NICT REPORT

National Institute of
Information and Communications Technology

2020

NICT Charter

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

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

NICTER
Network Incident analysis Center for Tactical Emergency Response

Message from the President

The National Institute of Information and Communications Technology (NICT) is Japan's sole national research and development organization in the field of ICT. Our mission is to address social issues and create new values through the advancement of ICT. To achieve our mission, we are doing research and development on the world's most advanced technologies, and are promoting technology transfer and social implementation of our R&D outcomes through collaboration and open innovation projects with organizations in Japan and overseas.

In NICT's 4th Medium- to Long-Term Plan (FY2016-FY2020), our R&D encompasses five core themes: (1) sensing fundamentals, (2) integrated ICT, (3) data utilization and analytics platforms, (4) cybersecurity, and (5) frontier research. In each of these themes, we promote basic and fundamental research and development and, creation of open innovation in our society.

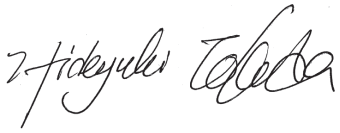
We not only cooperate closely with industries, universities, and government agencies for accelerating innovation, but also strengthen collaboration among internal and external research partners.

By FY2019, we made significant progress in these five core themes. In particular, we achieved cutting-edge performance and produced innovative solutions in quantum telecommunication, large-capacity communication via multicore optical fibers, neural information processing/communication, multiparameter phased array weather radar, post-quantum cryptography, and privacy protection technology. Regarding collaboration and open innovations, we have started practical cyber exercises (Cyber Colosseo) at the National Cyber Training Center in preparation for the Tokyo 2020 Olympic and Paralympic Games, and we have also accelerated our efforts to train security professional. In the field of data utilization infrastructure, we have broadened the operation of our translation bank system to include a wide variety of business fields, promoted its utilization in medical applications by collaborating with pharmaceutical companies, and enhanced the accuracy of our automatic translation system. We also created an AI data testbed from various AI-related projects and made the data available to public.

In addition, we have taken part in joint research and demonstration projects with other research institutes, businesses, universities, local governments and other organizations, both here in Japan and overseas, and we have promoted not only the commercial use of various advanced technologies developed by NICT, but also the international standardization of technologies by the ITU, IEEE and IETF, among others.

We have also strengthened our ties with partners across Europe, the US, and ASEAN countries. Furthermore, we are constantly taking on board everybody's opinions on matters such as R&D topics to focus on in the future, and we intend to extend an open data platform to make the diverse data obtained from our research available not only to researchers but also to the general public.

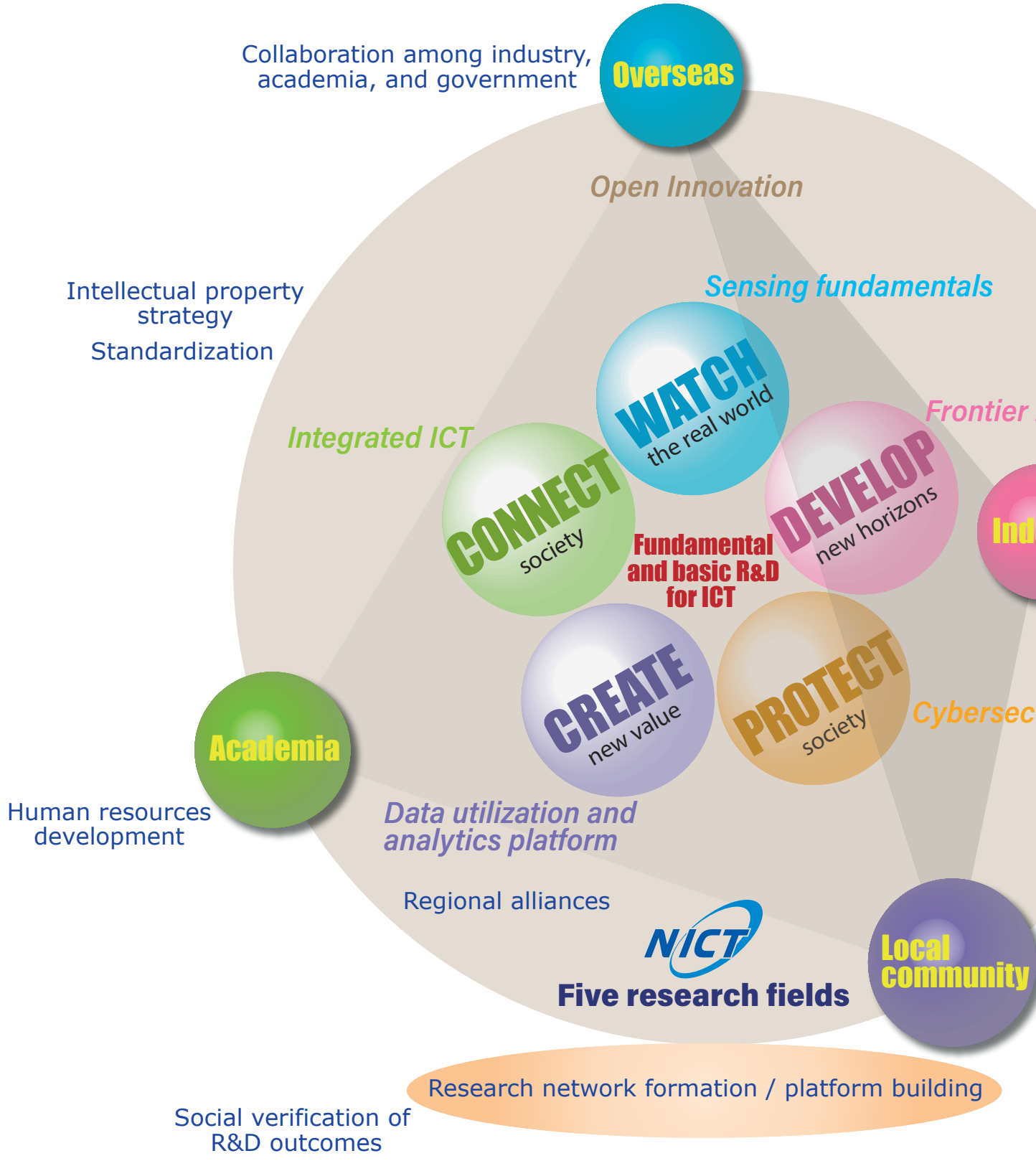
NICT will promote collaboration between industry, academia, and government agencies while working diligently with a broad range of partners, and work towards further development of the ICT field with an outward looking attitude. I hope that this annual report will help people to understand what we do here at NICT and promote further cooperation with other organizations, and I look forward to working with you in the near future.



President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki

Pioneering Future Society wit



th Cutting-Edge ICT

In order to demonstrate its potential fully in the new paradigm, in the Fourth Medium- to Long-Term Plan that started from April 2016, we are devoting ourselves to tackling the world's leading edge fundamental and basic R&D for ICT, based on these five foundations:

- "Watch" the real world through ICT
- "Connect" society through wireless and optical communications technologies
- "Create" new value through data utilization, etc.
- "Protect" society from sophisticated and complicated cyber attacks
- "Develop" new horizons of information and communications,

In addition, improving the quality of research and development, in order to more effectively implement our achievements to society, it is essential to build a system of collaboration among industry, universities, local governments, and research institutions at home and abroad. NICT, as a hub for open innovation in the field of ICT, will comprehensively promote broad range of efforts, in close cooperation with relevant parties, from the basic and fundamental research and development to support for new business activities, and will continue to contribute to the realization of a new social system.

Outline NICT : https://www.nict.go.jp/en/

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Sensing fundamentals

Applied Electromagnetic Research Institute

Director General　TAIRA Kazumasa

In order for humans to create new value using ICT, we need to observe and measure various phenomena and conditions in the environment surrounding us, creating data and converting it to information. The mission of the Applied Electromagnetic Research Institute is to realize this function through the use of electromagnetic waves. Our goals are "Protecting life and society, using the properties of electromagnetic waves to reveal phenomena that were not previously visible, and leading in the creation of new scientific value," and we are cultivating new fields for applications of electromagnetic waves, within NICT and also by building collaboration with industry and academia.

We are conducting research and development in areas of remote sensing technology, space environment measurement technology, space-time standards technology and electromagnetic environment technology. Remote sensing technology and space environment measurement technology acquire, collect and visualize information from various phenomena in the environment using electromagnetic waves. Space-time standards technology provides infrastructure for social and economic activity, for generating, supplying, and using high-quality time and frequency signals. And electromagnetic environment technology provides infrastructure for maintaining electromagnetic compatibility (EMC) among the various devices and systems.

Remote sensing technology

Our dual-polarization multi-parameter phased array weather radar (MP-PAWR) was developed under the Cross-ministerial Strategic Innovation Promotion Program (SIP) under Council for Science, Technology and Innovation, Cabinet office, Government of Japan. We began operation of this system and conducted tests to evaluate its effectiveness from late July to November 2018. This involved providing information predicting impending so-called "Guerilla rainstorms" to monitors of 2,000 people who were recruited from the public (Fig. 1).

We developed technology that measures the amount of water vapor using digital terrestrial broadcast signals. This

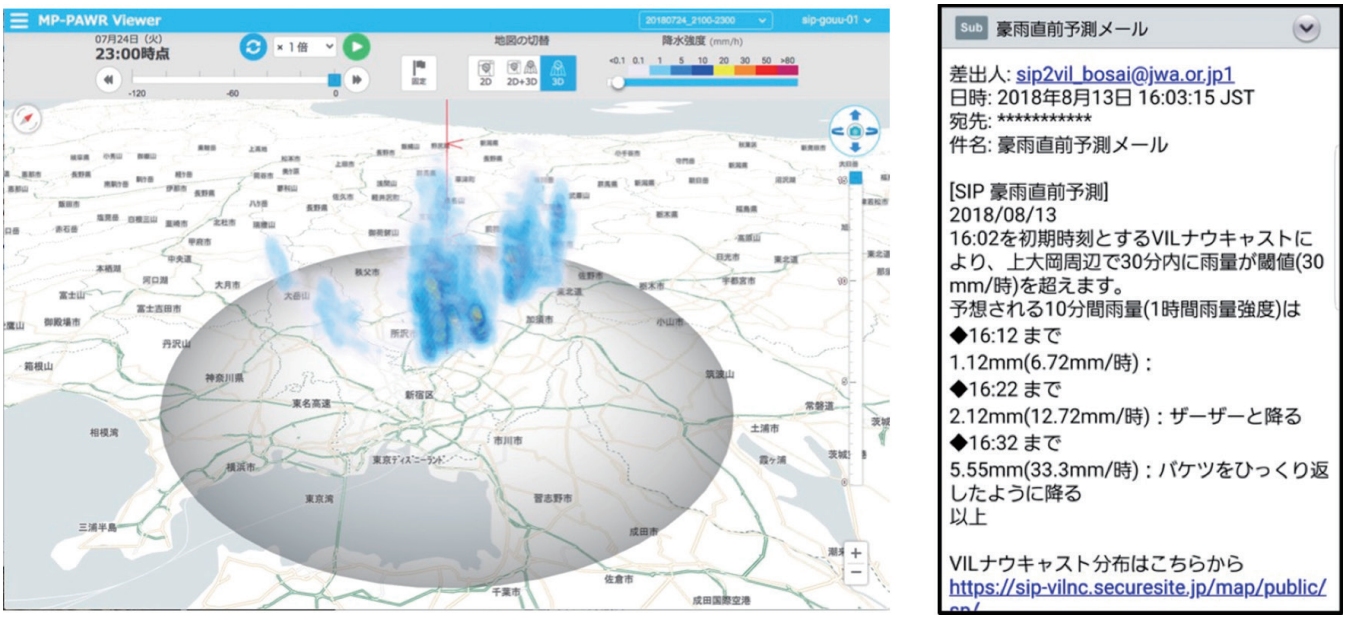


Fig.1 : MP-PAWR observations of precipitation displayed in a browser in 3D (left), and an early-warning of heavy rain delivered by email (right).

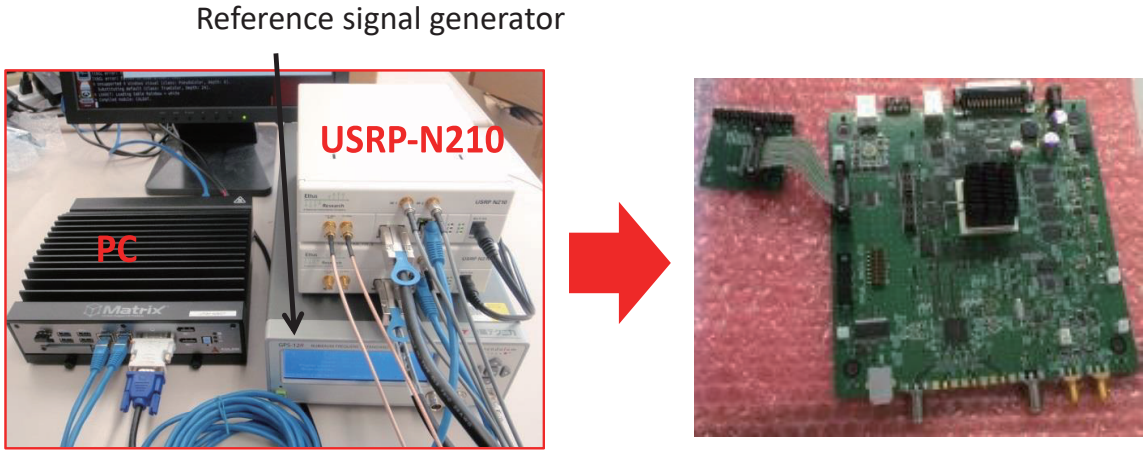


Fig.2 : Water-vapor observation system utilizing digital terrestrial broadcast signals: Prototype (left) and FPGA board for broad deployment version (right)

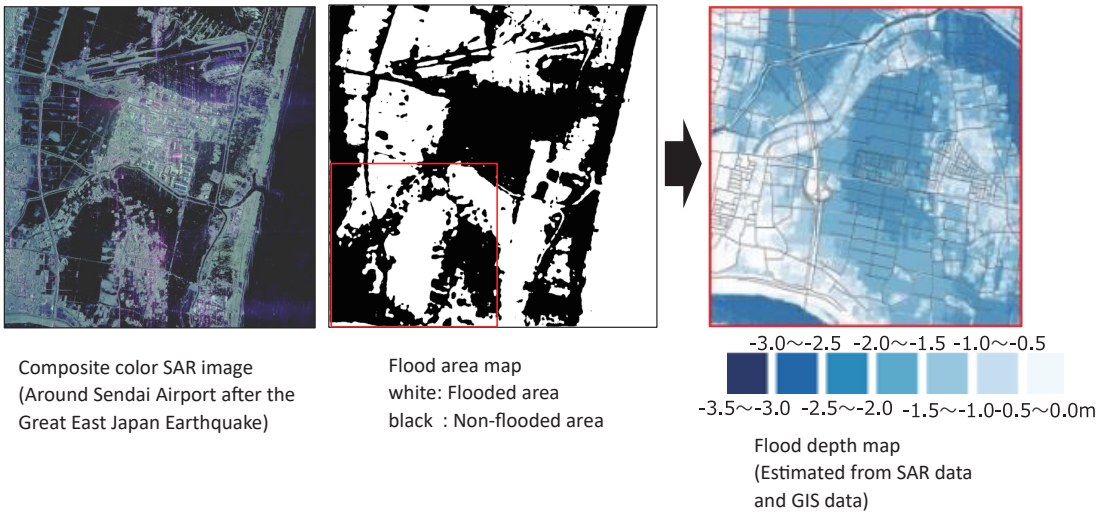


Fig.3 : Advanced result extraction of flood areas by integrating Pi-SAR 2 and GIS data

included a prototype version composed of a software radio (USRP-N210) and a PC, and a model for broad deployment, which utilized FPGAs to reduce size and power consumption. We also conducted operational testing (Fig. 2). The prototype is currently deployed in seven locations in the Tokyo region (11 observation lines along which atmospheric propagation delays are measured), making continuous observations.

We have made advances to information sampling technologies for our airborne synthetic aperture radar (Pi-SAR 2), which can be used broadly in applications such as maintenance and management of social infrastructure, vegetation surveys, and gathering information when disasters such as earthquakes and volcanic eruptions occur. These have included integrating output with GIS data to predict flooded areas and depths during a flood or tsunami and using machine learning technology to extract information with more advanced processing (Fig. 3).

Space environment measurement technology

We conduct ionospheric observations in 24-hour, 365-days-a-year with four radio observation facilities in Japan and one in Antarctica. This enables us to perform tasks such as observing radio-wave propagations, predicting and warning of anomalies, and issuing daily space weather forecasts. We have updated the Web site providing these forecast information, which is accessed approximately 70,000 times monthly. The Forecast information is also sent by email to approximately 7,000 registered recipients every day.

We have also made improvements to the accuracy of the numerical atmosphere-ionosphere model named "GAIA", which calculates from the ground to the ionosphere consistently, by including polar ionospheric effects and improvements to low-latitude electron density resolution as preparations for data assimilation methods

in future (Fig. 4).

We have begun to use a real-time magneto-hydrodynamic (MHD) simulations at space weather forecast briefings. We have developed a method to estimate the plasma environment in geosynchronous orbits using model with geosynchronous satellite observations and begun computing estimated electrostatic charges on artificial satellites.

To enable past solar observation data to be used in society, we have created a database with optical and radio observation data from the former Hiraiso Solar Observation facility and solar radio observation data from the Yamagawa radio observation facility and made the database available to the public. We have developed a probabilistic model for predicting occurrences of solar flares using machine learning, with the goal of increasing the accuracy of real-time predictions. We have also begun development of an ensemble solar storm arrival simulator in collaboration with Nagoya University, using their interplanetary scintillation (IPS) data, as a system for estimating the arrival time and quantitative effects of a solar flare.

Space-time standards technology

We have reliably performed the tasks of setting standard frequency values, radiating standard radio frequencies and reporting standard time. Throughout the year, standard frequencies were issued 99.99% of the time, and our Network Time Protocol (NTP) services were accessed approximately 6 billion times every day. To mitigate the risk of interruptions in generating and distributing Japan Standard Time (JST), we opened a Kobe sub-station on June 10, 2018. Since the substation was opened, we have maintained highly accurate synchronization of JST with the substation, to within 4 nanoseconds. In February 2019, we also transitioned from trial to formal operation of the Hikari Telephone JJY service, which is a new form of supplying JST.

The strontium (Sr) optical lattice clock maintained by NICT was recognized by the International Bureau of Weights and Measures (BIPM) as a secondary frequency standard, only the second such case in the world. The Sr optical lattice clock operated for ten days continuously, providing data more than 90% of the time, and was used to evaluate the tick rate of International Atomic Time (TAI) for the first time with a latency less than one month.

We established the first ever VLBI frequency link between the Italian National Institute for Astrophysics (INAF), NICT Kashima Space Technology Center, and NICT Headquarters, and began tests comparing frequencies from the Ytterbium (Yb) optical lattice clock at the Italian Istituto Nazionale di Ricerca Metrologica (INRIM), and the Sr optical lattice clock at NICT (Fig. 5).

