminals and distinguishes them from conventional fixed-station experimental equipment.

Furthermore, the developed terminals allow for flexible selection of configuration (ST or FX) and modem type (10 Gbit/s type or 100 Gbit/s type) based on communication requirements, as well as adaptive operation according to link conditions via internal adjustment functions.

This demonstration was achieved by overcoming technical challenges for mounting on mobile platforms—such as miniaturization of optical systems and high-precision, flexible beam control—through the development of novel functions such as variable transmission speeds and variable beam widths tailored to the communication environment. It represents a significant step toward the practical realization of Beyond 5G/6G Non-Terrestrial Networks.

As the next step, NICT is preparing for a new experimental campaign in 2026 in which the small optical communication terminals (ST and FX) will be mounted on mobile platforms to simulate realistic links involving satellites and HAPS. In these experiments, NICT plans to verify the performance of the coarse acquisition and tracking system and the fine tracking system while both communicating terminals are in motion, demonstrating the feasibility of a multi-terabit optical backbone under dynamic conditions for Non-Terrestrial 6G Networks.

Simultaneously, NICT is working on a CubeSat mission scheduled for launch in 2026, aiming to verify a gimbal-less FX terminal (called CubeSOTA) combined with a 10 Gbit/s modem in orbit. NICT aims to conduct free-space optical communication demonstrations at data rates of up to 10 Gbit/s between a Low Earth Orbit (LEO) satellite and the ground in 2026, followed by world first demonstrations of optical communication between a satellite and HAPS in 2027. While the CubeSat form factor cannot yet accommodate the power and volume of a 2 Tbit/s modem, NICT is proceeding with the miniaturization and environmental hardening of multi-Tbit/s modems for future on-orbit demonstrations. NICT aims to realize optical communication links in the multi-Tbit/s range between satellites, HAPS, and ground stations within the next 10 years.

Researchers

Person 1

HAYASHI Masamichi
Senior Researcher,
Brain Networks and Communication Laboratory, Center for Information and Neural Networks
Advanced ICT Research Institute

Dr. HAYASHI was born in Izumi City, Osaka, in 1982. After earning his Ph.D. in cognitive neuroscience, he worked as a postdoctoral researcher at the University of Helsinki, the University of Sussex, UC Berkeley, and Osaka University. He joined NICT in 2019. His research explores the neural mechanisms underlying subjective experience, as well as the efficiency and flexibility of information processing.

Uncovering the Neural Mechanisms Underlying the Flexibility and Efficiency of Information Processing in Humans

Every day we make choices involving numbers—picking a bunch of bananas with more fruit, or joining a checkout line with fewer people. Many animals also rely on quantity when choosing food or avoiding danger. This ability to sense and compare numbers is fundamental for survival. But how can the brain, with its limited number of neurons, represent the infinite range of possible numbers in the world around us?

Our study investigated whether there are any brain regions that represent relative numerical magnitudes—how large or small a number is within a given context. Using functional magnetic resonance imaging (fMRI), we measured brain activity while participants compared patterns of dots and judged whether each pattern showed a larger or smaller quantity than they had recently seen.

We found that early visual areas reflected exact quantities, while higher brain regions, particularly in the parietal and frontal lobes, represented numbers in a context-dependent and relative way (Fig. 1) [1][2]. In other words, the brain flexibly adjusts its sense of quantity depending on the situation, allowing efficient processing of a wide range of numerical information.