We are developing a chip-scale atomic clock, anticipated as a key device for the

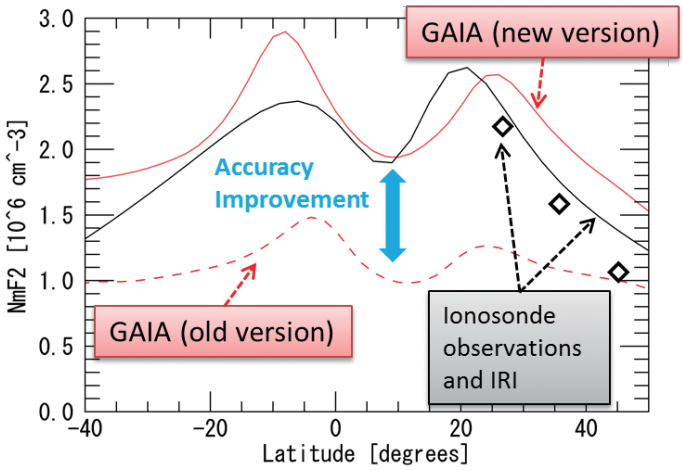


Fig.4 : Peak electron density distribution during a period of solar activity computed by GAIA

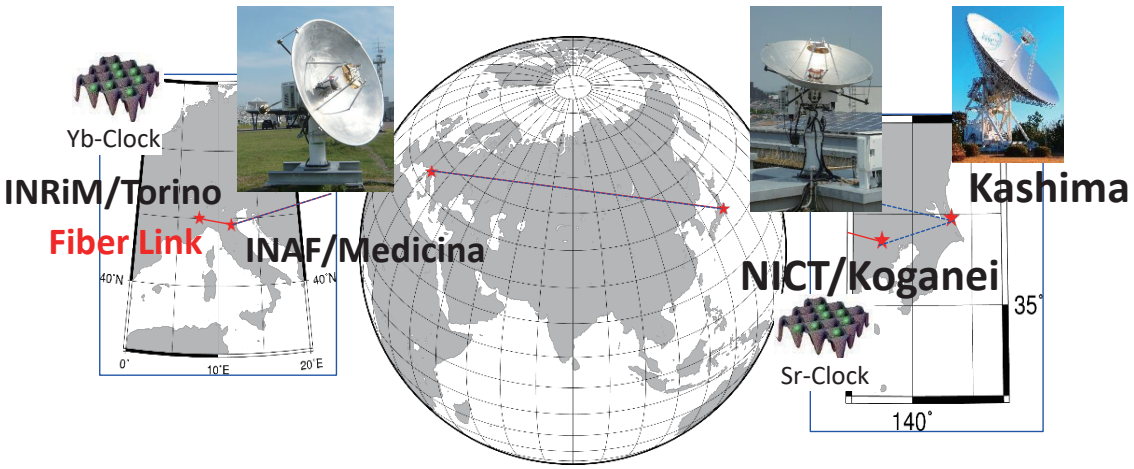


Fig.5 : Comparison of the frequencies of the NICT Sr optical lattice clock and the Istituto Nazionale di Ricerca Metrologica (INRiM) Yb optical lattice clock using VLBI

IoT era. As part of this development we have reduced the size and advanced the functionality of a 3.4 GHz oscillator, the heart of the atomic clock, utilizing a Film Bulk Acoustic Resonator (FBAR). We also developed a new MEMS reflective gas cell to exploit the reduced size.

Electromagnetic environment technology

We developed a wideband Transverse Electromagnetic (TEM) horn antenna for radiated immunity test in close proximity to a wireless communication device such as a cellular phone. The TEM horn antenna fully satisfied the international standard (IEC 61000-4-39; Testing and measurement techniques - Radiated fields in close proximity - Immunity test). It also achieved efficiency of approximately four times that of antennas available on the current market.

In RF power standard technology for the extremely high frequency band, we developed a 140-220 GHz calorie meter in collaboration with the National Institute of Advanced Industrial Science and Technology and evaluated uncertainty in equipment for calibrating commercial power meters.

We built a 3D measurement system for evaluating time characteristics and spatial distribution of electromagnetic disturbance for evaluation of electromagnetic interference on a wireless medical telemetry system with emissions from LEDs and other energy saving equipment in medical facilities (Fig. 6).

To develop technology for evaluating human exposure to radio waves up to the terahertz band, we precisely assessed electrical constants of biological tissues and organs, including measurement uncertainties, and established a database of the electrical constants up to the sub-millimeter-wave band. Human exposure to millimeter-waves was evaluated using the database and the results were cited as the rationale for exposure limits in the next revision of international guidelines.

Electromagnetic application technology

We transferred an active infrared imaging method for nondestructive testing to steel manufacturer, and it has been applied to observation of internal surface aging of steel pipes, and also began a collaboration with a construction company on visualization of the internal structures of buildings using microwave radiation.

With a screen fabricated using a NICT original Hologram Printing Technology (HOPTEC), we tested displaying full-color utilizing the high wavelength selectivity of the fabricated holograms (Fig. 7) and use of the technology for thin and light transparent displays. We also began collaboration with enterprise with the goal of expanding HOPTEC in society. We achieved increased stability and functionality of the wave front printing equipment itself, and through testing with newly developed device evaluation technology, we were able to fabricate stable, 20 cm × 10 cm holograms.

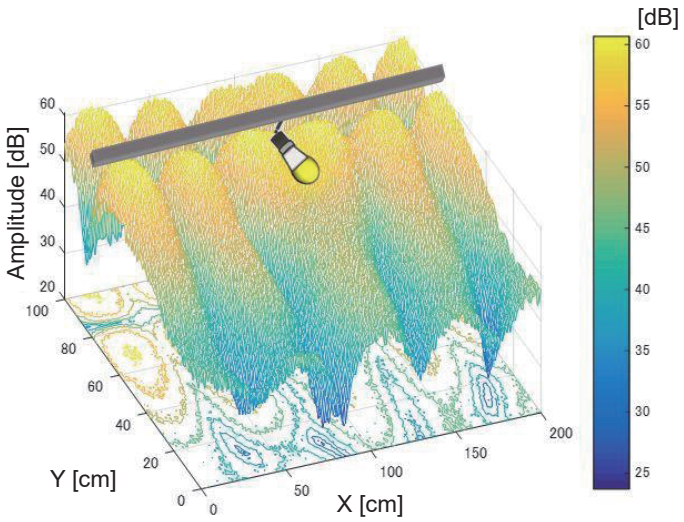


Fig.6 : Spatial distribution of electromagnetic disturbance near the power supply track for LED lighting

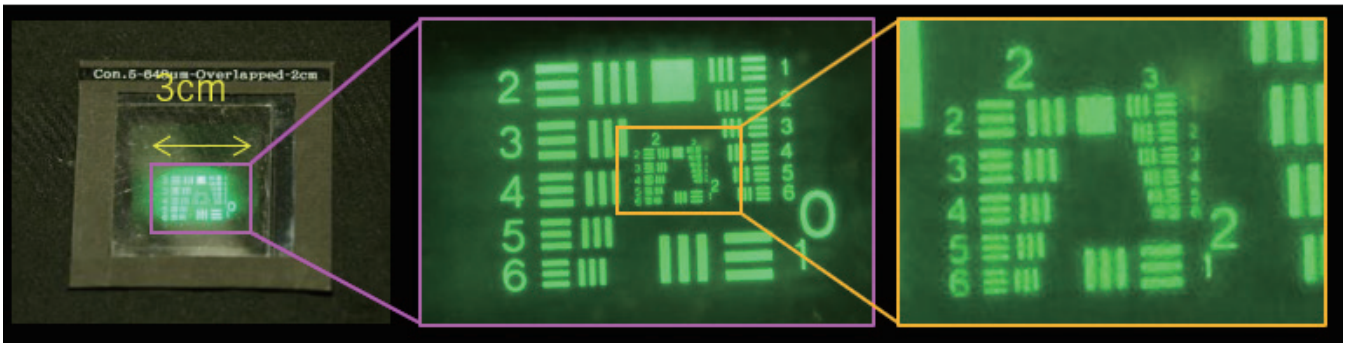


Fig.7 : An example of an optical element fabricated with wave front printing equipment (image formed is 2 cm deep)

Integrated ICT
Network System Research Institute

Director General　WADA Naoya

The Network System Research Institute promotes fundamental research and development of global and advanced network system technologies to meet the recent explosive growth in data traffic and for the diversification of communication quality and network service. This research aims to create a "connected society" that provides its citizens with new opportunities and revolutionizes business and social interactions.

Flexible optical path switching technology

As communication traffic increases and services using networks diversify, the optical networks supporting them must increase in capacity, use network resources more efficiently, and reduce power consumption. Currently, optical paths (wavelength paths) are provisioned based on predictions of traffic demand. However, it is difficult to change these settings and switch optical paths quickly, according to environmental changes such as traffic fluctuation or network failure. A major reason for this is a feature of conventional optical path nodes. When controlling (setup/release/switch) multiple optical paths at the same time, conventional optical amplifiers may cause optical power surges and fluctuations to remaining optical paths, and this often results in degradation of the Quality of Transmission (QoT).

To resolve this issue, NICT has developed a new burst-mode optical amplifier able to suppress optical power fluctuation and has proposed a new flexible optical path node. We conducted tests verifying parallel processing of multiple optical paths using this node and confirmed that high-speed control is possible without causing transitional signal degradation on the remaining optical paths. When controlling optical paths of four wavelengths together, the control time was 130 s with conventional technology. On the other hand, it was only approximately 30 s when the new flexible optical path node was used. In addition, since the control time is constant even when the number of controlled optical paths is increased, the reduction effect increases further for many wavelengths (Fig. 1).

Research, implementation, standardization, and deployment of ICN and CCN

NICT is conducting research on Information-Centric Networking (ICN) and Content-Centric Networking (CCN), which eliminates waste in conventional communication protocols, and obtains content from nearby network devices. This networking architecture enables users to receive high-quality communication services, with fast response times and low data losses. It also contributes to reducing energy consumption in the entire network by reducing traffic volume.

The software platform implementing CCN, called "Cefore," has been in development since 2017, and has been released as

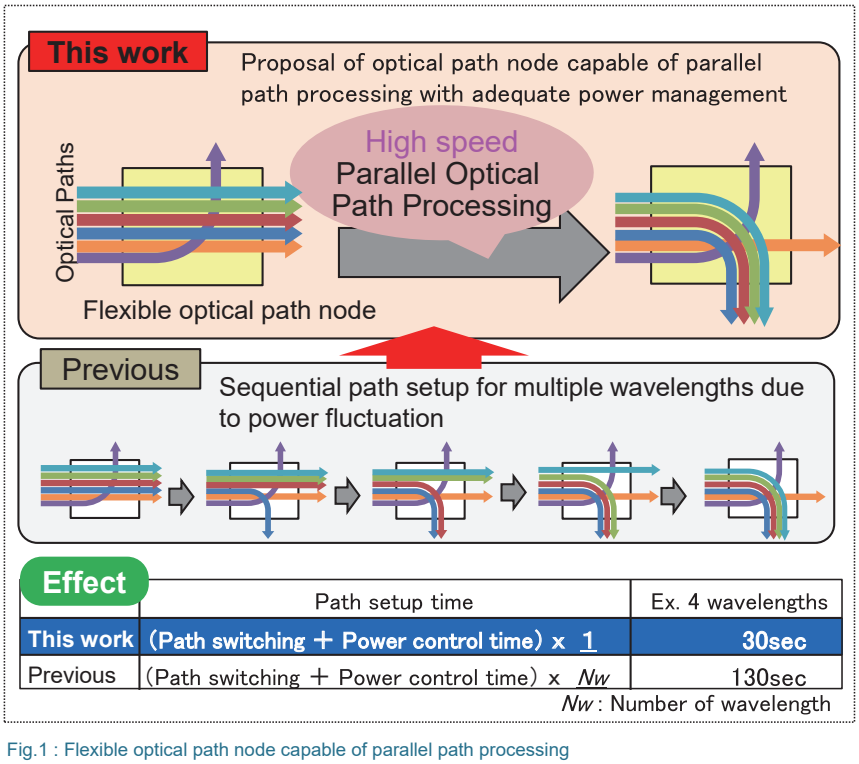


Fig.1 : Flexible optical path node capable of parallel path processing

open source starting in 2018. Cefore works on top of Linux, macOS, Raspberry Pi, and Android. Cefore consists of a lightweight packet forwarding daemon and extensible plugin libraries. It can support various types of nodes; for example, a tiny sensor node only with the forwarding daemon, or a high-spec backbone router with the forwarding daemon embedding functional plugin libraries.

In 2019, we have been doing fundamental research such as detailed design of the authentication function between ICN routers for protection of in-network caches and have continued activities not only to implement and enhance Cefore but also to promote it in society in Japan and overseas. At the Internet Engineering Task Force (IETF) and Internet Research Task Force (IRTF) meetings held in March in the Czech Republic, we made standardization and experimental proposals, participated in the IETF hackathon, and promoted development of Cefore. We also connected the ICN open testbed, called Container-based Unified Testbed for ICN (CUTEi), which was also developed by NICT; and to the GEANT network, a facility for research and education in Europe. This provides a test platform for research projects between Japan and Europe (Fig. 2).

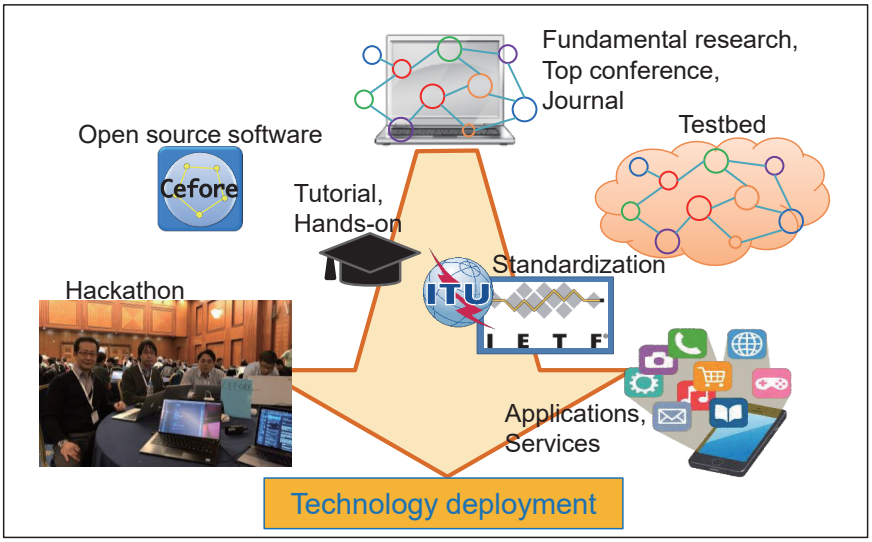


Fig.2 : Cefore initiatives

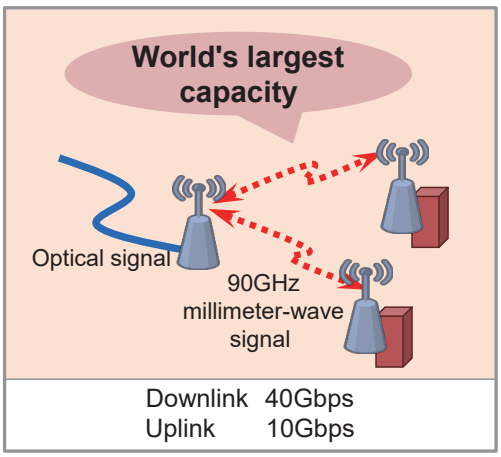


Fig.3 : High capacity transmission test using IFoF technology

Fig.4 : Radar antenna installed at Kuala Lumpur Airport

Radio over fiber research and development of application systems

Convenient, high-capacity wireless connectivity is desirable for the nearby networks to which terminals connect directly. High-frequency electromagnetic waves are essential for implementing high-capacity wireless communication. Technology able to accommodate these high-capacity wireless signals on optical fiber networks is also an issue. Radio over Fiber (RoF) is an advanced technology that enables convergent connection between optical fiber and wireless communications. NICT is conducting research on further platform technology to implement 100 Gbps wired and wireless seamless communication using RoF technology.

In 2018, we developed an Intermediate Frequency over Fiber (IFoF) technology that multiplexes data at an intermediate frequency, as part of research on this platform technology, and conducted successful world-class, high capacity transmission tests with an over-40 Gbps downlink and 10 Gbps uplink, using 90 GHz band radio frequency (Fig. 3).

NICT also developed a communications system for high-speed railways with industry-academia collaboration, based on an original 90 GHz band RoF technology, and successfully demonstrated world-leading high-capacity transmissions of 1.5 Gbps between a ground station and a Shinkansen train travelling at 240 km/h.

The results were selected for presentation as a post-deadline paper at the Optical Fiber Conference (OFC 2019), the world's largest event for optical communications research.

We are also developing an airport runway monitoring radar system in collaboration with enterprise, as an application of RoF technology. This system has the highest performance ever achieved, able to detect foreign object debris above the runway within 30 s, of sizes down to approximately 3 cm. It has been undergoing practical testing at Narita International Airport since 2016. In 2019, we have collaborated closely with Universiti Teknologi Malasia and enterprises in Japan and Malaysia, making a plan for testing at Kuala Lumpur Airport as well (Fig. 4).

Integrated ICT

Wireless Networks Research Center

Director General HAMAGUCHI Kiyoshi

The use of wireless communications in information and communication networks has grown dramatically in recent years, becoming an indispensable part of daily life. This trend has generated a need for R&D toward technologies that can further enrich life through the use of radio waves as part of a wide-ranging network environment that includes ground, marine, and space communications. The goal here is to create new value such as the next-generation mobile communications system (5G), large-capacity satellite communications, and the Internet of Things (IoT) and to achieve systems and applications that can provide users with unprecedented reliability and peace of mind.

Wireless network management technology

We demonstrated a method called STABLE (Simultaneous Transmission Access Boosting Low-latEncy) that we are developing to combine the multiple connectivity benefits of 5G with low latency characteristics, and we promoted the standardization of this technology at 3GPP RAN 1 (Rel. 16) (Fig. 1). We also studied the operating architecture of private microcells, and we succeeded in demonstrating a 28 GHz band service for 5G wireless based on cooperative behavior such as sharing information with existing operators. As a specific implementation of this service, we succeeded in demonstrating a wireless electronic traffic mirror that supports self-driving vehicles.

Wireless network customization technology

For wireless communication applications within the same factory, we cooperated with other companies to promote the modeling of wireless factors that are effective for achieving tolerable latency and the like (including wearable wireless terminals) (Fig. 2). By promoting the standardization of usage guidelines through FFPA (led by NICT), we completed the first draft of the security guidelines. Furthermore, with regard to the construction and operation of autonomous network topology from large numbers of wireless devices and the functional expansion of power-saving operations that are useful for outdoor applications such as farming, both of which are promising developments for IoT systems, we demonstrated transmission latency reduction and interference avoidance control based on the IEEE 802 standard specifications.

Wireless network reinforcement technology

For inter-terminal communication that can be used to construct a wireless network without requiring any infrastructure, we considered parameter expansion methods such as wireless device placement. We contributed to the standardization of IEEE 802 and the development of ARIB standards in line with the relaxation of UWB wireless systems. We also succeeded in sharing a single frequency by developing a simulator based on 3D space propagation characteristic data. We will continue with research and development of "Command Hopper" (Fig. 3), which contrib-

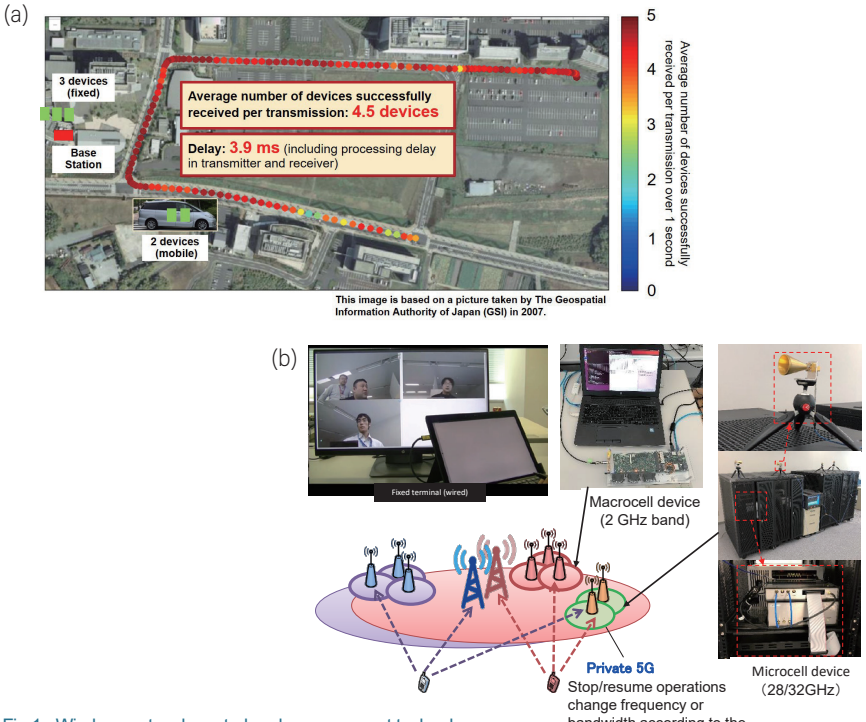


Fig.1 : Wireless network control and management technology: (a) STABLE demonstration, (b) Private microcell demonstration

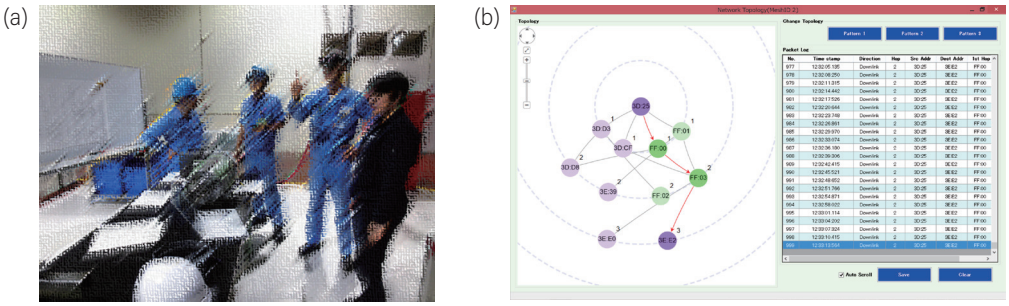


Fig.2 : Wireless network adaptation technology: (a) In-plant application experiment, (b) L2R demonstration by SUN wireless equipment

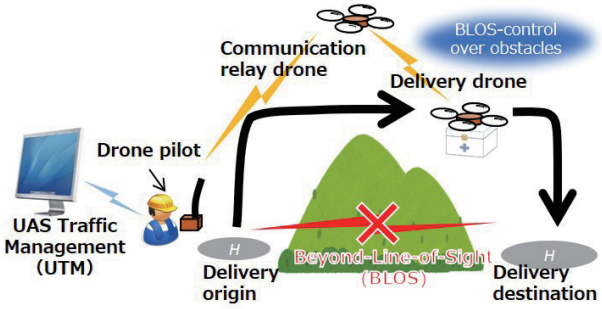


Fig.3 : Wireless network reliability enhancement technology: Overview of command hopper

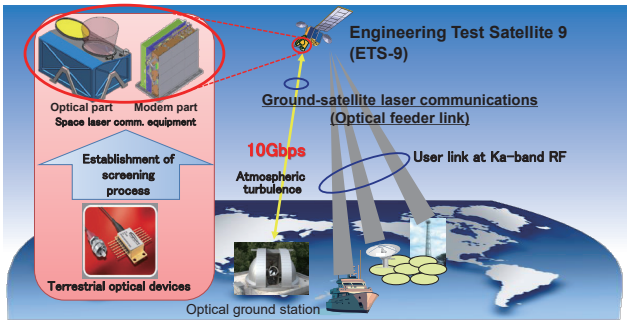


Fig.4 : Overview of configuration of optical feeder link experiment using ETS-9

utes to non-line-of-sight operation of drones and the like in environments where there are many radio wave obstacles, and "Drone Mapper", which shares location information and other details between flying objects. Furthermore, as wireless solutions for extreme environments, we demonstrated an effective underwater radio transmission technique that can detect objects buried under the sea floor, and a radio transmission technique for transmitting signals from inside to outside the body that helps in estimating the position of implanted or ingested radio devices.

Global optical satellite communications network technology

With the aim of demonstrating technology in space on board Engineering Test Satellite 9 (ETS-9), we worked on the development of the on-board ultra-high-speed optical communication terminal called HIgh speed Communication with Advanced Laser Instrument (HICALI) that is capable of the world's first 10-Gbps-class transmissions between a geostationary satellite and a ground station (Fig. 4). Building on these results, we made progress in the critical design of the on-board ultra-high-speed optical communication terminal, and we started working on the manufacturing phase of this flight system. In addition, NICT developed a compact optical transmitter called Very Small Optical TrAnsmitter (VSOTA, Fig. 2) for the RISESAT microsatellite developed by Tohoku University in Japan. Following a successful launch in January, 2019, we confirmed that VSOTA has passed its initial on-board check-out.

Space/ocean broadband satellite communications network technology

In the research and development of wide-area high-speed communication system technology, we studied systematic error correction methods for Digital Beam Forming (DBF) array feed units as a basic technology for on-board flexible payloads, and our measurements confirmed the efficacy of the gating method proposed in FY2017. Furthermore, for highly efficient operation control technology for hybrid satellite communication systems that have not existed before, we proposed a highly efficient traffic control algorithm that is implemented in the Network Operation Center (NOC). We confirmed the effectiveness of this algorithm by numerical simulation, and we published our results in a technical journal.

We measured the effects of vegetation on the propagation characteristics of mobile equipment by using the Wideband InterNetworking engineering test and Demonstration Satellite "KIZUNA" (WINDS) for Ka-band propagation characteristic measurements. To demonstrate the effectiveness of satellite communication in the event of disaster, we participated in the Japan Medical Association disaster drill by using WINDS to provide Internet connectivity. In addition, as an experiment in marine communication where broadband connectivity is only available via satellites, we performed real-time transmission tests in which surveys of submarines and sunken ships performed by the unmanned submarine explorer vessel called Remotely Operated Vehicle (ROV) in Wakasa Bay and the East China Sea, and the ROV images and videos were transmitted in real time to an on-shore base and successfully broadcasted via the Internet (Fig. 5).

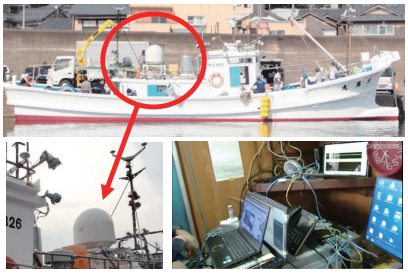


Fig.5 : ROV survey of submarines and sunken ships in Wakasa Bay

Data utilization and analytics platform

Universal Communication Research Institute

Director General KIDAWARA Yutaka

We are conducting R&D of human-friendly and intelligent communication technologies that can make ordinary people's everyday life richer and more secure. In particular, we are aiming at technologies that can extract and exploit the vast amount of knowledge and information circulating in our society, which we call "social knowledge," from a wide range of information media on the internet, including the WWW and SNS. Though such social knowledge sometimes circulates only inside communities of experts, we are aiming at making expert knowledge available even to non-experts.

The systems we developed so far can extract and accumulate a large amount of social knowledge and allow users to access the accumulated knowledge through simple question answering. Some of our systems also enable users to generate hypotheses easily, or to look at summaries of a vast amount of social knowledge. We are also collaborating with the Resilient ICT Research Center on the R&D of technologies used to help local governments and disaster victims to collect, from SNSs, information useful for reducing disaster damages. The technologies and systems we have described so far are focusing on social knowledge in the form of text, but we are also conducting R&D on an image analysis technology that can provide support for taking various actions.

WEKDA

We are developing "WEKDA (Web-based Knowledge Disseminating Dialog Agent)," a prototype of next-generation spoken dialog system that can conduct chitchat on a wide range of topics by exploiting a vast amount of social knowledge extracted from the Web. We aim at making such social knowledge more accessible to a wide range of people in their everyday lives.

WEKDA can provide answers to a wide range of questions. It can also generate replies to non-question input by generating relevant questions automatically using deep learning, retrieving answers to those questions from 4-billion web pages, and composing a reply from the retrieved answers. In this answer retrieval process, we use the question answering system WISDOM X, which we developed at our institute and is publicly available (https://wisdom-nict.jp/) since FY2014. In FY2018, we improved the question answering capabilities of WEKDA, allowing it to answer "why"-type questions, such as "Why has artificial intelligence achieved such progress?" and "how to"-type questions, such as "How can I get a good photograph of a kingfisher?" Both of these functionalities were implemented using state-of-the-art deep learning technologies. WISDOM X was already capable of answering why-type questions, but it provided as answers relatively long text passages, which are often redundant and difficult to be read aloud by spoken dialog systems such as WEKDA. We developed a novel deep-learning based technology that can summarize such long answer passages into non-redundant compact answers, which are more suitable for being read aloud, and integrated the why-type question answering capability to WEKDA by combining this compact answer summarization technology to an improved version of WISDOM X's why-type question answering technology that exploits deep learning (Fig.1). The how-type questions answering capability in WEKDA uses a completely new deep-learning technology and can give non-redundant compact answers, just like in why-type question answering.

Thus, WEKDA uses many deep learning technologies. Recently, high-performance neural networks for natural language processing tend to be quite large and are becoming computationally more challenging to use. One problem is that it is difficult to partition the large amount of parameters in those large networks and to store them distributed in multiple GPGPUs (a kind of device that enable efficient training and use of neural networks). This implies that the size of the networks is limited by the amount of memory in a single GPGPU. In order to overcome this difficulty, we have developed a novel deep learning framework that realizes such model-parallel training. This enables a single neural network to be partitioned and distributed over multiple GPGPUs. With this technology, we can train very large neural networks, that are otherwise difficult to process on a single GPGPU due to memory size constraints, by distributing them over multiple GPGPU servers. Also, by doing partitioning based on an intermediate representation of the neural network output used by various existing frameworks, such as PyTorch, we have been able to realize an open architecture that is not dependent on a specific framework (Fig.2).

Image big data processing technology

We are conducting research on technology to build an image corpus using the huge amount of image data (image Big Data) available on the Internet, and on how such a corpus can be used. In FY2018, we worked to improve an image clustering algorithm, which is one of image corpus building technologies that is expected to support tourism. We were able to improve the accuracy by 10% relative to earlier efforts, depending on the dataset. Also, by using GPUs to implement components that can be processed in parallel, we were able to increase processing speed by a factor of 200. We also prototyped a tourism support application using a tourism image corpus (Fig.3). By taking a photograph of a building, the application is able to give an explanation of it and provide guidance to other noted buildings in the area.

On another front, we are also working on collecting disaster related information from images posted to social media and make use of it for disaster response. We have proposed a framework covering the processes from collection to presentation of information and begun a test implementation. We have also begun research on an image comparison technology in collaboration with a private enterprise. This technology can be used, for example, to detect differences between photographs of a given location during a disaster and those taken during normal circumstances.

We are also steadily advancing research on technical elements of fVisiOn, a table-top 3D display technology not requiring glasses. This is a visualization technology that helps users to more effectively use collected and descriptive image information. We have expanded research activities on multiple levels, including further improvements in image quality, techniques for creating 3D content from real-world objects, and developing contactless interfaces with 3D images. For example, in research to express image conditions in more detail, we have succeeded in reproducing images in a real environment by increasing the number of projectors virtually. In this way, we have been able to achieve clearer 3D images by having over 1,000 virtual projectors that is three to four times the number of projectors of the previous prototyping (Fig.4).

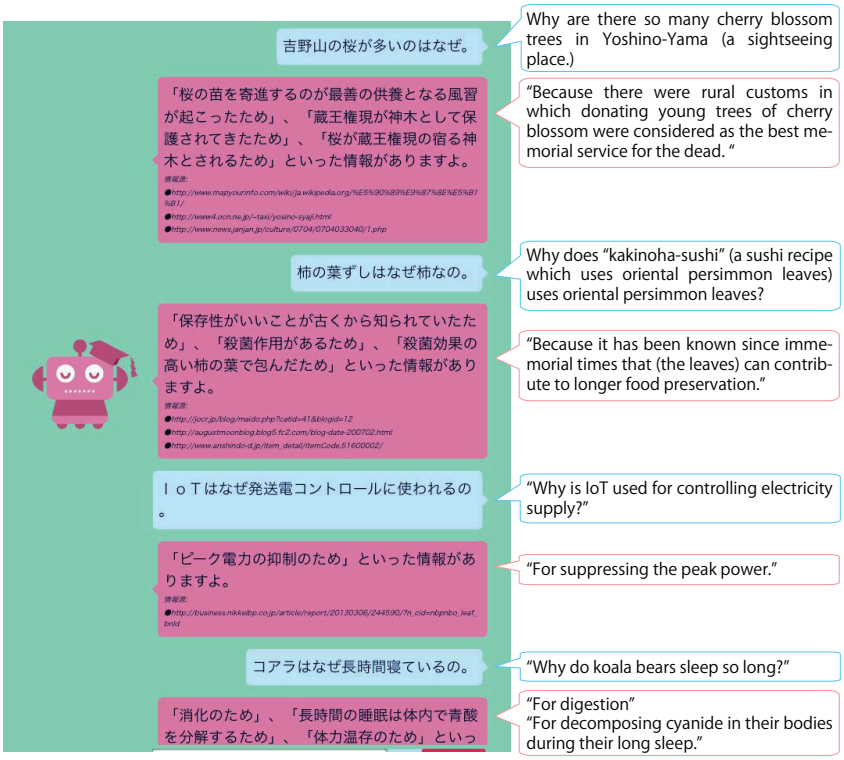


Fig.1 : Example of answering "why" questions with WEKDA

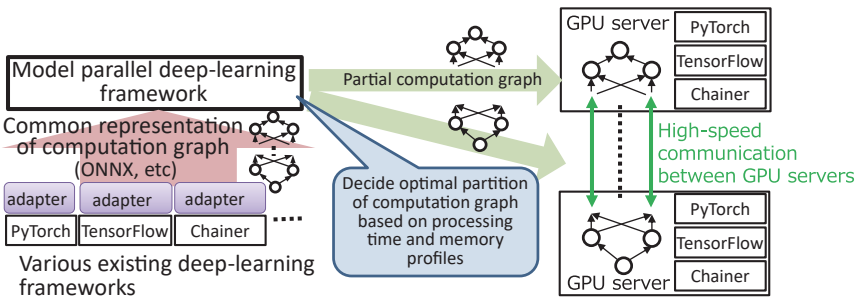


Fig.2 : Model parallel deep-learning framework

Fig.3 : Tourism application

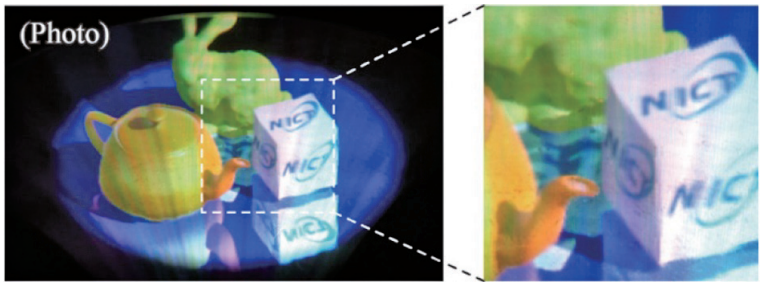


Fig.4 : 3D image equivalent to 1,200 projectors (optically composed images on the actual device)

Data utilization and analytics platform

Center for Information and Neural Networks

Director General YANAGIDA Toshio

To create new ICT that is useful for improving people's lives and welfare, CiNet aims to measure activity related to cognition, senses and movement that takes place in the human brain (which is the source and destination of all interpersonal communication), and to establish techniques that can efficiently decode and encode this brain information. To this end, we are working on applying high-level brain information processing to fields such as information processing architecture design and biomarker discovery, and we are promoting research and development of technologies that improve the motor skills, sensory abilities and social activity of individual people. We are also conducting basic research on the evaluation of comfort and safety based on brain information, and we are researching and developing basic technology for estimating changes in human emotions and cognition based on changes in brain information and on people's reactions to changes in multisensory input.

Furthermore, we are working to enhance neural measurement techniques that underpin this research and development, and to develop compact measuring devices and other equipment that can be used in everyday life. We aim to realize integrated brain information data analysis by integrating, sharing, and analyzing the huge quantities of brain function data generated by this measurement technology.

Electroencephalograph analyses

As part of our research about brain function analysis, we are investigating the relationship between alpha waves and cognitive functions by electroencephalograph (EEG) recording in different psychophysical regimes. Moreover, as a medical application of EEG analyses, we developed a new system for epileptic seizure detection in collaboration with the University of Tokyo and Jichi Medical University. Artificial visual recognition system powered by deep neural network technology can successfully detect epileptic seizures from scalp EEG plot images and performed far superior detection accuracy to existing commercially available techniques (Fig. 1).

Fig.1 : Deep convolutional neural network for the detection of seizures from brain wave images. Highly accurate detection is achieved by using a deep neural network to identify the imaged electroencephalogram data, taking a hint from the fact that skilled doctors detect seizures visually.

Human assistance research

As part of the technology being developed to estimate and improve the motor skills and sensory skills of individual people, we have worked on the development of fundamental technologies related to brain-machine interfaces, and we are developing and evaluating clinical research models in collaboration with research groups including one at Osaka University. We have also promoted the development of high-density multi-channel flexible nerve electrodes. Furthermore, in addition to promoting research and development of action modification systems and virtual human musculoskeletal models, we have demonstrated that the actions of individuals are unconsciously corrected by "prediction errors" (which arise when the actions of others differ from the actions one was expecting).

Brain information decoding technologies

Brain information decoding technologies that read perceptual and cognitive information from human brain activity are expected to play an important role in sup-

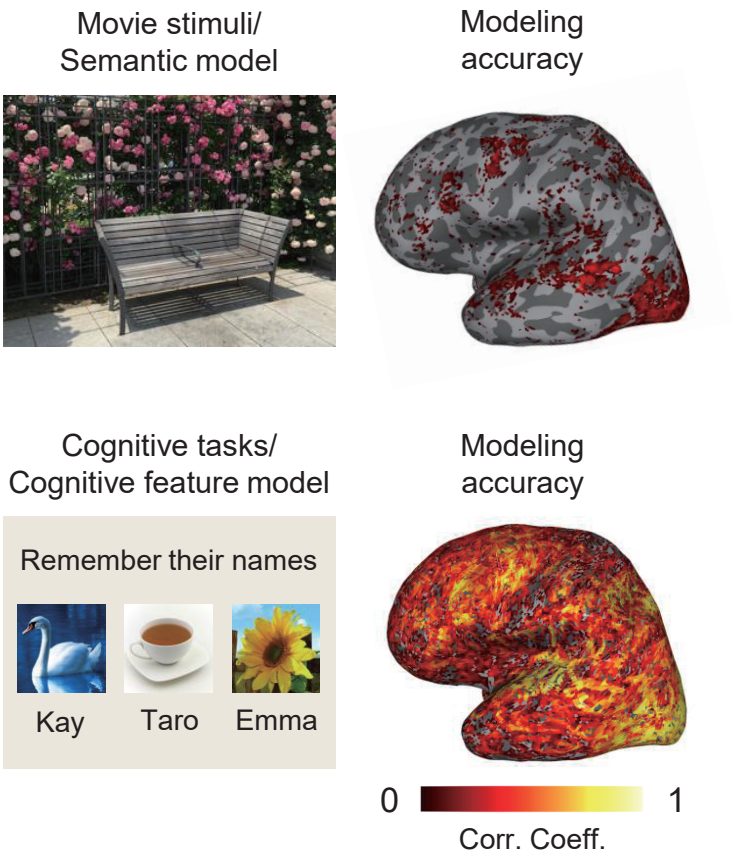


Fig.2 : Development of cognitive brain models that can predict human brain activity while performing multiple tasks

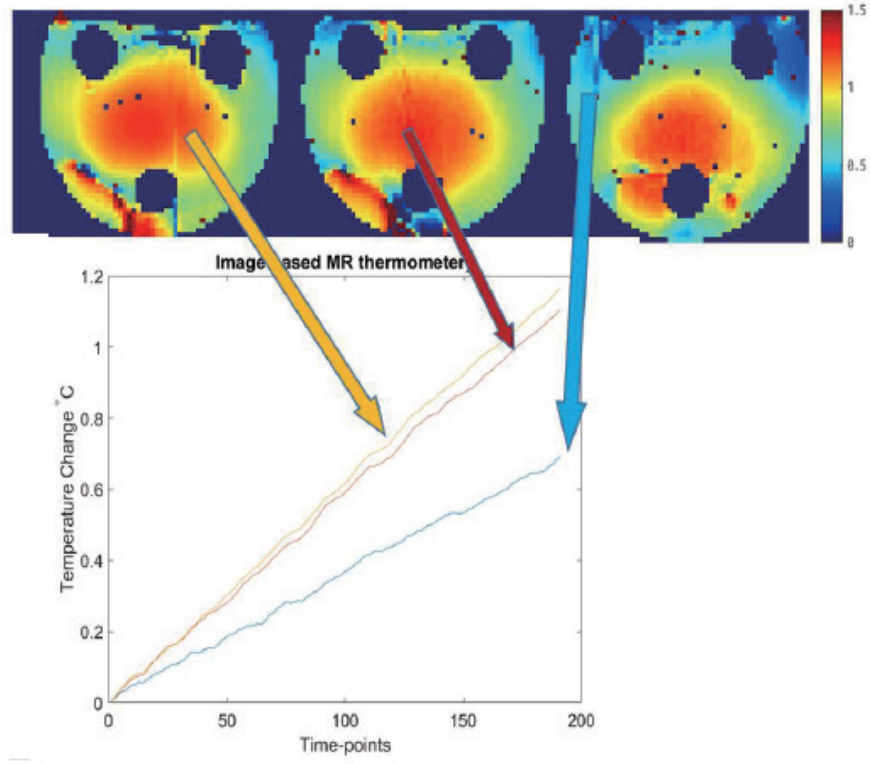


Fig.3 : Using a phantom to verify a change in temperature: results of measuring a temperature increase from MRI images

porting new ways of evaluating products and services. By modeling whole-brain activity in humans performing over a hundred, different active cognitive tasks, we succeeded in developing techniques for predicting and decoding brain activity in people who are performing new tasks (Fig. 2). We also developed a method for estimating several classes of perceptual outcomes of audiovisual stimuli by using an artificial brain model that does not require additional fMRI measurements for new stimuli.