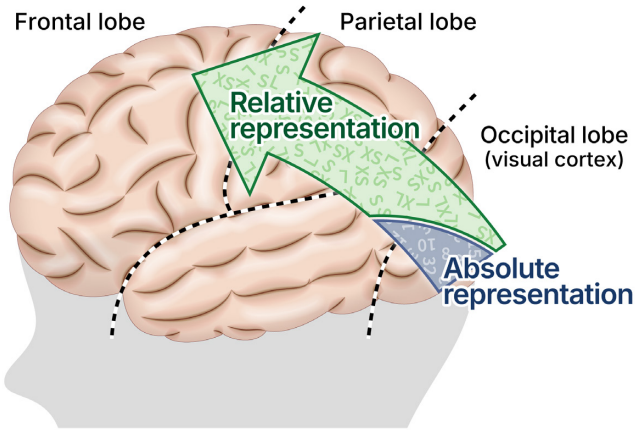

Fig.1 : Hierarchy of absolute and relative representations of numerical quantity

We are now extending our research to examine whether similar relative magnitude representations exist in other domains, such as size or time. I believe that understanding this flexible and efficient mechanism in the brain may also contribute to the development of new artificial intelligence. By learning how the brain adapts its information processing to changing environments, we may be able to design AI systems that think and decide in a more human-like, adaptive, and resource-efficient manner.

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[2] NICT press release, "Uncovering the Brain's Flexible Mechanisms for Representing Diverse Numbers," March 25, 2025. https://www.nict.go.jp/en/press/2025/03/25-1.html

Q&A

What is the most interesting point in your research?

Subjective perceptual experiences are deeply personal and invisible from the outside. I find it fascinating that we can quantify them through behavioral and brain activity measurements, linking individual differences in perception to the workings of the brain..

What is the goal of this research theme?

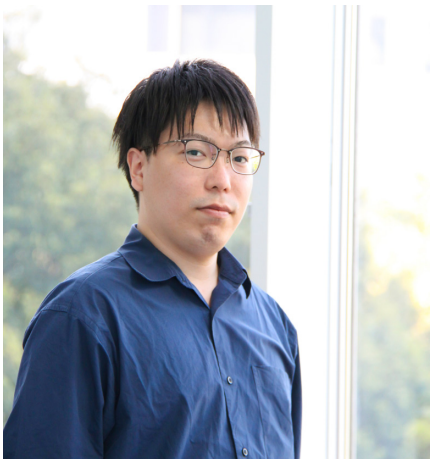
Ultimately, I aim to uncover and manipulate the mechanisms behind subjective perception, enabling us to enhance, control, or even create entirely new perceptual experiences that were previously impossible.

What are you aiming at as a researcher?

One great appeal of research is that discoveries can last forever. I hope to leave behind findings that stand as proof of my life and continue to inspire future generations.

Researchers

Person 2



KIMURA Hayato
Researcher,
Security Fundamentals Laboratory,
Cybersecurity Research Institute

Born in Kanagawa in 1996, and he earned the B.E. and Master of Information and Telecommunication Engineering degrees from Tokai University in 2019 and 2021. Joined LINE Corporation (now LY Corporation) in 2021 and moved to NICT in 2025. His work focuses on applied cryptography, application security and offensive security.

Bridging Automated and Human-Led Approaches for Real-world Cryptographic System Security Evaluation

My research explores flexible ways to evaluate the security of cryptographic systems. This includes promoting automation, but also emphasizes switching between human-led and computer-assisted approaches, depending on context. Rather than committing exclusively to one method, my work promotes a framework where each approach is used when it provides the greatest insight, bridging theoretical techniques and real-world security practice. Like following a recipe in cooking, some steps benefit from careful manual preparation while others can be efficiently handled by machines; combining both produces the best results.

Building on my experience in application vulnerability assessments, I apply this perspective to end-to-end encrypted messaging systems and decentralized platforms. For example, our discoveries of vulnerabilities in Nostr were achieved entirely through manual analyses, demonstrating the power of expert-driven investigation. In contrast, our work on Rocket.Chat showed how a potential weakness first indicated by ProVerif could be elevated to a realistic attack through human evaluation. These cases illustrate how combining and selectively switching between manual and automated methods can produce results that neither can achieve alone.

My goal is to refine and share this approach so that the broader security community can evaluate complex, multi-protocol environments more effectively. By integrating automation tools with expert judgment in a principled way, we can build a new generation of evaluation practices that proactively identify and mitigate risks in secure communication systems. I hope this research will contribute to a culture where flexible, context-aware evaluation becomes standard practice, ultimately strengthening public trust in cryptographic technologies.