Multi-shot EPI technology

An imaging method called Echo Planar Imaging (EPI) is used in fMRI. Although it has excellent temporal resolution, its spatial resolution is poor, and it is prone to image distortion and signal loss. By developing an improved measurement method called multi-shot EPI and designing a new method that can suppress the generation of spurious images by static magnetic field instabilities, we have implemented fMRI with a high signal to noise ratio (SNR) and excellent spatial resolution (Fig. 3).

Measurement of brain activity relating to interactions between human and the outside world

We have focused on the measurement of brain activity related to interactions between humans and the outside world, such as people and the environment. It has become clear from questionnaires and brain activity measurements that complicity in aggressive behavior leading to bullying and the like correlates more strongly with social anxiety than with lack of empathy, which is the generally accepted cause. We also succeeded in developing a technique that makes it much easier than before to measure working memory, which is an essential brain function for interaction with the outside world. Furthermore, we clarified that the motivation people feel when taking part in competitive games is manifested in specific brain activity.

Data utilization and analytics platform
Advanced Speech Translation Research and Development Promotion Center

Director General KIDAWARA Yutaka

The Advanced Speech Translation Research and Development Promotion Center (ASTREC) promotes research and development of multilingual speech translation technology and its social implementation. Our work is based on Japan's Global Communication Plan (GCP), which aims to eliminate the world's language barriers and facilitate human interaction on a global scale, while forming part of a nationwide initiative that includes skilled researchers and engineers both from NICT and private companies. We aim to accelerate open innovation using multilingual speech translation technology to realize an advanced ICT-based society where language barriers do not exist. In FY2018, we continued to make efforts to reduce the language barriers faced by foreigners visiting Japan for the Tokyo 2020 Olympic and Paralympic Games by improving the accuracy of our multilingual speech translation technology and expanding the range of languages and fields in which it can operate. Also, in cooperation with private companies, we have conducted field experiments in various fields and through cooperative research projects, some of which have led to practical applications.

Research and development of multilingual speech translation technology toward 2020

As the basis of our speech recognition technology, we built a speech corpus consisting of a total of 2,093 hours: 750 hours of Korean, 533 hours of Chinese, 325 hours of Myanmar, and 233 hours of Thai, etc. As for speech recognition, the improvements made to our speech recognition models have led to significantly higher recognition accuracies for Japanese, English, Chinese, Korean, Thai, Vietnamese, Indonesian, Myanmar, Spanish, and French (word error rates have been reduced as much as 18-41% compared to the end of FY2017). As for text-to-speech, the improvements made to our acoustic models led to a better speech quality for Indonesian and Myanmar. We also developed new text processing modules and acoustic models for Spanish and French and have reached a practical level of speech quality for both languages. These improvements in speech recognition and text-to-speech have been implemented into our field experiment system VoiceTra and have been released to the public. Fig. 1 shows the progress of VoiceTra made in FY2018.

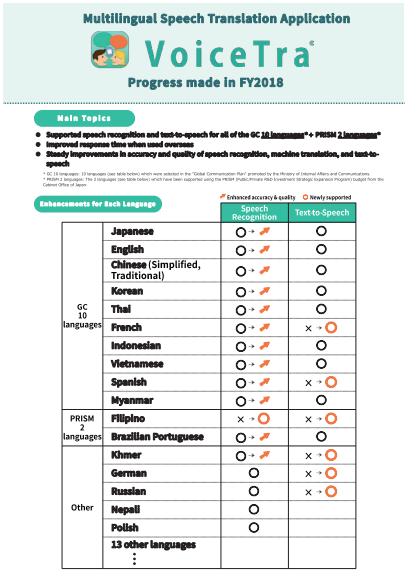


Fig.1 : Progress of VoiceTra (FY2018)

Research and development of language identification technology

VoiceTra requires users to configure the language settings before use, which made it difficult to even start a conversation when one cannot tell what language the

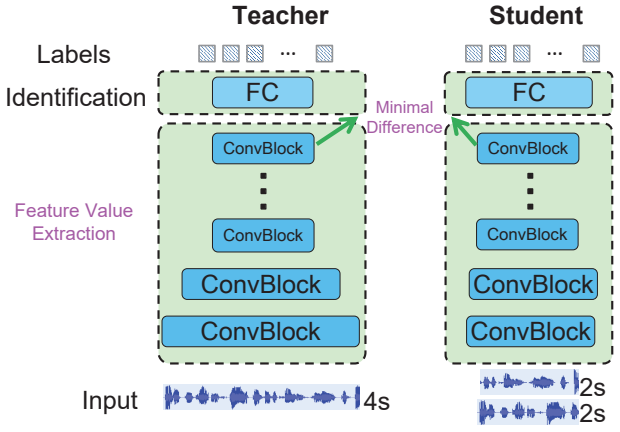


Fig.2 : Language identification model training using knowledge distillation

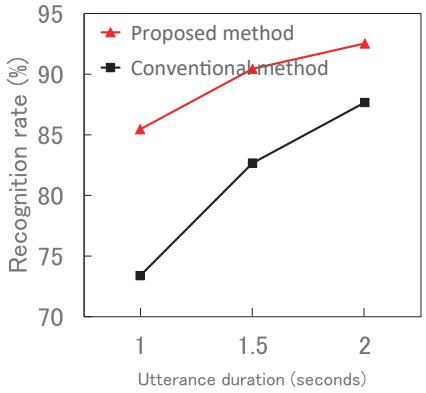


Fig.3 : Comparison of language identification accuracies for 8 languages

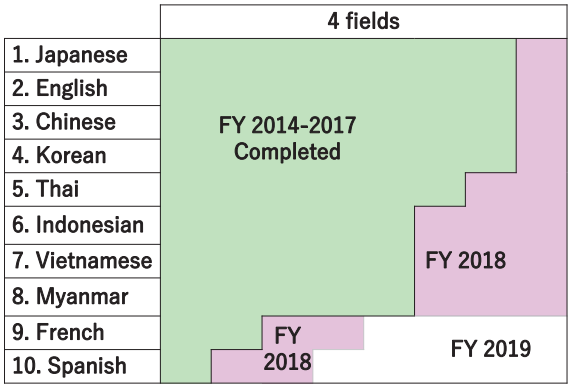


Fig.4 : Development of the world's largest-scale translation corpus of spoken language to be completed in FY2019

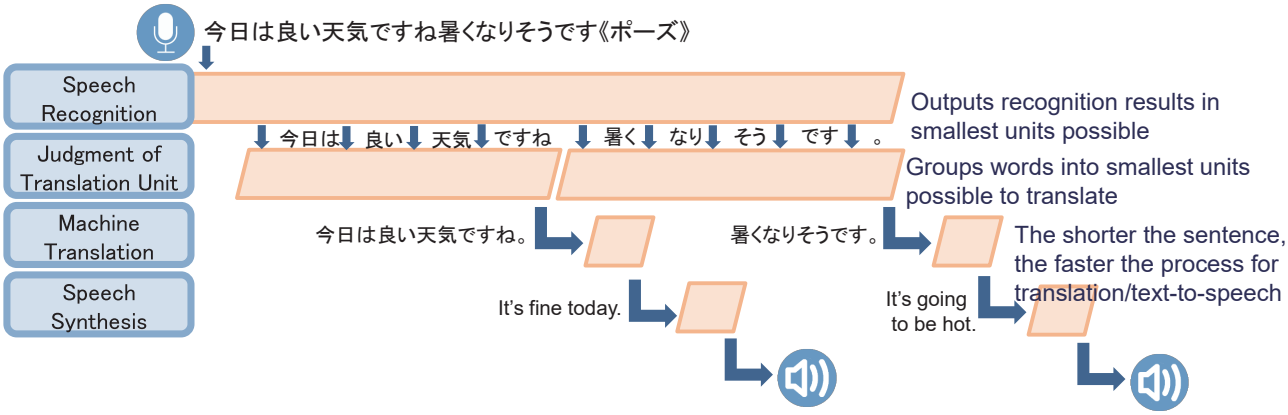


Fig.5 : Sequential process in smallest units

other person speaks. Furthermore, the conventional language identification technology required about 10 seconds of speech and could not be applied to real-time conversations. To tackle these issues, we proposed a method using knowledge distillation technology, where small-scale neural networks (student)—capable of highly-accurate, real-time language identification from short utterances—can be developed from neural networks (teacher) which are capable of accurately extracting feature values required for identifying languages from longer utterances (Fig. 2). Using this method, we developed a language identification technology which can identify which of the 8 languages (Japanese, English, Chinese, Korean, Thai, Myanmar, Vietnamese, and Indonesian) is being spoken from about 1.5 seconds of utterance, achieving above 90% identification accuracy (Fig. 3).

Research and development of multilingual machine translation technology toward 2020

We have added a total of 4.54 million sentences to our translation corpus of spoken language in ten different languages for fields such as travel, medical care, and disaster prevention (110K sentences of Japanese, English, Chinese, Korean, respectively, 380K sentences of Thai, 800K sentences of Indonesian, Vietnamese, Myanmar, respectively, and 660K sentences of Spanish and French), exceeding far beyond the original target of 3 million sentences. The development of this translation corpus is to be completed at the end of the next FY and is proceeding well on schedule (Fig. 4). Furthermore, we have added 580K sentences of spoken language and 1.4 million sentences of written language through two of our commissioned research projects* as well as through our "Hon'yaku (Translation) Bank" scheme and expanded our translation corpus to a total of 10 million sentences. This large-scale development of our translation corpus for various fields is an important progress in accelerating the advancement of machine translation technology for both spoken and written languages.

Real-time multilingual subtitling system

We are currently preparing a research platform in anticipation of future research and development of a simultaneous interpretation system. As a prototype system for research purposes, we have developed a "real-time multilingual subtitling system." This system minimizes the latency by running speech recognition, machine translation, and text-to-speech modules sequentially in the smallest units possible (Fig. 5).

* Projects are "Research and Development of Speech Translation System for Local Governments" and "Multimodal Language Understanding using Deep Learning and Advancement of Machine Translation."

Cybersecurity

Cybersecurity Research Institute

Director General KUBOTA Minoru

In the Internet of Things (IoT) era, many sensors and other devices will be deployed in our surroundings and connected to networks. They will allow us to lead more convenient and 'smart' lives; however, security measures for guaranteeing the safety of such devices are becoming a pressing issue behind the scenes. The scope that cybersecurity should cover is expanding daily; in particular, it must be able to protect people from information leaks and privacy violations when big data collected from such IoT devices is utilized. The Cybersecurity Research Institute conducts research and development (R&D) on how to deal with the latest pressing concerns and emergent issues in our information society.

Cybersecurity technology

We conduct R&D on cutting edge cyberattack monitoring and analysis technologies, to enhance cyber protection capability on such things as government agencies, local governments, academic institutions, companies, and critical infrastructure. We also engage in research on collecting and analyzing huge amounts of data from these diversifying cyberattacks and aim to utilize it in automatic cyberattack countermeasures. We also strive to achieve quick R&D outcome deployment through application and verification in NICT's own cyber incident response system to strengthen the technology.

We have conducted joint research together with Delft University of Technology in the Netherlands and Yokohama National University, on a security technology for IoT devices, involving experiments notifying users when IoT devices have been infected with malware. In these experiments, we collaborated with an ISP in Europe, sending warnings to users by multiple methods. The effects were measured, and the results were presented at the NDSS2019 international conference, receiving a Distinguished Paper Award.

We conducted R&D on a technology to automatically classify IoT malware using machine learning, as a technology to analyze the large volume of security related information collected by the Cybersecurity Universal Repository (CURE). This work received a Best Paper Award at the AsiaJCIS 2018 international conference (Fig. 1).

In cyber security reporting, we have published the NICTER Observation Report 2018, with results of year-round dark-net observation and analysis, and published information on the NICTER Blog and NICTER Web site.

Technologies for building and using a security verification platform

We oversee R&D on technologies for emulating cyberattacks in a safe environment, the construction of a security verification platform that is indispensable for verifying newly developed protection technologies and verifying cyberattack countermeasure technologies in an emulation environment. To resist targeted attacks and other cyberattacks, we have made further advancements to the NIRVANA KAI cyberattack integrated analysis platform and developed the new NIRVANA KAI-Ⅱ vulnerability management platform, to provide rapid and effective management of vulnerabilities due to defects in OS and software (June 11, 2018 press release) (Fig. 2).

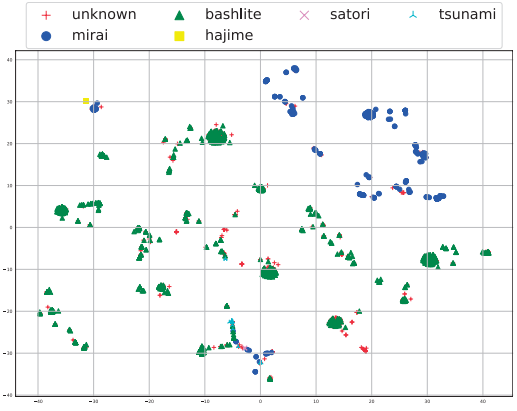


Fig.1 : Result of malware categorization based on degree of similarity

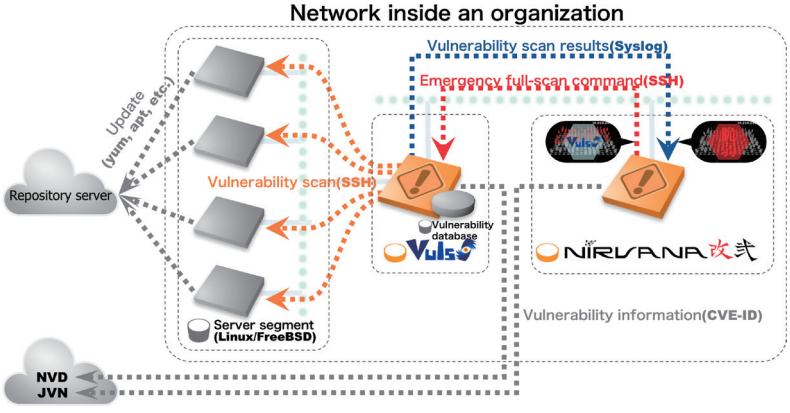


Fig.2 : The NIRVANA KAI-II system architecture

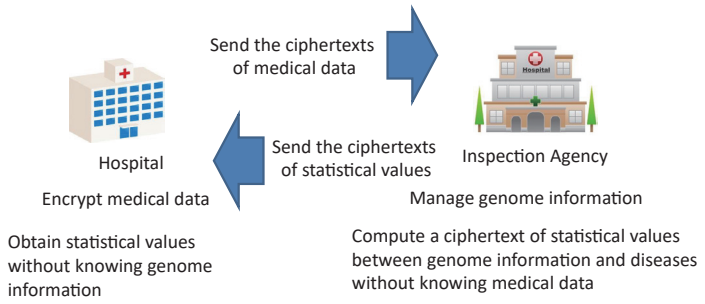


Fig.3 : Evaluation method for preventing the case where medical records of different diseases are unexpectedly mixed without knowing medical data

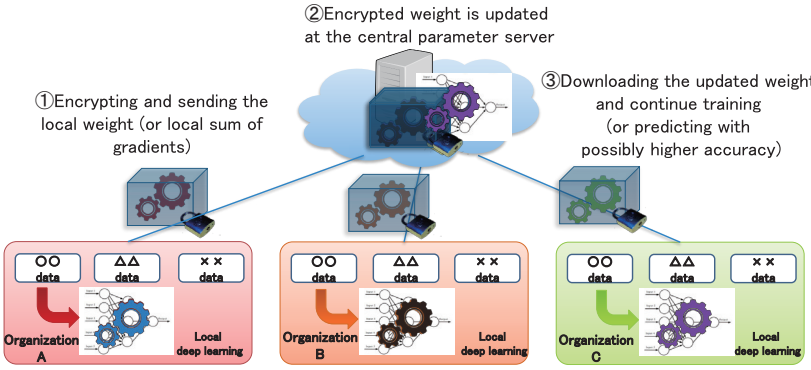


Fig.4 : DeepProtect system: collaborative deep learning system in a privacy-preserving and secure manner.

These results were exhibited in operation at Interop Tokyo 2018.

We have also expanded use of the STARDUST large-scale deception framework by external organizations, strengthening external ties. STARDUST was designed to attract attackers initiating targeted attacks, into a simulated environment where their behavior can be analyzed over long periods of time.

In other work, in the NICT commissioned research "Web-based Attack Response with Practical and Deployable Research InitiatiVE" (WarpDrive), we developed a browser-plug-in sensor in collaboration with the Ghost in the Shell REALIZE PROJECT and began user participation trials in June 2018 (June 1, 2018 press release). As a result, we reached 7,700 users as of the end of March 2019, establishing a network for observing Web-based attacks.

Cryptographic technologies

We handle R&D on functional cryptographic technologies providing new functionality to meet the new social needs accompanying the IoT evolution, and security evaluation of cryptographic technologies contributing to the promotion and standardization of new cryptographic technologies, and to the construction of safe and secure ICT systems. We also engage in R&D on privacy enhancing technologies for the practical utilization of personal data and the promotion of technical support activities for appropriate privacy measures.

Functional cryptographic technologies

NICT is conducting R&D on homomorphic cryptographic methods, which permit computational operations on data in encrypted form, with functionality to prevent introduction of erroneous data. This can be used to perform chi-squared tests on medical data in encrypted form without revealing the content, while also preventing introduction of data beyond the scope of the analysis (Fig. 3). We conducted trials to verify this method in collaboration with Tsukuba University (July 18, 2018 press release). We are also conducting R&D on other functional cryptographic technologies. We have proposed a framework, which we call Opcount, for evaluating efficiency of cryptographic schemes over pairing groups. Given a specification of the targeting scheme, Opcount aims to select appropriate parameters for underlying elliptic curves. The paper received Innovative Paper Award in the Symposium on Cryptography and Information Security 2018 (SCIS2018). In secure computation, a type of functional cryptographic technology, we proposed a method implementing three-input majority voting using three cards, and this work received an IEEE Information Theory Society Japan Chapter Young Researcher Best Paper Award at the ISITA 2018. We were also able to realize a threshold public-key encryption scheme from weaker computational assumptions than earlier schemes, without sacrificing efficiency. This work received an outstanding paper award at the Computer Security Symposium 2018 (CSS 2018).

Evaluating safety of cryptographic technologies

We are continuing research toward practical implementation of lattice cryptography, which is a type of post-quantum cryptography and homomorphic cryptography that is promising for realizing secure computation suitable for privacy protection. The new LOTUS*1 cryptography scheme was developed based on lattice theory and is difficult to break even with a quantum computer. It was announced as a Round 1 candidate at the NIST*2 Post-Quantum Cryptography (PQC) Workshop, part of the NIST PQC Standardization Project being run by NIST in the USA.

*1 LOTUS : Learning with errOrs based encryption with chosen ciphertexT secUrity for poSt quantum era

*2 NIST : National Institute of Standards and Technology

Privacy protection technologies

Regarding privacy-protecting data analysis technology using AI, we have continued R&D on Deep Protect, a privacy-protecting, deep-learning system able to perform deep learning on data sets held by multiple participants while maintaining confidentiality among the participants (Fig. 4). We began trials to detect unauthorized transactions using real bank transaction data, in collaboration with Kobe University and Eltes Co. Ltd. (February 1, 2019 press release).

Frontier research

Advanced ICT Research Institute

Director General HOSAKO Iwao

The Advanced ICT Research Institute promotes the research and development of advanced cutting-edge technologies based on the high-level basic research that we have been working on since we were established. Our current Medium- to Long-Term Plan involves conducting research and development utilizing innovative materials, functions/principles, and biofunctions at the Frontier Research Laboratories aimed at achieving innovative ICT breakthroughs. We have established three technology development centers in the Institute: the Quantum ICT Advanced Development Center, the Green ICT Device Advanced Development Center, and the DUV ICT Device Advanced Development Center. The focus is on socially implementing their research achievements from a needs-oriented view in the very near future.

High-functionality ICT device technology

To realize technologies such as optical communication systems that combine high speed, large capacity, and low power consumption, we are studying ways of providing new and enhanced functionality in ICT devices by techniques such as functional fusion and the atomic/molecular-level control of materials and structures.

In research aimed at commercializing miniature ultra-fast optical modulators, we have established unique processes for tasks such as suppressing charge injection by means of field control or increasing the resistance at the bottom of trenches formed by etching in the production of organic electro-optic (EO) polymer/Si hybrid optical modulators, and we have confirmed that this makes it possible to achieve optical modulation with greater efficiency (VπL = 1.6) than with optical modulators made from EO polymer or Si alone (VπL = 4).

In the research of high-speed low-power optical phased array devices, we designed and prototyped a narrow pitch optical phased array (OPA) incorporating technologies such as an EO polymer with a high glass transition temperature, enhanced chemical stability, and charge injection suppression. With this prototype, we were able to demonstrate high-speed operation at 100 kHz with a maximum steering angle of 22.5° (Fig. 1). We were invited to present this research at MRS Spring 2018 and Photonics West 2019 and received the Image Information Media Future Award and Frontier Award from the Institute of Image Information and Television Engineers.

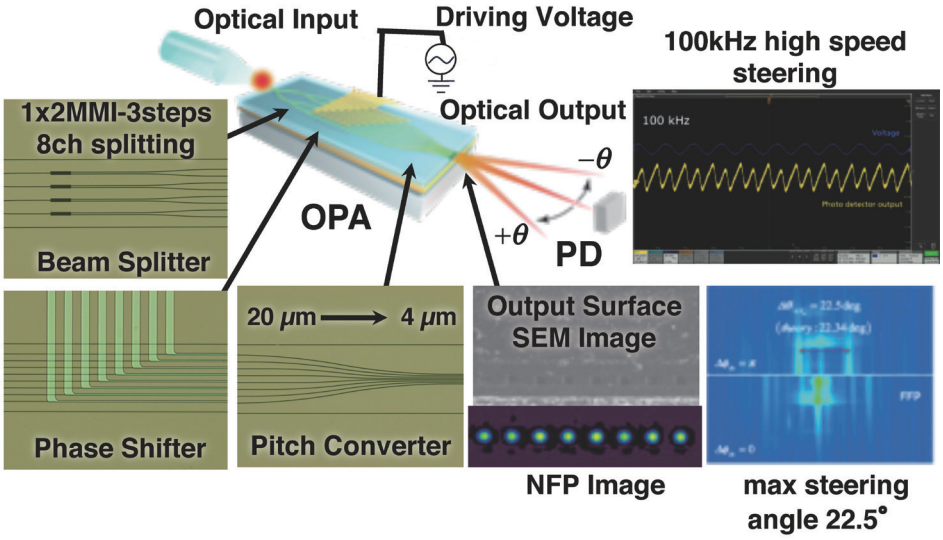


Fig.1 : Design, fabrication, demonstration, and evaluation of a narrow pitch optical phased array using a high-Tg EO polymer

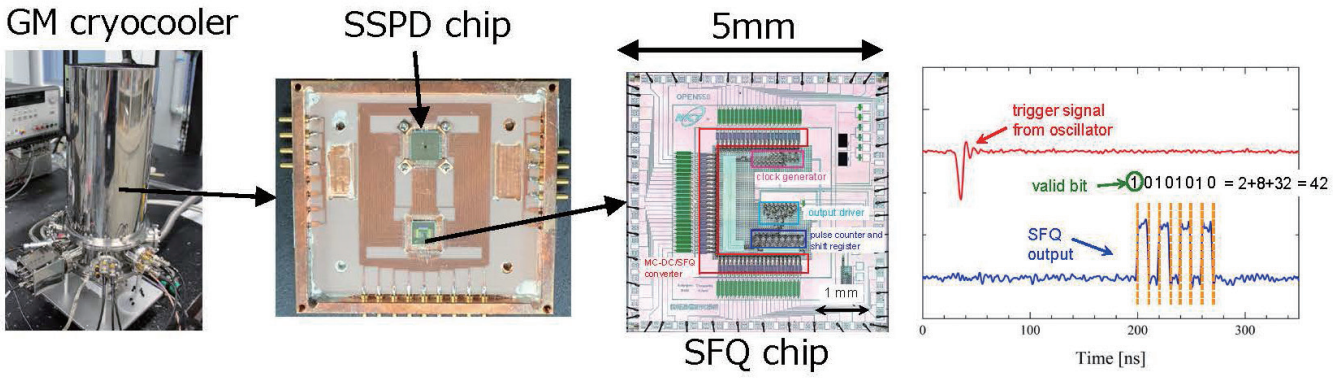


Fig.2 : 64-pixel SSPD array system with an SFQ encoder circuit (from the left: cryocooler, chip packaging, chip layout of SFQ encoder, and output waveform). Spatial and temporal information of photon detection events were successfully read out as digital codes.

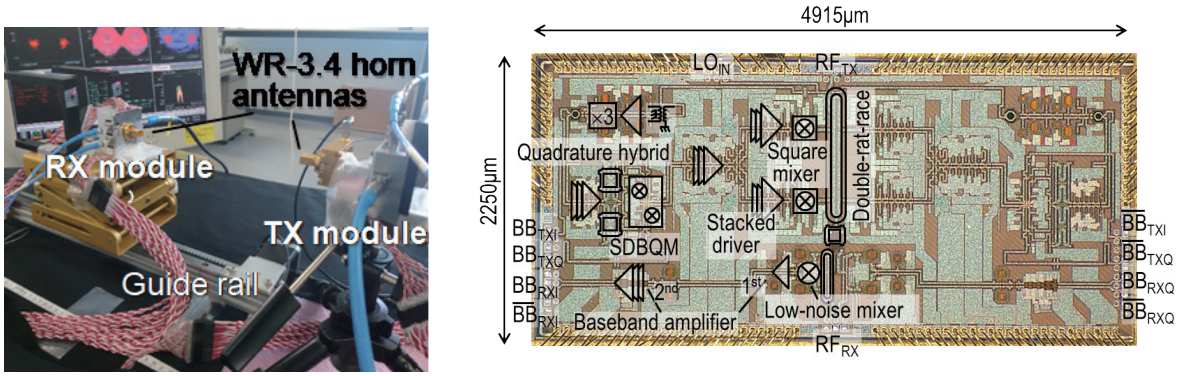


Fig.3 : (Left) Wireless data transmission experiment with CMOS integrated circuit modules for both transmitter and receiver. (Right) Photomicrograph of a one-chip transceiver that integrates the transmitter and receiver into a single silicon chip

In research and development aimed at the broad application and development of superconducting nanowire single-photon detectors (SSPDs), we demonstrated the world's first fully operational 64-pixel SSPD array in a mechanical refrigerator with SFQ cryogenic signal processing (Fig. 2). Furthermore, in research and development aimed at detecting quantum-entangled photon pairs (a technique used in quantum communication systems), we successfully demonstrated that the use of an SFQ comparator for time discrimination makes it possible to achieve a photon coincidence count rate with better time precision than a conventional TCSPC module, and we succeeded in performing measurements of HOM interference.

High-frequency terahertz fundamental technologies

In research aimed at over-100-Gbps wireless communication, we are conducting a wide variety of activities including development of fabrication techniques for semiconductor devices, passive elements, and other components of terahertz integrated circuits. We developed a receiver module incorporating a 300 GHz silicon CMOS receiver integrated circuit. By combining it with a transmitter module, we were able to perform test transmissions involving both transmission and reception with CMOS modules and achieved a transmission performance of 20 Gbit/s. Furthermore, we were able to implement a "one-chip" transceiver (Fig. 3) by integrating the transmitter and receiver on a single silicon chip instead of using separate transmitter and receiver chips. By making improvements to the receiver circuit, we achieved substantially better performance of 80 Gbit/s, which is a big step forward towards commercialization (announced at ISSCC 2019).

With regard to the research and development of highly stable light sources that can be applied to ultra-high-frequency communication and measurement systems, we will continue to develop microfabrication technologies that are essential to the realization of highly stable comb light sources with narrow linewidths by utilizing technologies for deep dry-etching of SiN materials (approx. 600 nm). We have achieved an optical microresonator with Q = 2×10^5 and an extinction ratio of >10 dB.

BioICT fundamental technologies

In our research and development aimed at constructing an information detection system using biomaterials, following the introduction of the DNA binding module implemented in 2017, we evaluated the performance of artificial molecular devices that use DNA as a rail, and succeeded in developing the world's fastest artificial molecular motor. We also enhanced our autophagy induction technology using artifi-

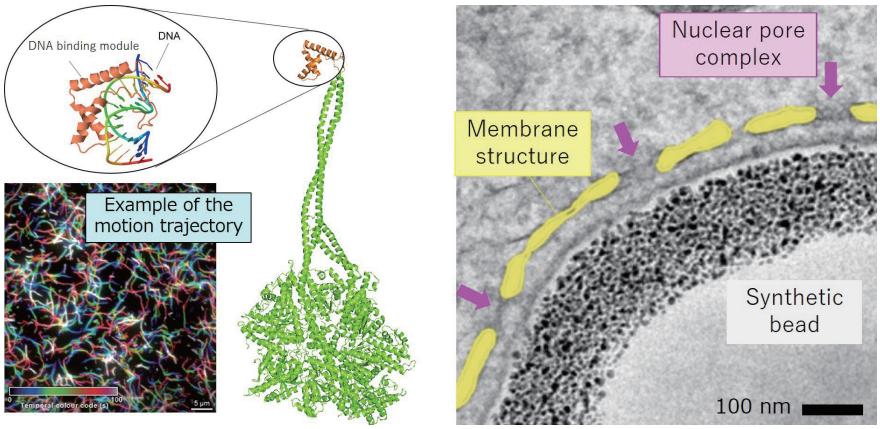


Fig.4 : (Left) Artificial molecular motor and evaluation of its motility. (Right) Formation of nuclear membrane structure by synthetic beads.

cial beads developed here at NICT, we successfully formed an artificial nuclear membrane, and we obtained the basic technology for the construction of such systems (Fig. 4).

In technology for the control and evaluation of biological functions, we constructed a real-time system for the observation of memory formation in insect brains, we performed cell structure measurements with high precision (15 nm) using an optical microscope in combination with a chromatic aberration correction method that we developed, and we succeeded in acquiring data for the reproduction of electron microscopy.

Regarding the excellent information extraction and utilization functions of living organisms, we enhanced a mixture identification technique and succeeded in quantitatively confirming that bacterial sensors can identify chemical mixtures.

Quantum cryptography and physical-layer security technology

In FY2018, we demonstrated an information-theoretically secure distributed storage system on the Tokyo QKD network. In addition, the key management technology developed for the Tokyo QKD network was used to implement a wide-area highly secure distributed storage network. Using this network, we successfully demonstrated the distributed storage and restoration of pseudo electronic medical records (Fig. 5).

Quantum node technology

In the field of quantum measurement standard technology, we are working on the next generation of portable frequency standards, whereby the frequency stan-

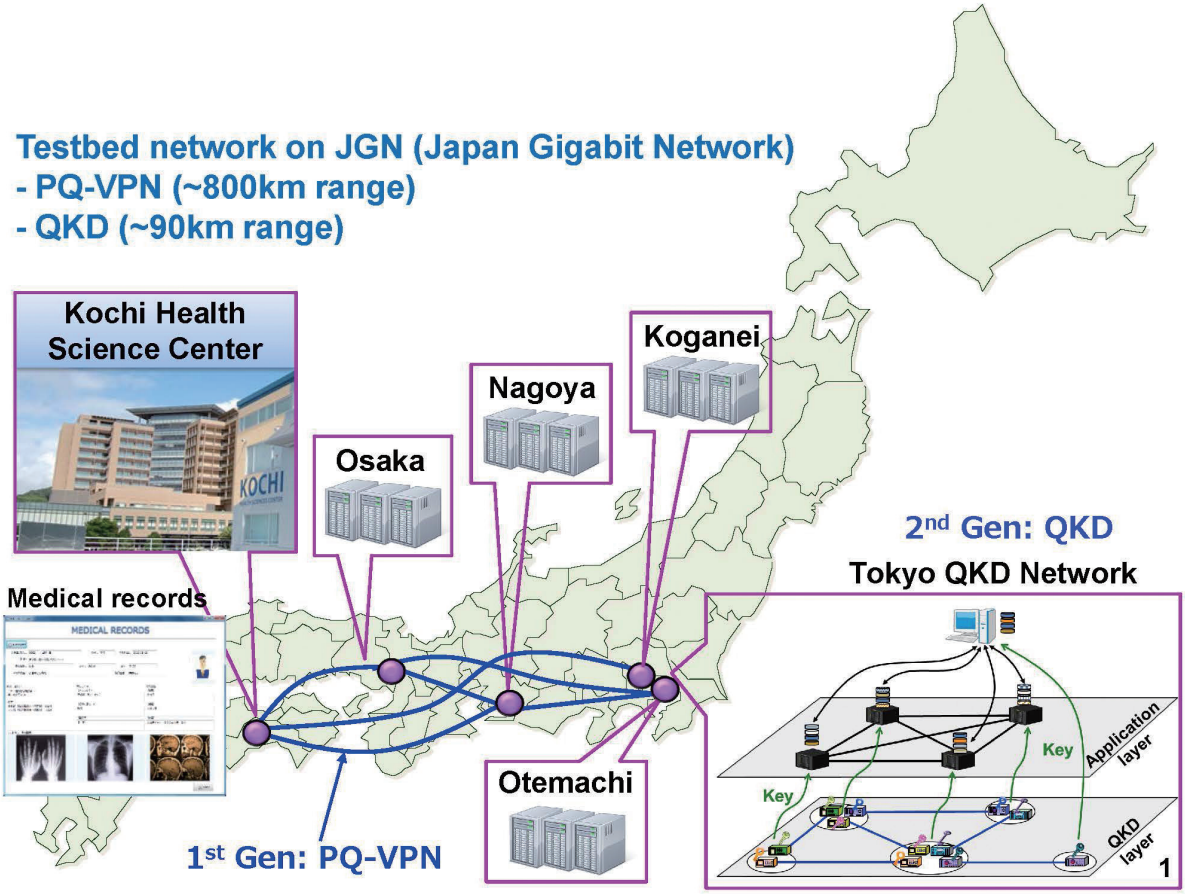


Fig.5 : Global secret sharing data storage network on JGN

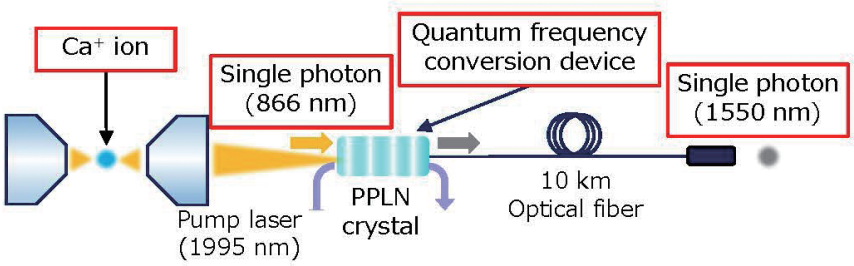


Fig.6 : Quantum state transfer from a Ca ion to a photon, followed by 10km transmission via an optical fiber

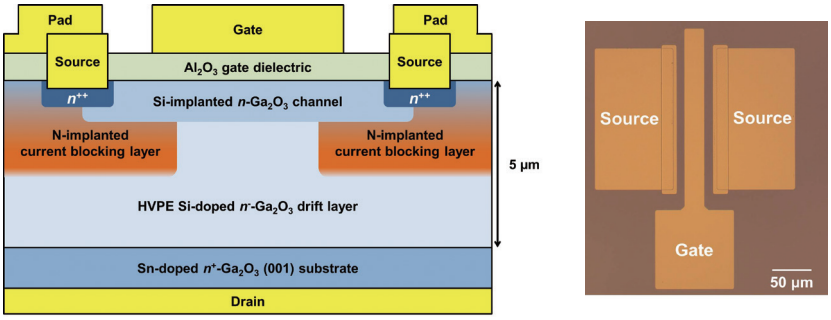


Fig.7 : (Left) Cross-sectional schematic and (right) optical micrograph of vertical Ga_2O_3 transistor

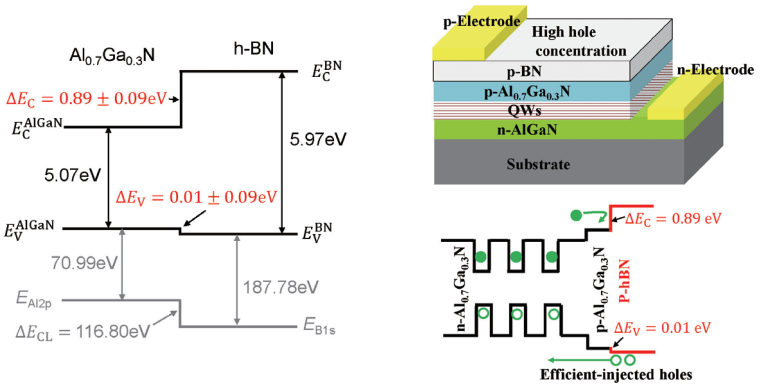


Fig.8 : Schematic band alignment of an h-BN/$Al_{0.7}Ga_{0.3}N$ heterojunction and a DUV LED using an h-BN p-type layer

dards of current large-scale systems are miniaturized though the use of ion traps. In FY2018, as a constituent technology of these portable frequency standards, we implemented a clock laser subsystem in which the frequency is stabilized to a calcium ion quantum transition. We also applied the ion trap technology to quantum communication. Using this technique, we were able to transfer information from a calcium ion qubit to an infrared photon and thence into a photon at the telecom wavelength without destroying the quantum state. As a result, we performed the world's first demonstration of long distance (10 km) quantum communication via an optical fiber (Fig. 6).

Ga_2O_3 electronic device technology

In 2011, NICT identified tremendous potential in gallium oxide (Ga_2O_3) and successfully demonstrated its transistor operation for the first time. Due to the material properties represented by the very large band gap, Ga_2O_3 devices can be expected to have a higher breakdown voltage, higher power capacity, and lower loss characteristics than existing semiconductors when used in power switching devices. An important advantage of Ga_2O_3 from an industrial point of view is that it can be used to produce large high-quality single-crystal wafers easily and inexpensively.

In FY2018, we fabricated vertical normally-on Ga_2O_3 transistors using a newly developed nitrogen (N) ion implantation doping technique and characterized them. The doping technique was used to form a current blocking region. Figure 7 shows a schematic cross-sectional view of the device structure and an optical micrograph. The transistors fabricated in FY2017 using magnesium ion implantation doping showed a large drain leakage current while those fabricated in FY2018 using N ion implantation doping had no leakage current. The transistors fabricated using this new technology achieved an "on" current eight orders of magnitude greater than the "off" current. The drain current on/off ratio is the most important characteristic for switching devices. This on/off ratio greatly exceeds the value generally required for many practical applications (over five or six orders of magnitude difference).