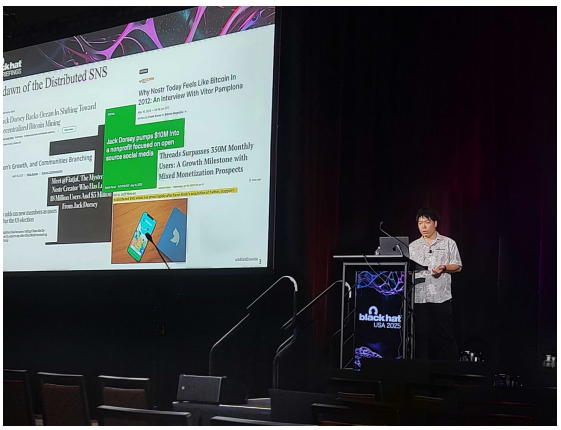


Fig.1 : Hayato Kimura presenting his research at Black Hat USA 2025 Briefings, one of the leading global conferences on cybersecurity.

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Q&A

What is the most interesting point in your research?

I focus on systems currently in use or soon to be deployed, where security evaluations have responsible real-world impact. Having the opportunity to report findings promptly to service providers and work with them to implement solutions in society is an extremely rewarding and meaningful experience.

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

My happiest moments are when vulnerabilities I report are fixed by service providers and publicly acknowledged. Seeing research results directly improve widely used platforms confirms that our work benefits real users beyond publishing academic papers.

What are you aiming at as a researcher?

I aim to foster a culture of security evaluation that adapts to the context of each system, its scale, design, and user impact by selecting a suitable mix of automated and manual methods. Ultimately, I want to help build communication infrastructure that is both technically secure and trusted by society.

Researchers

Person 3

HARA Yusuke
Senior Researcher,
Neuro-ICT Laboratory, Kobe Frontier Research Center,
Advanced ICT Research Institute

Dr. Hara was born in Okayama in 1984. After earning a doctoral degree at Tokyo University of Agriculture and Technology and working as a JSPS Research Fellow (PD) and an assistant professor at Tohoku University, he joined NICT in 2018. He has been involved in the research and development of advanced ICT inspired by the insect brain. Ph.D. (Agriculture).

Unraveling the Latent Potential of the Insect Microbrain to Drive Innovation in ICT

Insects are the most species-rich organisms on Earth, comprising several million species. How do their tiny brains generate such a wealth of species-specific behaviors? We recently addressed this question using two fruit-fly species with contrasting courtship strategies. *Drosophila melanogaster* (*D. mel*) males court females by vibrating their wings to produce a love song, whereas males of the congeneric species *Drosophila subobscura* (*D. sub*) regurgitate crop contents and present them as a "gift" (Fig. 1a). We found that brain insulin-producing cells (IPCs; Fig. 1b) serve as a central regulator for gift-giving in *D. sub*, as activating them induced this behavior whereas inactivating them abolished it. However, IPCs are also present in *D. mel*, which does not show gift-giving. Comparative analyses revealed that *D. sub* IPCs connect to neurons that command courtship initiation, while *D. mel* IPCs lack these connections. Remarkably, genetic manipulation of *D. mel* IPCs to connect to the courtship-command neurons resulted in males exhibiting gift-giving behavior during courtship. This represents the first example of "cross-species behavior transplantation" through targeted manipulation of brain circuits[1][2].

Our study demonstrates that rewiring pre-existing neurons can generate novel behavior, illustrating how the insect microbrain produces diverse behaviors with minimal computational resources. As a next step, I aim to elucidate how the microbrain achieves flexible multisensory integration. This line of research will provide insights for advancing ICT, such as AI and sensor-fusion technologies, where energy efficiency is an urgent challenge. Through interdisciplinary activities leveraging NICT's R&D infrastructure, I seek to open new frontiers in ICT.

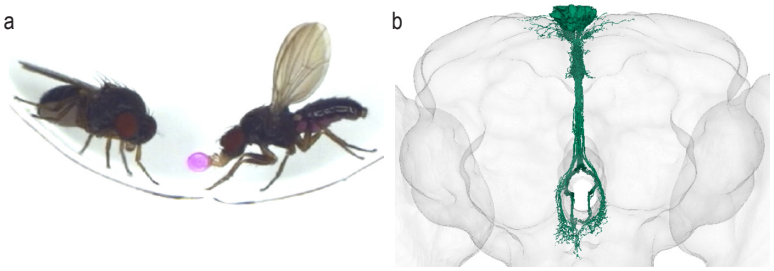

Fig.1 : (a) A *D. sub* male (right) offering a nuptial gift to a female (left) during courtship. Image courtesy of Dr. Ryoya Tanaka (Nagoya Univ.). (b) IPCs (green) in the *D. mel* brain reconstructed using neuPrint[3], based on the FlyEM Male CNS Connectome[4], licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/).

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4. Berg S et al. "Sexual dimorphism in the complete connectome of the *Drosophila* male central nervous system." bioRxiv, 10.09.680999, 2025.

Q&A

What is the most interesting point in your research?

When recording the electrical activity of brain neurons using electrophysiological techniques, I listen to their signals through an audio monitor. Each neuron produces its own characteristic sound, and even the same neuron can change its tone depending on the environment. It is fascinating to directly hear the hidden "personality" of living brain neurons.

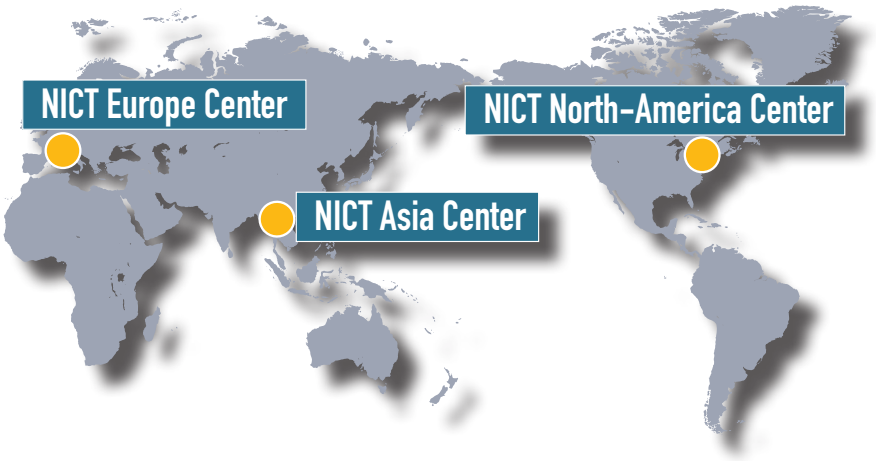
What has been your happiest moment with your current research theme?

When I encounter an unexpected phenomenon and am certain that no one else has ever observed it, I feel I am standing at the frontier. Such moments, together with a sense of reverence for the profundity of nature, are the most fulfilling to me as a scientist.

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

As global warming accelerates, ensuring sustainability in ICT systems has become a critical challenge. The insect brain—characterized by its minimally redundant yet highly efficient circuitry, enabling real-time, multimodal processing with remarkably low energy consumption—offers a compelling conceptual foundation for developing novel and energy-efficient ICT.

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

NICT Overseas Centers

Asia Center

Director of Asia Center
SAKUDA Yoshihiro

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

The NICT Asia Center is strengthening personnel connections with research institutes and universities in Southeast Asia while also supporting and delivering information on NICT's research and development in Southeast Asian countries. For over 20 years since its predecessor, the CRL Asia Research Center, was established in Bangkok in 2002, the NICT Asia Center has made wide-ranging efforts while adapting to changes in the R&D environment in the information and communications field in the Asian region.