DUV optical device technology

In FY2018, with the aim of improving the efficiency of deep-ultraviolet light-emitting diodes (DUV LEDs), we worked on the fabrication of a new p-type heterostructure with p-AlGaN materials with a high Al fraction using hexagonal boron nitride (h-BN) with a wide bandgap (Eg ~ 6eV) and high transparency in the deep-ultraviolet region. First, we deposited an h-BN layer by RF sputtering on an HVPE-grown $Al_{0.7}Ga_{0.3}N$/sapphire template and demonstrated the fabrication of an h-BN/AlGaN single-crystal heterojunction. Then, to evaluate the characteristics of h-BN with respect to the hole and electron transport properties across the heterojunction, we performed an angle-resolved X-ray photoelectron spectroscopy (XPS) analysis of the band offset characteristics of the valence and conduction bands at the heterojunction interface. We found that the valence and conduction band offsets at the h-BN/$Al_{0.7}Ga_{0.3}N$ heterojunction were approximately -0.01 and 0.89 eV, respectively. These results indicate that h-BN is an excellent material for hole injection into $Al_{0.7}Ga_{0.3}N$. Moreover, the electrons can be effectively blocked from the h-BN. These findings should prove valuable in the design of group-III-nitride-based optoelectronic devices, particularly highly efficient DUV LEDs (Fig. 8).

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General HARAI Hiroaki

ICT Testbed Research and Development Promotion Center has merged several testbeds, including JGN: a High-Speed R&D Network Testbed; RISE: Wide-Area SDN Testbed; StarBED: a Large Scale Emulation Testbed, and JOSE: a Large Scale IoT Service Testbed, to develop NICT's Integrated Testbed and to provide various services. In this way, we have built and have been operating a testbed that covers a range of environments, from real platforms to emulated environments, which enables us to support various types of IoT related demonstration experiments.

We are also conducting R&D on infrastructure technologies necessary for realizing large scale emulation testbeds. Large-scale real platform testbeds and parts of emulated platforms are combined to configure large scale emulation testbeds, which enables us to conduct technical verifications under a variety of environments. The cutting-edge technologies are deployed on large scale real platforms for very practical technical verifications.

In other R&D, we are also working on a service infrastructure based on the creation of a new system that achieves synergistic effects through cross-sectoral and cross-industrial integration.

Construction of NICT's integrated testbed

We have merged JGN: High-Speed R&D Network Testbed; RISE: Wide-Area SDN Testbed; StarBED: Large Scale Emulation Testbed; and JOSE: Large Scale IoT Services Testbed, to develop NICT's Integrated Testbed, to provide various services. Thus, we have built and have been operating a testbed that covers a range of environments, from real platforms to emulated environments, which enables us to support various types of IoT related demonstration experiments. In addition to developing and testing the elemental technologies of each testbed, we are working to install these technologies into the testbeds and preparing to provide them to the users. The configuration of the testbed is shown in Fig. 1.

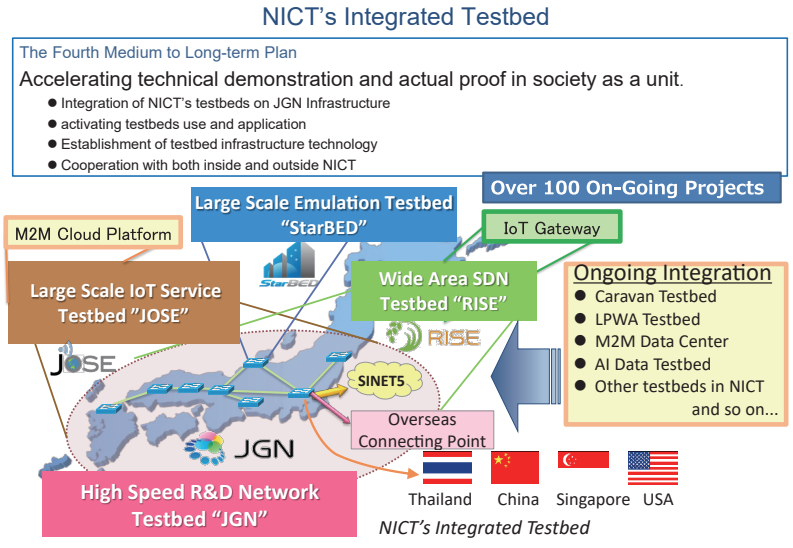


Fig.1 : NICT's Integrated Testbed

Development of a high-precision monitoring system for ultra-high-speed networks

In FY2018, anticipating widespread use of 400 Gbps networks in the future, we have studied a parallel architecture for high precision monitoring. We implemented and systemized the architecture using 100 Gbps hardware, the fastest programmable network interface environment available today, and expect that it will work in the NICT testbed environment. The capture and filtering components of the system were implemented to support 100 Gbps, and the filtered data at multiple locations was aggregated for further analysis by storage and analysis components. We implemented the system which enables to distribute these components over NICT testbeds, namely the JGN High-Speed R&D Network Testbed and the StarBED Large Scale Emulation Testbed, respectively (Fig. 2).

Demonstration of ultra-wideband network applications

In FY2018, we exhibited at SC18 held in Dallas, USA. We used JGN Asia 100 Gbps

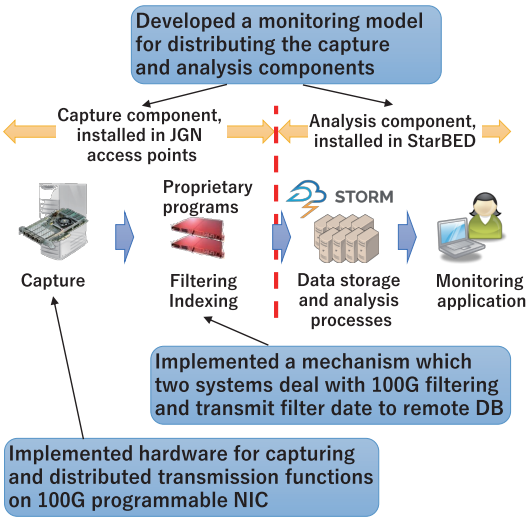


Fig.2 : Model of the developed monitoring system

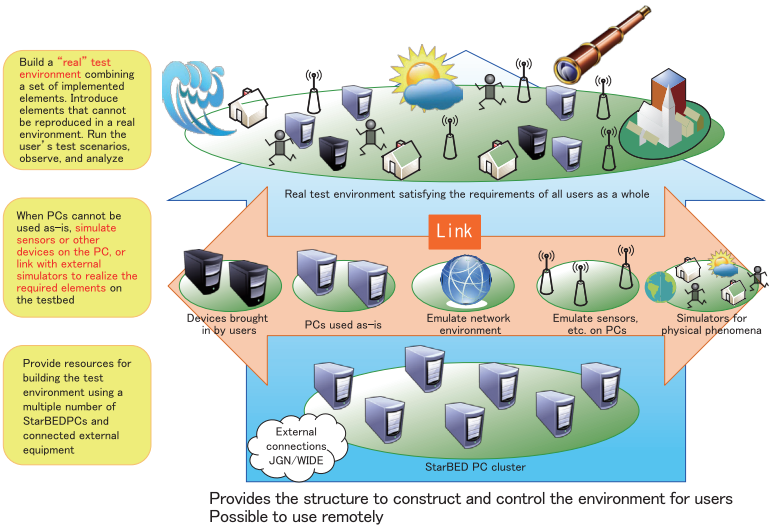


Fig.3 : Emulating an IoT environment on StarBED

circuits and 100 Gbps circuits from other organizations in the Pacific Rim region, and demonstrated the Reconfigurable Communication Processor (RCP) and other technologies in collaboration with Alaxala Networks and Keio University.

Emulation technologies (Fig. 3)

In FY2018, using the BluMoon Bluetooth emulator, we developed the AOBAKO verification platform for Bluetooth Low Energy (BLE), which incorporates actual devices. We developed JAIan as a Software Defined Testbed (SDT) application which virtualizes the testbed environment and allows you to incorporate any monitoring equipment into any location in the topology. We also developed algorithms for expanding the scope of support for the NETorium radio propagation emulator.

Empirical R&D on local data production/consumption services, applying "data flow" to flow of people and goods

In FY2018, we developed an IoT wireless router that enables "in passing" communication between vehicles and between vehicle and infrastructure using radio technologies compatible with the Wi-SUN standard for IoT radio communication. Wi-SUN is a wireless communication standard used in smart meters, which are being introduced into approximately 78 million homes throughout Japan. The IoT wireless routers were installed and deployed in 65 taxis and 50 beverage vending machines operating in an urban area of Tokyo, to build a regional IoT test platform composed of fixed and mobile stations, using local resources.

In data transmission testing with this platform, data detected by mobile stations (taxis) in the Odaiba area in Tokyo had been transmitted to 56 taxis within 24 hours using the "in-passing" communication function. This verified a case where the data was transmitted throughout an area exceeding 430 square kilometers of the serviced area. We have also developed the WiWi-Taxi service for sharing customer-finding information with other taxi drivers operating nearby, using a similar "in-passing" communication function between vehicles, and conducted tests of its utility. A screenshot of the test application and the service installed in a taxi are shown in Fig. 4.

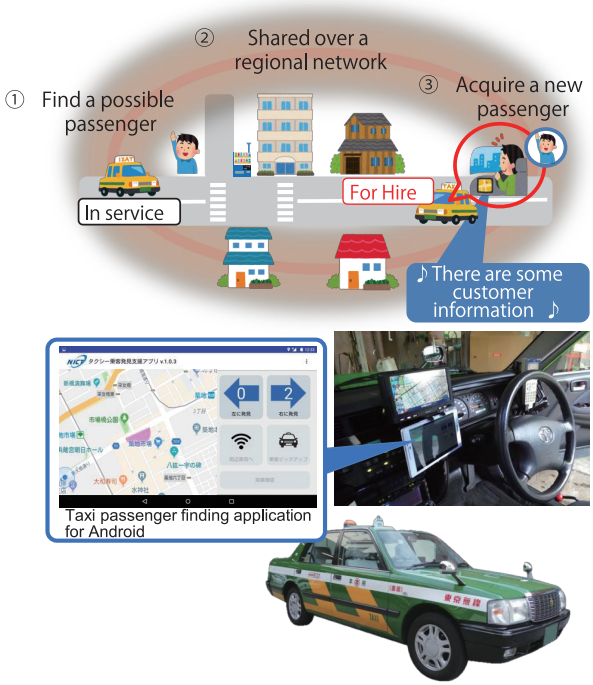


Fig.4 : Finding a new passenger using the WiWi-Taxi passenger finding service

Open Innovation

National Cyber Training Center

Director General　SONODA Michio

The National Cyber Training Center was established on April 1, 2017. Its purpose is to plan and promote practical cyber training by making the best possible use of NICT's technical know-how, research results, and research facilities. To train professionals in the fields of cybersecurity and ICT, we are engaged in training practical security operators and R&D-oriented security innovators, and we are also conducting our own research and development relating to these two aspects of our training (Fig. 1).

Security operator training

In the training of security operators, we are targeting the staff of public and private organizations with the aim of cultivating the ability to respond promptly to incidents when their organizations are faced with serious cyber-attacks. To this end, we are providing two types of hands-on cyber defense training: CYDER (Cyber Defense Exercise with Recurrence), and Cyber Colosseo.

Our CYDER training has included three courses. Course A provides introductory training for local public bodies and government administrations and the like, while courses B-1 and B-2 provide intermediate-level training. In 2018, we prepared scenarios tailored to the needs of trainees, and in order to provide more opportunities for people to receive training, we introduced a new B-3 course aimed at businesses involved in the provision of key social infrastructures. Following on from the previous year, as a result of implementing over a hundred training exercises in all 47 of Japan's prefectures, we have now trained over 8,000 people since our first intake of trainees in FY2013 (Fig. 2), making CYDER Japan's largest cybersecurity training program.

Cyber Colosseo aims to educate people with the necessary skills in a staged, planned fashion during the two-year run-up to the Tokyo 2020 Olympic and Paralympic Games, and has been conducting exercises for people involved with the security of the games since FY2017. Its core program consists of Colosseum Exercises, where trainees perform practical hands-on tasks including offensive and defensive battles. From FY2018, we introduced a new

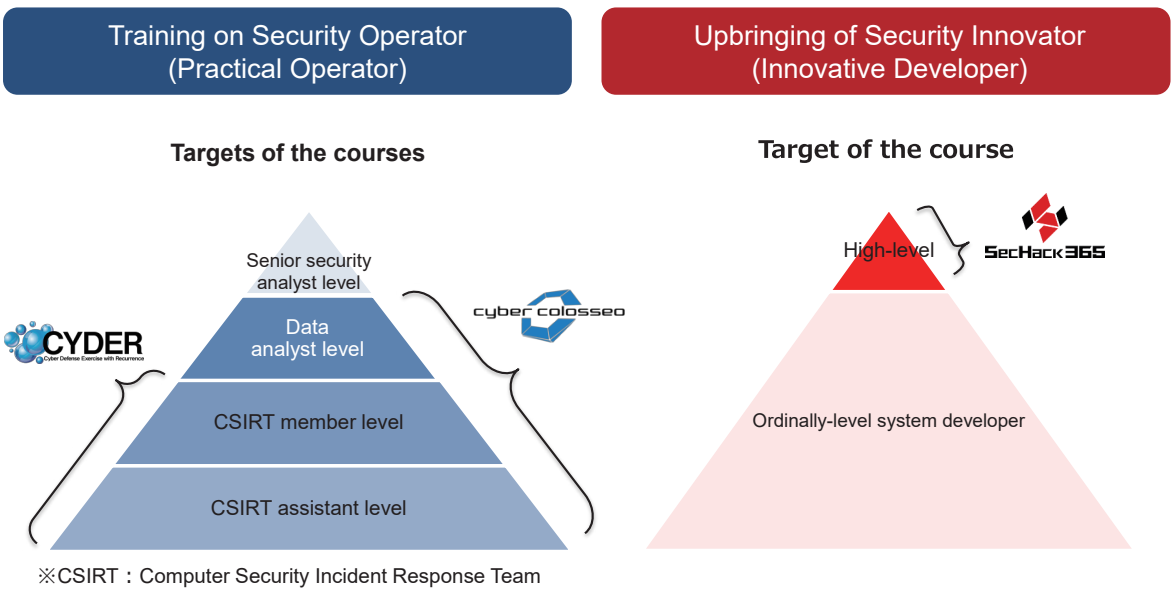


Fig.1 : Overview of the National Cyber Training Center

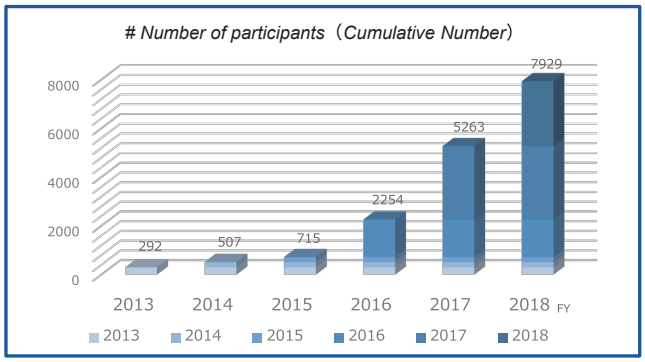


Fig.2 : The growing number of CYDER participants

Fig.3 : SATO Yukari, State Minister for Internal Affairs and Communications, at the SecHack365 presentation meeting (from MIC website)

Colosseum College offering a selection of courses to support the acquisition of core knowledge and peripheral knowledge that tie in with the colosseum exercises. In FY2018 as a result of these efforts, our Colosseum Exercises and Colosseum College trained a total of 137 and 347 people, respectively.

Security innovator training program

Our Security Innovator training program is running SecHack365 with the aim of equipping trainees with a security mindset and the ability not only to use existing tools but also to research and develop innovative security software and other tools, thereby cultivating high-level security experts. SecHack365 is a one-year youth training program (for people under the age of twenty five) that aims to produce "Security Innovators" (i.e., researchers and developers with advanced cybersecurity skills). It includes long-term ideathon and hackathon experience, hands-on training, online software development training, observation tours of innovative companies, and a final results presentation event.

In FY2018, the second year of this project, we selected an intake of 50 trainees from among 345 applications, and we provided them with training in security-related research and development. In addition to providing these trainees with a remote R&D environment and trainer guidance, they also received instruction at six group training events held throughout Japan, and the results of their R&D were published at a final presentation meeting in March. This presentation meeting was attended by large numbers of media representatives and cybersecurity professionals who were able to interview and question the trainees about the contents of their presentations. They were also paid a visit by SATO Yukari, the senior vice-minister for public management, home affairs, posts and telecommunications (Fig. 3). As a result, there was a lot of interest from society in this new training program for young ICT workers run by a government agency. Six people selected from among our previous and current students were dispatched to SXSW (South by Southwest), one of the world's largest creative events held in Austin, USA, and three of them won awards from the sponsoring company, Eluvio, in a hackathon held at this event.

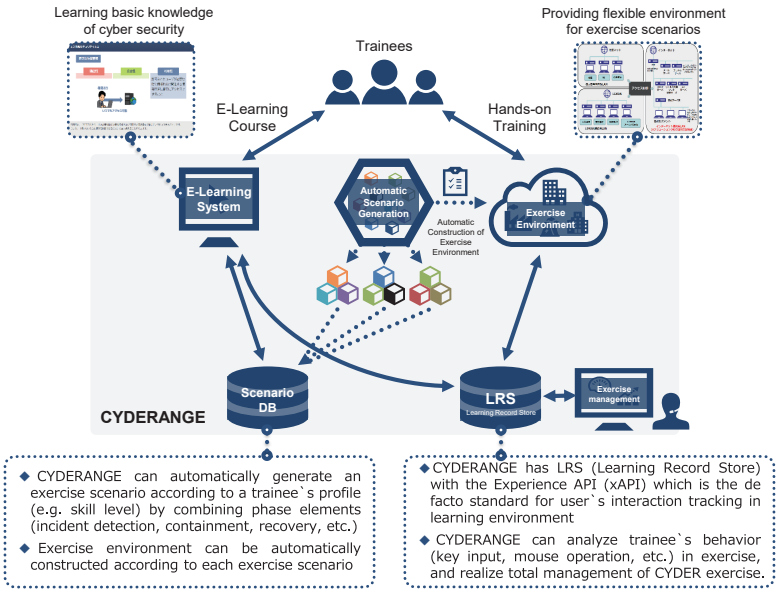


Fig.4 : Image of CYDERANGE

Launch of CYDERANGE

By making use of the knowledge gathered up to FY2017 by running CYDER and by making use of NICT's cybersecurity-related technology, we have developed an exercise automation system called CYDERANGE that can automatically generate training scenarios and training environments. In FY2019, we started full-scale operation of CYDERANGE in the CYDER program. In various fields, including finance, communication infrastructure and medicine, we developed and operated finely-optimized cyber training environments quickly and at low cost. By analyzing the huge amounts of data generated by CYDERANGE, we plan to make further improvements in the quality and efficiency of our training exercises (Fig. 4).

Open Innovation

National Cyber Observation Center

Director General YANO Hiroyuki

As a measure contributing to cyber security for IoT devices, we are performing the duties of surveying IoT devices for issues such as inadequately set passwords and providing the information to telecommunications carriers in cases where subsidy is received from the government, within that budget. This is done utilizing NICT's technical knowledge and based on government policies such as the Cyber Security Strategy (July 27, 2018 Cabinet decision), and on Item 2, Article 8 of the Supplementary provisions of the Act on the National Institute of Information and Communications Technology.

In FY2018, we set up operational systems including establishing the National Cyber Observation Center in January 25, 2019, as an organization to perform these duties. We also studied ways of performing these duties appropriately, effectively, and efficiently in collaboration with the Ministry of Internal Affairs and Communication and other related organizations. This study was initiated on February 20, 2019.

Amendment of the Act on the National Institute of Information and Communications Technology and approval of an implementation plan based on the amendment

Cyber attacks targeting IoT devices have been on an increasing trend in recent years.