From 2025, the NICT will begin joint research with Chulalongkorn University, where the NICT Asia Center is located, in the field of biosensing technology on top of existing photonic network. To commemorate the 10th anniversary of the start of collaboration with Chulalongkorn University and the relocation of the NICT Asia Center to the university, the NICT Asia Center held an event in September 2025, attended by NICT President Tokuda and key researchers. The event included a signing ceremony for a Memorandum of Understanding with the university to extend the collaboration between the two parties for five years, a tour of the joint laboratory at the NICT Asia Center, and other programs. In November 2025, the "CU-NICT Workshop on Advanced ICT Research 2025," was held with over 100 participants, including Associate Dean Sawekchai Tangaramvong from Chulalongkorn University and NICT Vice President YANO Hiroyuki. The workshop featured presentations on a wide range of research fields, including biosensing technology, biological information processing, and photonic network technology, and NICT staff hosted a virtual tour of the NICT Kobe Frontier Research Center in the workshop.

In May 2025, NICT President Tokuda visited Singapore, signed a Memorandum of Understanding with Singapore University of Technology and Design, and observed joint research achievements in the field of Beyond 5G. In addition, NICT President Tokuda held talks with the Infocomm Media Development Authority. President Tokuda then visited AI Singapore and A*Star Institute for Infocomm Research and engaged in talks with staff from the institutions on large language models (LLMs).

Regarding publications, the NICT Asia Center holds exhibitions at the Thailand National Science and Technology (NST) Fair hosted by the Thai government every August, and the KMITL Innovation Expo hosted by King Mongkut's Institute of Technology Ladkrabang (KMITL) to provide information in Thai about NICT's various activities. At the Thailand NST Fair 2025, the NICT Asia Center distributed paper hats (brain hats) on which the names and functions of the main parts of the human brain were written to the primary visitors comprised of elementary and junior high school students, and the hats were well received.

The NICT Asia Center will continue to support research collaborations and publishing information about NICT's initiatives, primarily in Thailand and Singapore, and other Southeast Asian countries.

Fig.1 Group photo at the "10th Anniversary Event of the Start of Collaboration between NICT and Chulalongkorn University's Faculty of Engineering, and the Relocation of the NICT Asia Center" (Dr. Witaya Wannasuphoprasit, Dean of the Faculty of Engineering, Chulalongkorn University (center left), and Dr. TOKUDA, NICT President (center right))

Fig.2 Photo of the National Science and Technology Fair (distribution of brain hats, visitors creating hats)

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

Bangkok, growing as a technical cooperation hub in ASEAN

SHONO Shiho, Associate Director of Asia Center

In recent years, Bangkok has quietly grown as a hub for international events, from ASEAN summits to technical conferences on AI, digital policy, and communications. As technological and economic trends shift across Asia, Bangkok is advancing from a mere gateway to Asia to a place where spontaneous collaborations emerge. A growing sense of co-creation is evident on the ground in Bangkok, where governments, universities, companies, and research institutions are coming together to address common challenges. A number of projects focusing on climate change, disaster resilience, language AI, and digital inclusion have been launched in Thailand and other closely-connected countries. Such projects help foster the formation of more organic research networks across ASEAN. All Asian countries are becoming equal partners, building a model in which the values and strengths of the region are reflected. A challenge for Japan is how to build trust with its neighbors and co-create the future. For Japanese researchers, perhaps the journey for co-creation begins with a simple smile and a cup of Thai coffee in Bangkok.

NICT Overseas Centers

North-America Center

Director of North-America Center
HONDA Tomoyuki

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

The North-America Center was established as a base of NICT in the North American region in October 2000. It was mainly intended to promote joint research with the U.S. and Canadian government agencies and research institutions, and collect information concerning their policies and R&D trends in the field of information and communications technology. In particular, as the U.S. is a front-runner in the science and technology field and is strongly allied with Japan, NICT is actively promoting joint research projects with the country. To be specific, based on the Joint Statement Endorsing Principles for 6G: Secure, Open, and Resilient by Design announced by ten countries including Japan and the U.S. in February 2024, NICT participated in an international cooperation program in the telecommunications field named VINES (Verticals-enabling Intelligent Network Systems) conducted by the U.S. National Science Foundation and has already begun moving toward the implementation of joint research. In addition, it is an important role for the North-America Center to disseminate information on NICT's activities to North America and sow the seeds for joint research in the future. In September 2025, we held a NICT Forum under the theme of cyber security for the purpose of sharing NICT's R&D achievements and building a network with concerned parties in Japan and the U.S. At the forum, Japanese and American experts made presentations and asked and answered questions.

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

Fig.1 : National Science Foundation (NSF) conducting the joint project with NICT

Fig.2 : NICT Forum 2025

Confusion under the Second Trump Administration

On November 12, 2025, when I was writing this article, a temporary funding bill for the budget for the next fiscal year starting October was passed in the U.S. This ended a record 43-day government shutdown which caused the pause of government functions and disruption of people's lives, such as the deferment of release of government statistics, reduction of flights, and furlough of federal employees. The second Trump administration is becoming extremely confused. Putting up the slogan of "Make America Great Again," it is attempting to cancel granted subsidies and reduce the budget and the number of federal employees in the science and technology policies. There are moves to blow a whistle indicating that the reduction of public funds may accelerate the decline of fundamental research and research accompanied with risks and the outflow of talented persons and that the status of the U.S. as the world leader may be threatened. We need to pay close attention to the future trends of the U.S. science promotion policies.

NICT Overseas Centers

Europe Center

Director of Europe Center
FUJINUMA Koichi

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

The NICT Europe Center, based in the heart of Paris, promotes collaboration in R&D with countries in Europe and grasps the latest trends by conducting visits throughout Europe.

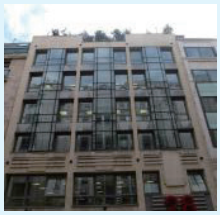
The mission of the NICT Europe Center is to (1) promote and support international joint research through participation in international conferences and other events and deepen networks with European research institutes, government agencies, and industry organizations to promote collaboration; (2) support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

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

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

In 2025, NICT independently exhibited at the Mobile World Congress 2025 in Spain in March. In July, NICT organized a Japan-Germany joint workshop and a Japan-France joint workshop and collaborated with organizations in Europe through proactively participating in several conferences and exhibitions.

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



NICT Europe Center
12 Rond-Point des Champs-Elysees (5e etage)
75008 Paris, France
tel: +33 (0)1 88 80 68 30
E-mail: europecenter@ml.nict.go.jp

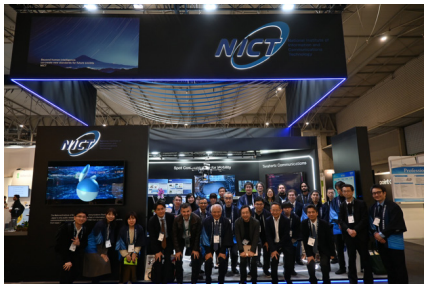


Fig.1 : Exhibition at the Mobile World Congress 2025 (Spain) (March 2025)

Fig.2 : France-Japan Joint Workshop 2025 (July 2025)

Saint-Malo, a Historic Port City in France

EGUCHI Tomoyuki, Associate Director of Europe Center

Saint-Malo is a historic port city in Brittany, northwest France. In the area near the sea, the ramparts and stone-paved streets offer a historic streetscape showcasing the long history of the city. The walled area itself is not so large, it takes a mere two hours to go around on foot. Various restaurants and souvenir stores line the streets and you can experience a diversity of cultures. On a fine day, just walking around Saint-Malo will make you feel refreshed. In this seaside city, many tourists enjoy the beach in summer. Saint-Malo is also a place where we can savor Brittany cuisine featuring local specialties such as butter.

Although Saint-Malo is a small city, you can experience and learn about the many charms, including the history and food culture of France. Please come to Saint-Malo if you have a chance to visit France.