In October 2016, in fact, serious damage was reported in various countries, including the Internet outage caused by a large-scale cyber attacks (DDoS attacks) that co-opted IoT devices infected by the Mirai malware.

Considering the situation, the "Amendment of the Act on the National Institute of Information and Communications Technology" came into force on November 1, 2018, adding a survey of vulnerable IoT devices to NICT operations for a period of 5 years.

Based on Article 9 of the Supplementary provisions of the Act on the National Institute of Information and Communications Technology, a request for approval of a plan for implementation of the duties in

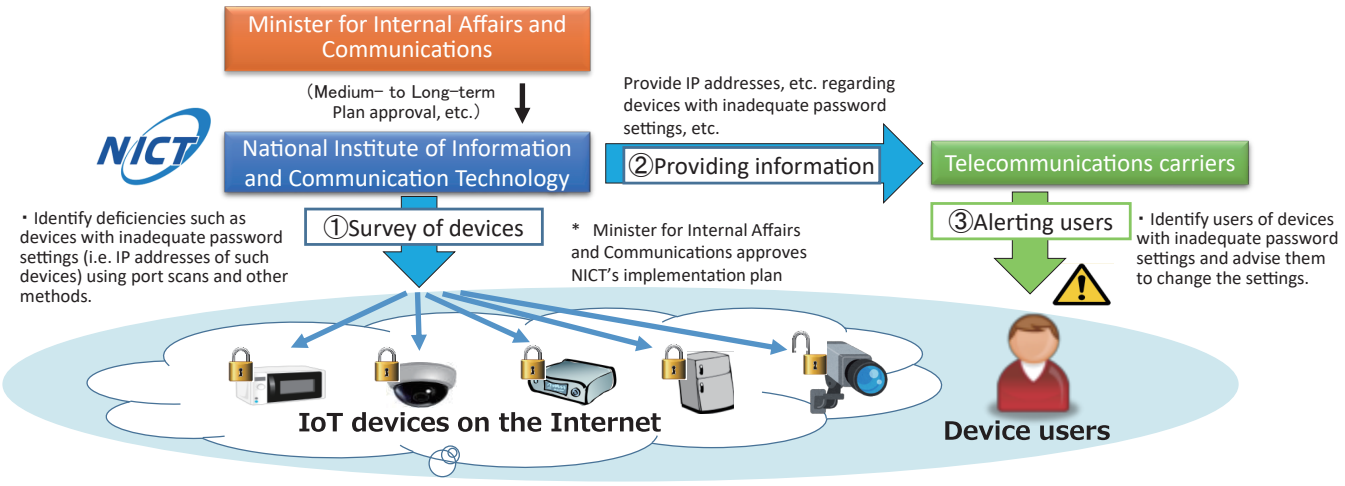


Fig.1 : IoT device survey and initiatives to warn users

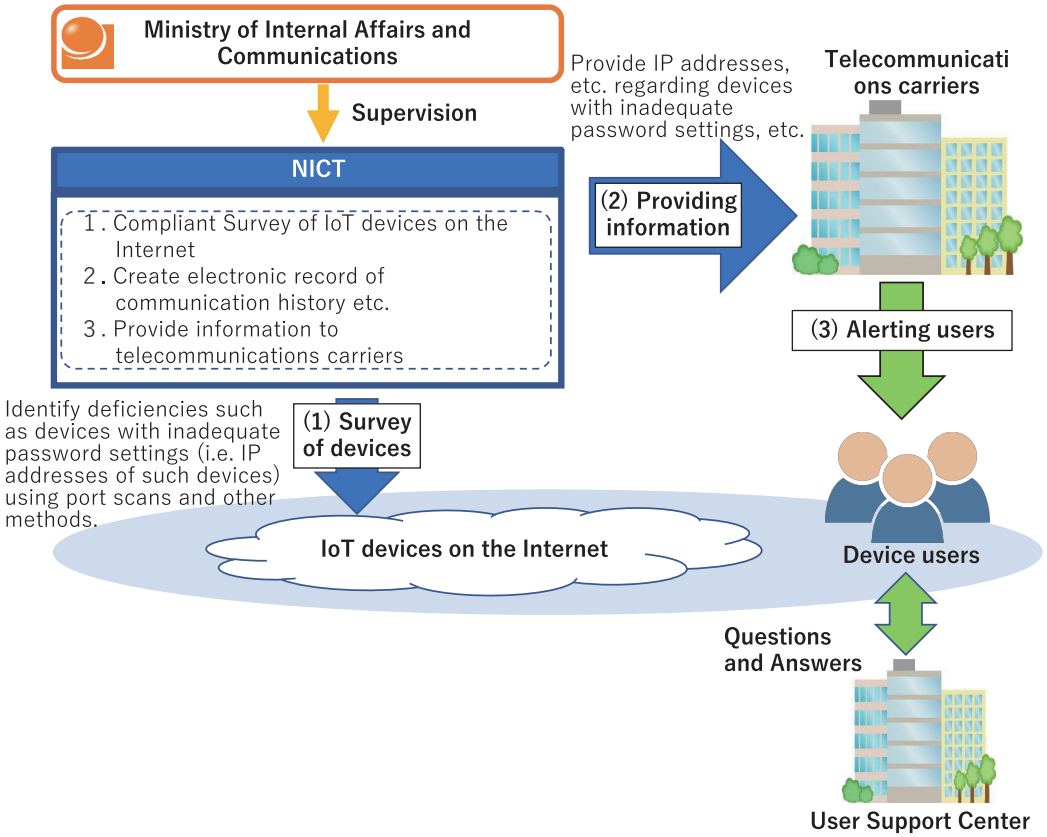


Fig.2 : Overview of duties

Item 2, Article 8 of the Supplementary provisions of the Act on the National Institute of Information and Communications Technology (hereinafter "implementation plan") was submitted on January 9, 2019 to the Information and Communications and Posts Administrative Council (Chairman Prof. Emeritus TAGAYA Kazuteru, Chiba University), which approved the implementation plan and was consulted on January 25, 2019. Ministry of Internal Affairs and Communications (MIC) received a response effectively indicating that the plan could be approved, and approved it that same day.

With the approval of the implementation plan, NICT established the National Cyber-Observation Center on January 25, 2019, as an organization to perform the duties related to surveying IoT devices for inadequately set passwords.

On February 20, 2019, the MIC and the NICT, in cooperation with telecommunications carriers, started conducting the "NOTICE (National Operation Towards IoT Clean Environment) " project to survey vulnerable IoT devices and to alert users to the problem.

Overview of duties

NICT surveys IoT devices on the Internet and identifies vulnerable devices, such as those with weak password settings. NICT provides the information of the devices to the telecommunications carriers (Fig.1).

The specific duties performed under NOTICE are as follows.

(1) Survey of devices

(a) Port scan survey

For the approximately 90 million global IPv4 addresses in Japan, connection requests were sent to devices at the addresses to check whether a session could be established.

(b) Survey using specially authorized access procedures

For devices that require ID/password authentication, performed specially authorized access procedures, entering IDs and passwords to determine if access is possible. Programs and systems were developed to perform this survey.

(2) Create an electronic record of communication history

For the devices accessible by the special procedures in step (1)(b), created an electronic record of communication with the device, including the source and destination IP addresses and the date and time (timestamps).

(3) Provide information to telecommunications carriers

Using the records created in (2) as evidence, notified the telecomunications carriers related to the destination IP addresses in the records, indicating that telecom equipment is vulnerable to transmitted cyber attacks.

Open Innovation

AI Science Research and Development Promotion Center

Director General KIDAWARA Yutaka

The AI Science Research and Development Promotion Center (AIS) was founded in April 2017. At AIS, we aim to set up an R&D environment that is accessible to industry, academia, and government for the use of data collected by NICT, and to provide a one-stop service with a view to social implementation (Fig. 1). The main activities of AIS are described below.

Overview of Translation Bank and translation data collection

At NICT, we are conducting R&D on an automatic translation technology called Neural Translation, under the "Global Communication Plan," whose goal is to implement multi-lingual speech translation technology in society by the year 2020. The technology uses a type of neural network widely used in AI technology, having a deep, layered structure. To improve the accuracy of automatic translation using Neural Translation, it is important to improve the neural network algorithms, and also to secure a large volume of translation data from various fields. On the other hand, there are many and various documents that have already been created in multiple languages, within government agencies, and governments at the prefectural and municipal levels, as well as private enterprises. These include pamphlets for tourism and other purposes, business documentation, and user manuals. The 3rd Intermediate Report (July 20, 2017) of the Information and Communications Bureau, Information and Communication Technology Subcommittee, Technology Strategy Committee, describes how words having the same meaning and sentence pairs could be extracted from these various documents, and if this data could be summarized, perhaps at NICT, it could be incorporated and contribute to improving the accuracy of the translation system. In September, 2017, based on this idea, NICT in collaboration with the Ministry of Internal Affairs and Communications began operating the Translation Bank, a national program to collect translation data. We anticipate that this translation data, collected by NICT through Translation Bank, will be used to increase the accuracy and diversify the fields covered by translation technologies produced in Japan (Fig. 2).

In FY2018, we began collecting translation data from government ministries and agencies, and we are continuing efforts to expand the program nationally. Our goal is to contribute to revitalization of the economy and society in Japan by improving translation accuracy in various fields, eliminating language

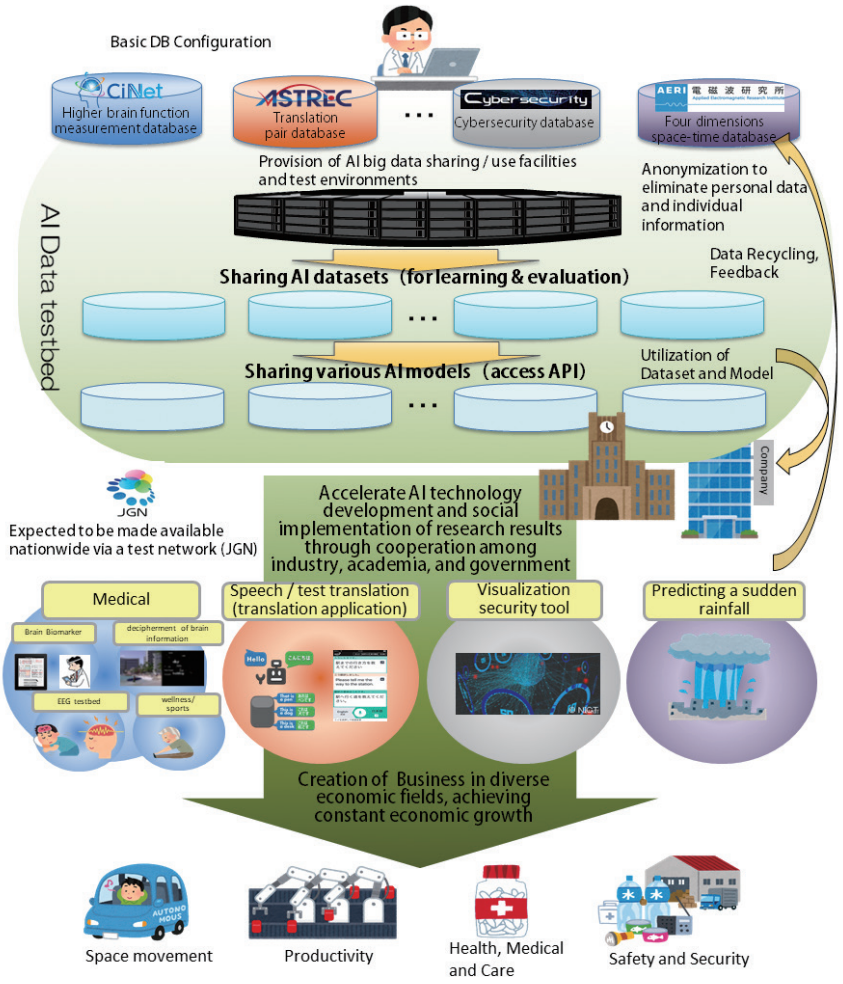


Fig.1 : Overview of the AI Science Research and Development Promotion Center (AIS)

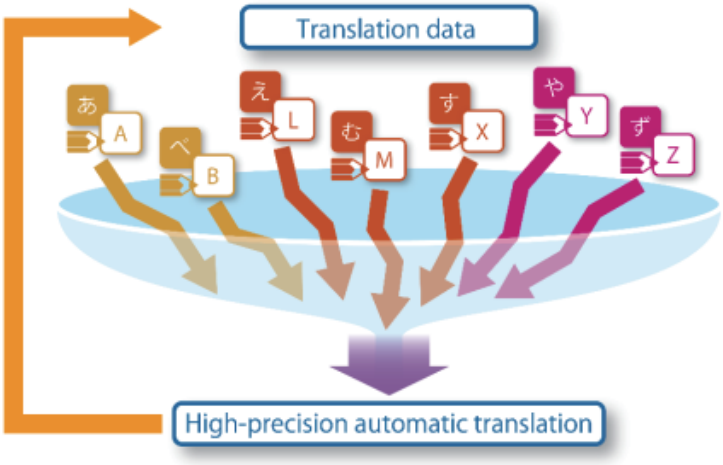


Fig.2 : Our translation bank concept (Hon'yaku Bank)

Fig.3 : Highly-accurate translation fields

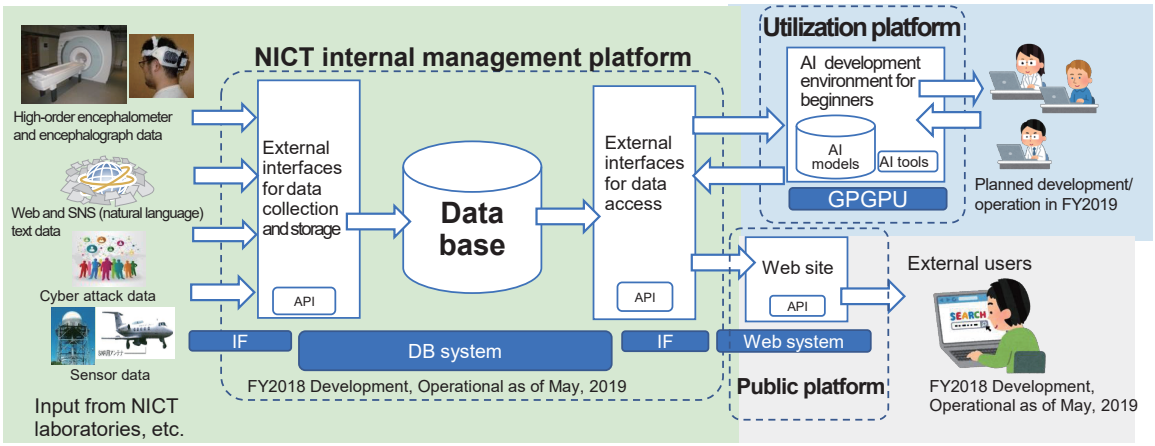


Fig.4 : AI data testbed system

barriers, and making Japan the easiest country in the world in terms of multilingual communication (Fig. 3).

Design and development of an AI data testbed

Based on "Advanced AI Data Testbed Compute Facility" completed in FY2017, we have designed and implemented the following platform systems, which will enable various AI data sets to be managed, shared, and published (Fig. 4).

(1) Management platform: A platform database for centrally managing AI data sets of various types and formats. In FY2018, we performed the detailed design and implementation of a brain information and security database, in a collaborative project that was completed at the end of February, 2019.

(2) Publishing platform: Detailed design and implementation of a Web-based system to provide the collected AI data sets to users. The data publishing Web site opened in May, 2019.

(3) Utilization platform: A sandbox function making it easy for new AI users to use AI tools in a GPGPU environment. To support a variety of data sets and AI tools, we surveyed AI-related standard benchmark data sets and designed the basic functions.

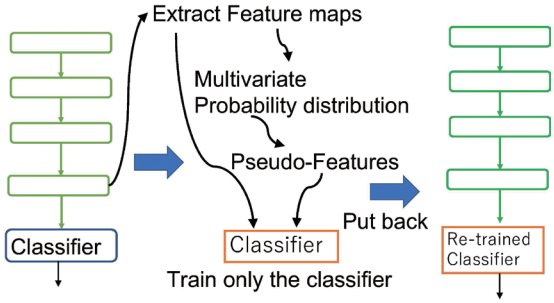


Fig.5 : Pseudo Feature Generation method for imbalanced data in Deep Learning

Development of Deep Learning methods for imbalanced data

When applying Deep Learning to real problems, the amount of data between classes is usually biased, and this can prevent learning accuracy from improving (e.g.: When classifying medical images, 90% of data is from healthy patients, and 10% have pathology). We have developed a new method, named Cavity Filling, to remove such biases in the data and improve learning accuracy, by taking feature from intermediate layers after learning and using them to generate simulated features (Fig. 5). In a ten-class image classification task, we demonstrated performance improvements of up to 10% compared with earlier methods (under sampling, SMOTE method, and etc).

Open Innovation
Resilient ICT Research Center

Director General SUZUKI Yoichi

Learning from the damage to communications networks caused by the 2011 Great East Japan Earthquake, the Resilient ICT Research Center was established in April 2012 in a campus of Tohoku University located in Sendai City, creating a base for research in the disaster affected area. Its purpose was to conduct R&D on ICT resistant to such disasters under a framework of collaboration among industry, academia, and government. Resilient ICT Research Center initiatives feature both fundamental research on disaster-resilient technologies and promotion of implementation in society, to maximize the results of R&D. Together with basic research, the center has initiatives to implement results in society, including planning and execution of demonstrations that utilize research results, collaborating with external organizations, and establishing regional research bases.

Flexible optical switching platform technology

In research on hardware-subsystem platform technology that can control multi-wavelength optical signals dynamically, we have introduced an acousto-optic device capable of high-speed dynamic equalization of wavelength channels in one device, and demonstrated its ability to suppress optical power fluctuations in three wavelength channels simultaneously and rapidly, within approximately 7 μs (Fig. 1).

We have also developed a high-speed, multiple radio-frequency (RF) signal generator able to synthesize and output a multi-frequency electrical signal, as a controller for equalizing optical signals with multiple wavelengths at once, using the acousto-optic device. Based on optical spectrum data obtained from the optical signal monitoring subsystem, the controller quickly and automatically outputs RF signals of frequencies and amplitudes appropriate for equalizing multiple optical signals using the acousto-optic device.

Basic emergency recovery technology for optical networks

For collaboration among communication carriers, we conducted a proof-of-concept experiment to establish and automatically control a temporary shared network between the carriers. This was an initiative to promote collaboration and technologies that will reduce the time and costs needed for recovery tasks after a disaster, by maximizing utilization of surviving communication infrastructure resources and recovered high-priority resources, and by sharing communication recovery tasks (Fig. 2). We have also conducted research and development on automated identification and management of failure between carrier MPLS networks and temporary shared networks due to secondary disasters.

Toward sophisticated regional networks

We have developed a highly reliable, highly efficient LoRa flooding technology, as a wireless communication technology that is able to cover wide areas with low power consumption, although with low bit rates. Generally, only one-to-many, single-hop, long-range LoRa transmission has been defined as LoRaWAN and used, but we have developed an efficient and reliable flooding medium access control protocol using private LoRa to dem-

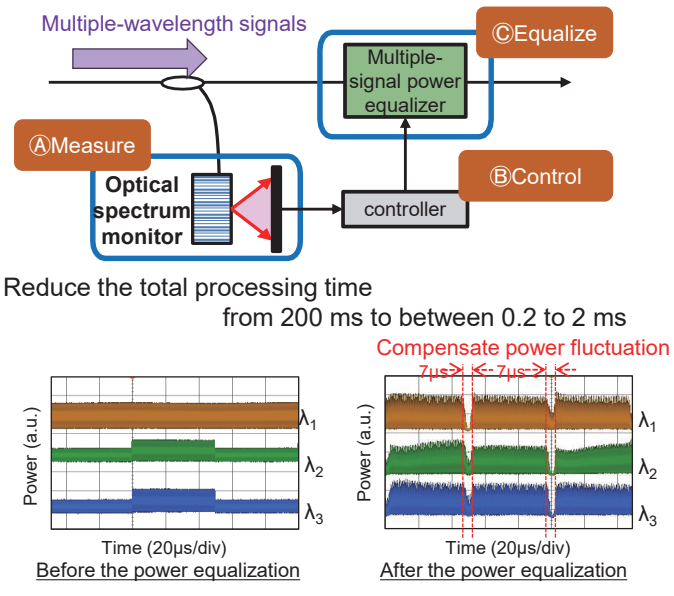


Fig.1 : Multi-signal power equalization for flexible optical switching

onstrate multi-hop transmission for the first time, and shown the potential to cover even wider ranges (Fig. 3 (a)). We also used the technology to develop a patient-transport information sharing system, and successfully demonstrated its effectiveness in field tests. In the field tests, we placed LoRa stations on hospital roofs in Shibuya Ward, Tokyo, where there is a concentration of tall buildings, and showed that LoRa terminals in moving vehicles within 2 km of the stations could communicate with the stations, and that stations were able to share information using the LoRa flooding technology (Fig. 3 (b)).