Fig.3 : Saint-Malo harbor view

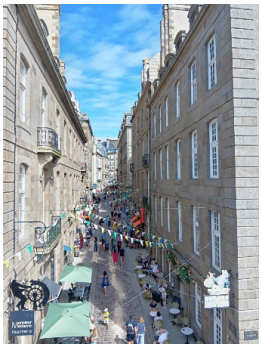
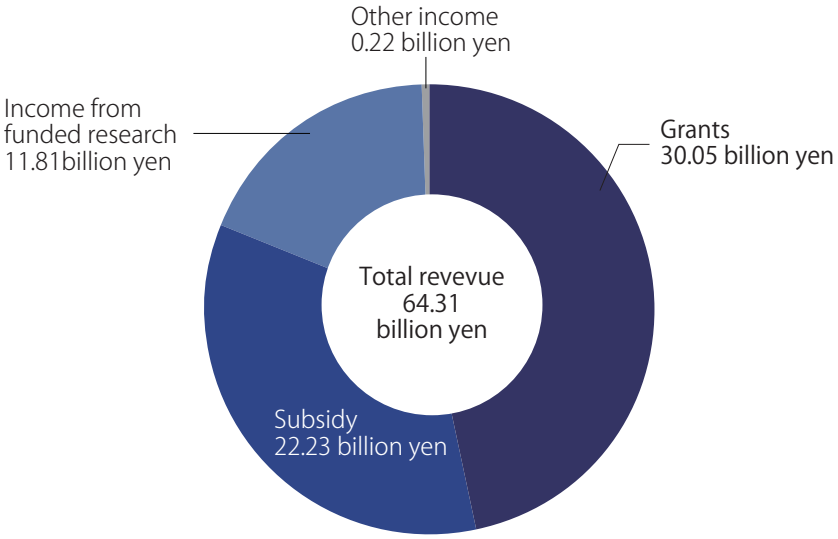


Fig.4 : Saint-Malo streetscape

Budget

The original budget for FY2025

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



Total expenditure for FY2024 was billion yen in a reported basis.

Yen-dollar conversion ratio: 145.49yen/dollar (Aplil 2025)

Work Force

1,547 (as of April 1, 2025)
(Including fixed term employees)

History

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

Aug.	1891	● Electrotechnical Laboratory is established as a part of 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) officially starts (Kemigawa)
June	1948	● Physical Institute for Radio Waves is integrated
Aug.	1952	● Radio Research Laboratory is established
May	1964	● Kashima Branch opens (30-m diameter Parabola Antenna Facility completed)
Aug.	1979	● Telecommunications Satellite Corporations of Japan (TSCJ) is established
Aug.	1982	● Kimitsu Satellite Control Center opens
April	1988	● Reorganized from Radio Research Laboratory to Communications Research Laboratory(CRL)
May	1989	● Kansai Branch opens (Kobe)
Oct.	1992	● Renamed as the Telecommunications Advancement Organization (TAO) Commencement of advanced communication and broadcasting research and development
July	1997	● Yokosuka Radio Communications Research Center is established
July	2000	● Keihanna Info-Communication Research Center is established
Jan.	2001	● Ministry of Posts and Telecommunications becomes Ministry of Public Management, Home Affairs, Posts and Telecommunications
April	2001	● Communications Research Laboratory, Incorporated Administrative Agency is established
July	2001	● Promotion system on facilitating research and development in private basic technology commences
March	2002	● Satellite control operations are terminated
April	2003	● Partial takeover of operations of Promotion Center for Facilitating Research and Development in Private Basic Technology
April	2004	National Institute of Information and Communications Technology, an incorporated administrative agency (NICT) is established by merging CRL and TAO
April	2012	Resilient ICT Research Center is established
April	2013	Center for Information and Neural Networks(CiNet) is established
April	2015	Renamed as National Institute of Information and Communications Technology, National Research and Development Agency
April	2016	Cybersecurity Human Resource Development Research Center (Currently, National Cyber Training Center) is established
March	2021	Beyond 5G R&D Promotion Project starts
April	2021	Quantum ICT Collaboration Center is established

NICT Primary Facilities

Headquarters

Koganei-shi and Kodaira-shi, Tokyo

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

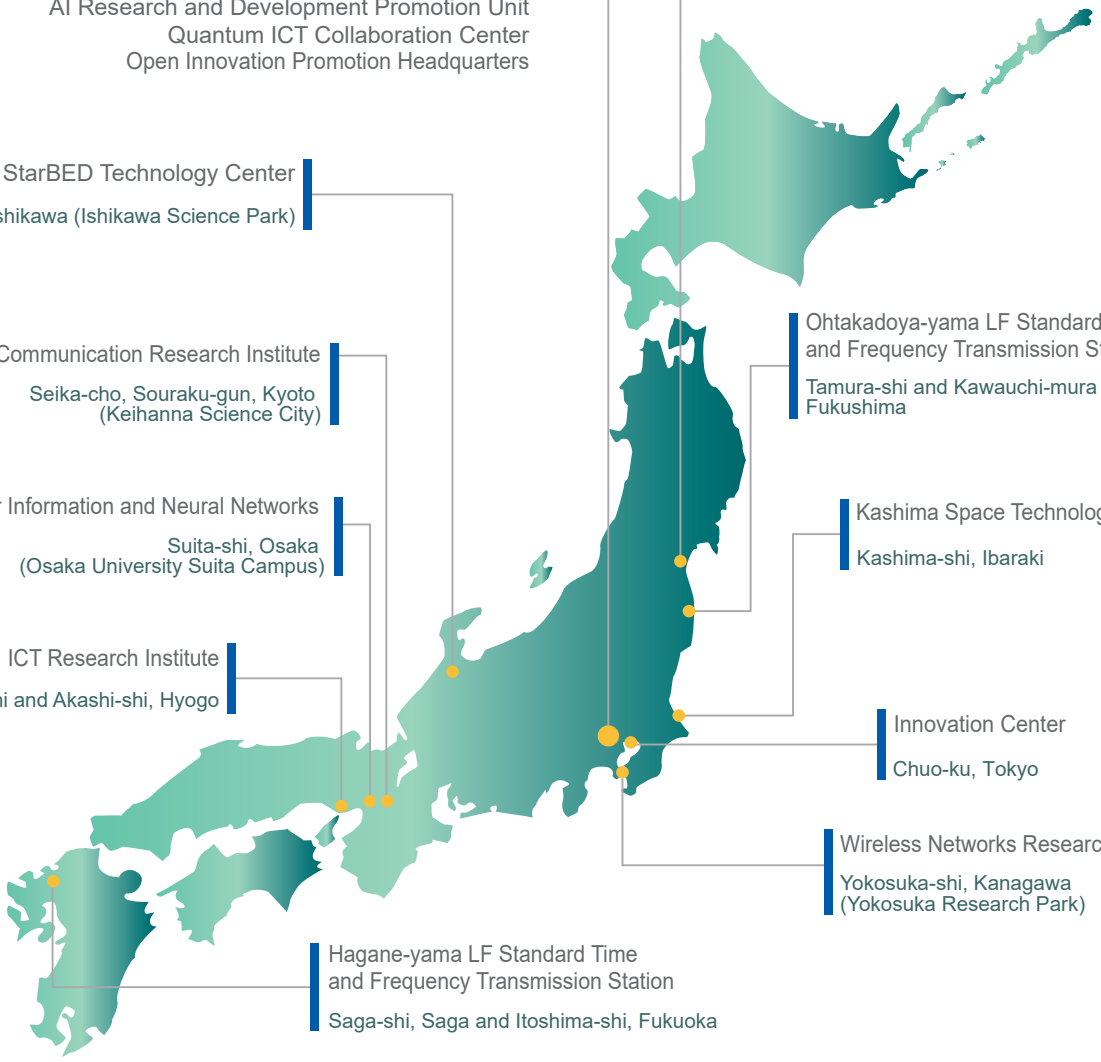
Resilient ICT Research Center
Sendai-shi, Miyagi
(Tohoku University Katahira Campus)

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

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

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

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



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

Kashima Space Technology Center
Kashima-shi, Ibaraki

Innovation Center
Chuo-ku, Tokyo

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

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

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

Overseas Centers

Asia Center
North-America Center
Europe Center

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National Institute of
Information and Communications Technology

Public Relations Department
4-2-1, Nukui-Kitamachi, Koganei, Tokyo 184-8795, Japan
e-mail：publicity@nict.go.jp
URL：https://www.nict.go.jp/en/


NICT
National Institute of
Information and
Communications
Technology