Dynamic network construction technologies

We have developed wireless LAN device drivers incorporating IEEE802.11ai and distributed Radius authentication as a wireless communication control technology for rapid network construction. We installed wireless devices equipped with parts of these wireless LAN device drivers in five locations in Konan City, in Kochi Prefecture; including the fire department headquarters, a tsunami refuge tower, and in mountainous areas; and also in vehicles. We demonstrated transmission and collection of high-resolution images without depending on public mobile telephone networks for the first time (Fig. 4). In this demonstration, basic functionality of a method that could be used to gather information even if public mobile communication is out-of-service due to disaster.

Real-time analysis of disaster information from social knowledge

Working toward practical implementation of DISAANA, a system that analyzes disaster related information on Twitter, and D-SUMM, a system that summarizes disaster reports posted on Twitter, we conducted activities utilizing DISAANA and D-SUMM in comprehensive disaster training exercises in Oita Prefecture, earthquake training exercises in Osaka City, and earthquake training exercises by the 8th District of the Maritime Safety Agency headquarters, demonstrating these technologies.

We also cooperated on a Strategic Innovation Promotion Program to build a pilot version of a disaster chatbot prototype system, which uses dialogue with residents to collect disaster information and provide aid information after a large-scale disaster, and conducted experiments to demonstrate the concept in Kobe (December 2018) and Shimoda (January 2019) cities (Fig. 5).

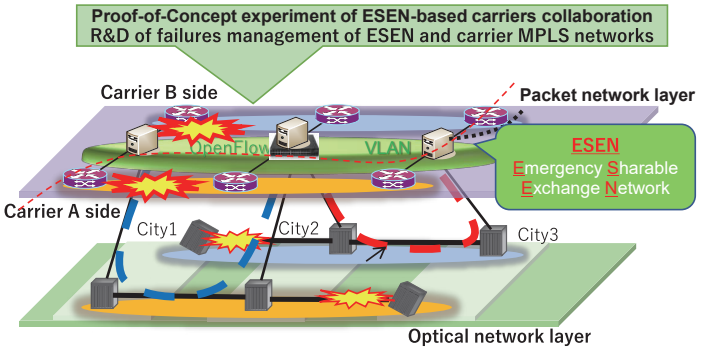


Fig.2 : Carrier collaboration experiment

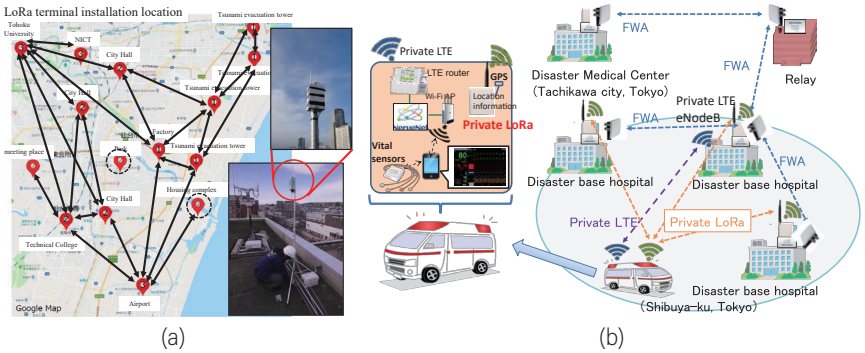


Fig.3 : LoRa flooding technology demonstration: (a) Experiment in Sendai City, (b) Experiment in Shibuya Ward

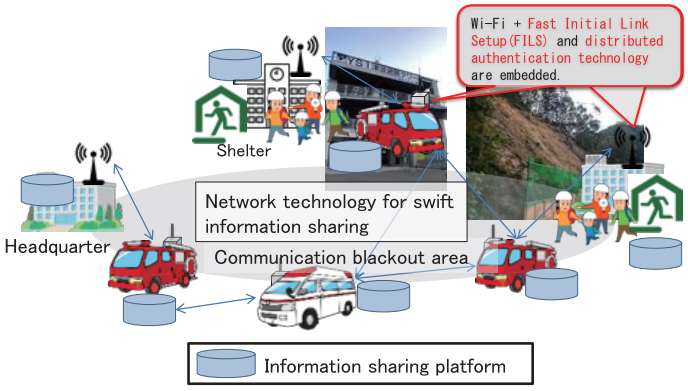


Fig.4 : Overview of wireless communication technologies for fast network building

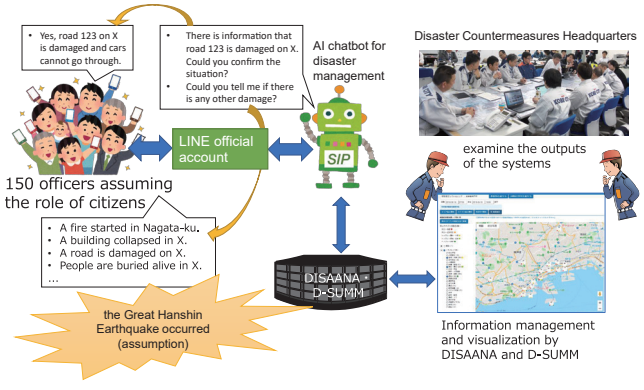


Fig.5 : Overview of disaster chatbot demonstration in the Kobe City

Open Innovation

Big Data Integration Research Center

Director General ZETTSU Koji

The Big Data Integration Research Center focuses on real space information analytics technologies that enable advanced environmental awareness and adaptive navigation based on integrated analysis of a wide variety of sensing data collected over IoT for realizing smart and sustainable societies. We are researching and developing data mining and AI technology for discovering and predicting cross-domain associations of advanced environmental data and diverse social data. By connecting these research and development activities with the needs of users in fields such as transportation, healthcare, disaster prevention, and mitigation, we will conduct demonstration experiments and the like in open innovation collaborations with universities, businesses, local governments, and other organizations.

R&D of fundamental technology for cross-data collaborations

We are constructing an xData (cross-data) Platform on NICT's Integrated Testbed implementing our data analytics methods (Fig. 1). It provides API and tools for discovering association rules for sensing data from different fields, as well as learning and predicting their association patterns. The platform also enables collecting and combining sensing data from heterogeneous data sources in a common format. As a result, it facilitates discovering and predicting associative events spanning different fields, such as unusual weather → traffic disruptions and transborder air pollution → health impact. We have developed applications for visualizing the prediction results on a digital map and providing risk-adaptive navigation.

To construct a model case of utilizing the xData Platform, we held a Hackathon event to develop car navigation applications including the display of risk information and customized route guidance (Smart Sustainable Mobility Hackathon, 23–24 February 2019, Tokyo; approximately 20 participants). The xData Platform provides map data generated by associative prediction of traffic disruption risks for heavy rainfall or heavy snowfall events. In another model case for environmental and health data, the xData Platform provides short-term prediction of air quality for health, or AQI, through an associative prediction API. We held a Datathon event (23–24 March, 2019, Fukuoka City; approximately 40 participants), where the participants experienced a smart environmental healthcare application that supports walking in good air. It provides points based on the amount of user activity (e.g., step count, heart rate) acquired by wearable sensors and short-term predictions of AQI. The participants also proposed ideas for advanced services for smart environmental healthcare.

For the enhancement of cross-data analytics technology, we proposed a deep learning method for discovering association patterns from integrated raster images of diverse sensing data. The experimental result showed an accuracy of 83.6–91.6% in the discovery of traffic risk (Relative Accident Risk) caused by heavy rain. We also developed a deep learning method for associative prediction using environmental data based on a convolutional recurrent neural network (CRNN). Experimental results for short-term prediction of AQI in transborder air pollution cases achieved an accuracy of 70–90%, where AQI for 1–12 hours ahead in Fukuoka City was predicted from atmospheric observation data for the previous 24 hours in both Japan and Chinese coastal areas.

Development of real-time storage and analysis platform for social big data

In the research and development of advanced data mining techniques for temporal databases containing sensing data and the like, we developed an algorithm (Sequential/Parallel Weighted FP-growth) that accelerates association rule discovery in rare cases such as accidents and disasters. By pruning unnecessary association rules as well as devising termination conditions for the discovery process, we succeeded in reducing the computation time and memory usage to about half those of the conventional method (WFI). Furthermore, in social media data analysis for discovering connections between users (social graphs) and their effect on people's behavior, we developed a method for creating a progress model that uses hidden variables to learn the growth of skills through the repetition of item selection actions and a statistical method that estimates the difficulty of each item by using the learning results of the progress model. We have conducted evaluation tests to demonstrate their effectiveness.

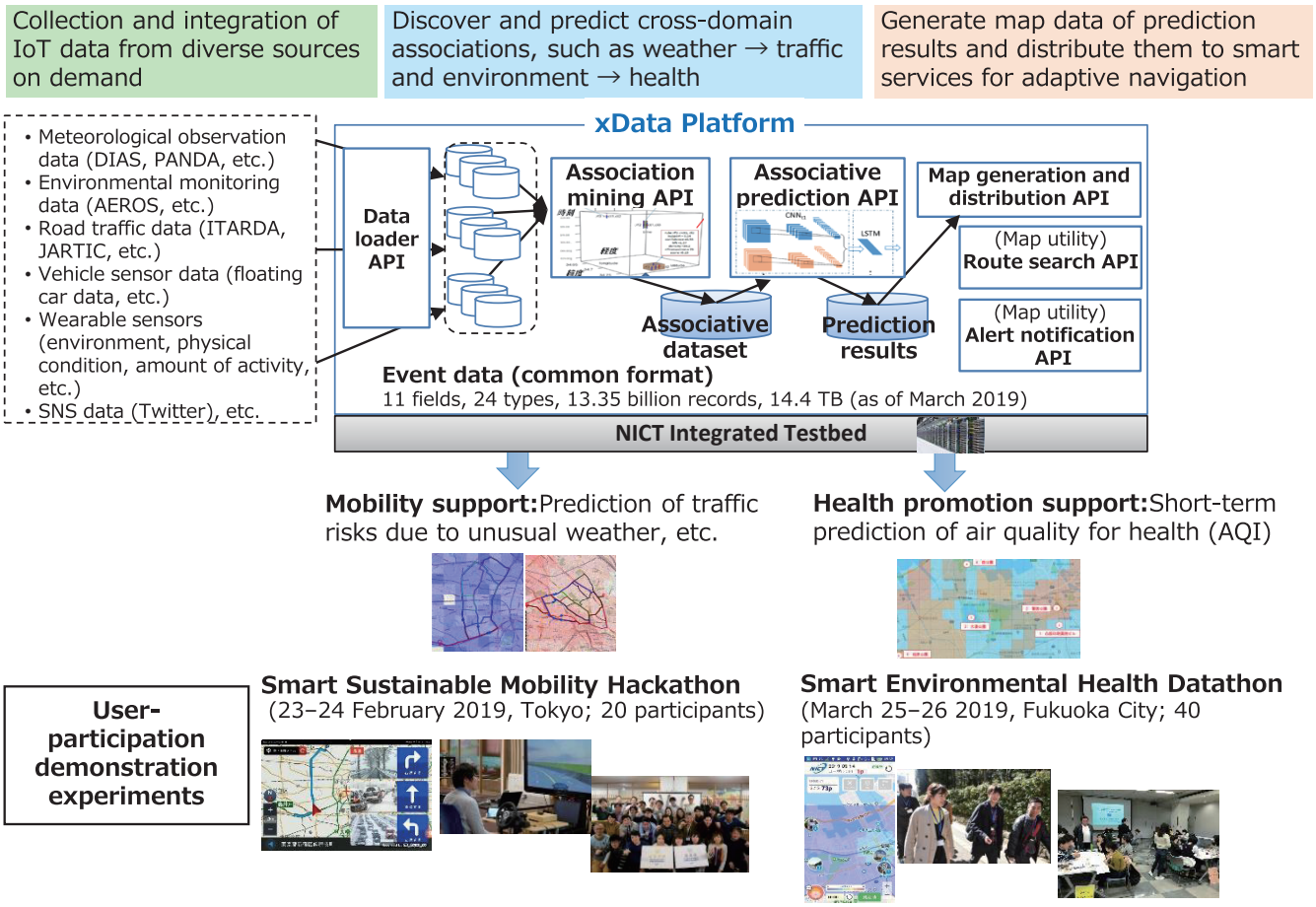


Fig.1 : Overview of xData (cross-data) Platform

Open Innovation

Terahertz Technology Research Center

Director General HOSAKO Iwao

The terahertz band corresponds to electromagnetic waves at frequencies ranging from roughly 100 GHz to 10 THz (3 mm to 30 μm in wavelength), which lies between so-called radio waves and light waves. Electromagnetic waves in this region have so far been difficult to generate and detect. As a result, the terahertz band remained unused and unexplored. The Terahertz Technology Research Center has concentrated NICT's diverse activity in R&D ranging from materials to systemization and has driven forward with the research and development of cutting-edge measurement technology to support the realization of terahertz wireless communication systems. In addition, by working with organizations such as the Terahertz Systems Consortium, we will promote joint studies with industry and academia and contribute standardization aimed at improving the environment so that the terahertz band can be used effectively (Fig.1).

Core technology for terahertz radio testbed

To realize 100 Gbps-class terahertz communication, we are developing a terahertz-wave signal generating technology based on radio-over-fiber technology, with advanced optical fiber technology. In FY2018, we achieved increased the bandwidth with optical frequency comb signals, with the goal of generating high-frequency terahertz signals. Specifically, we increased the total bandwidth using a method of synchronizing and linking multiple independently driven optical frequency comb signals. We built a feed-forward frequency synchronization loop, as summarized in Fig.2. We expect that we will be able to apply this technology to a system that will generate wide-band terahertz signals with high spectral purity.

Fundamental technologies for terahertz spectrum measurements

In spectrum measurement, we require an octave (0.3-0.6 THz) ultra-wide bandwidth in order to measure spurious signal characteristics, as specified in radio regulations. We aim to establish fundamental technology that will enable high-speed, highly-accurate spectrum measurements

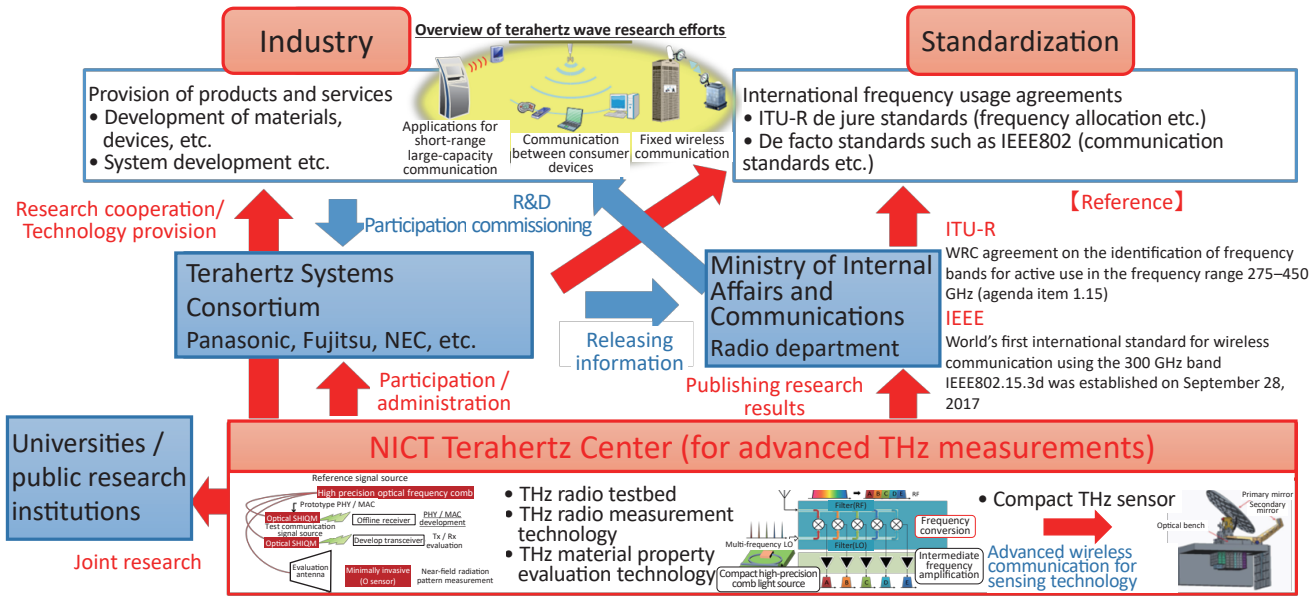


Fig.1 : Overview of Terahertz Technology Research Center

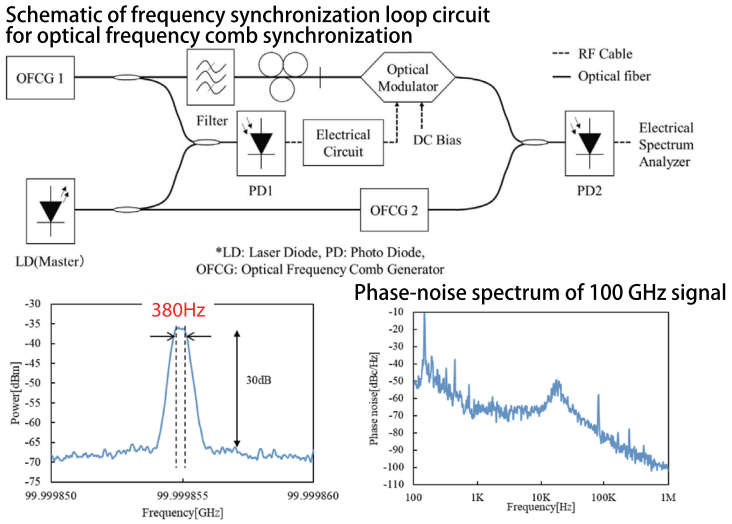


Fig.2 : Overview of optical frequency comb synchronization system and obtained 100 GHz signal frequency fluctuation and phase noise spectrum

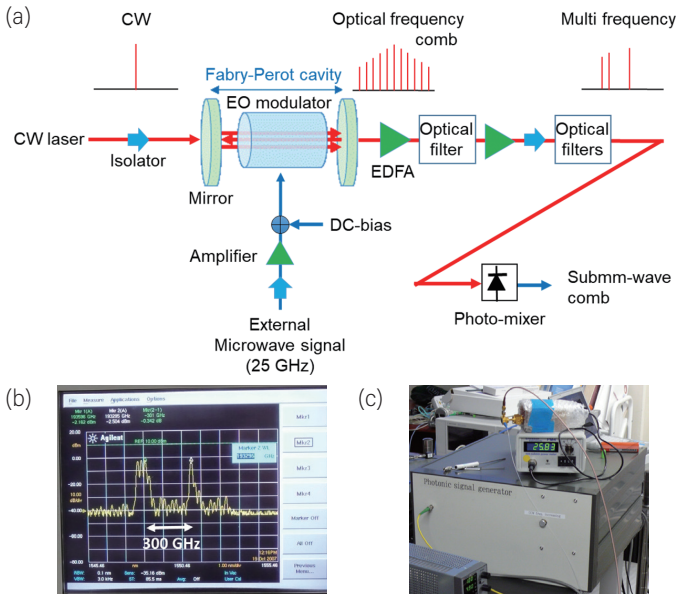


Fig.3 : (a) Sub-millimeter wave band frequency comb signal generator block diagram, (b) 1.5 μm-band optical spectrum, (c) Sub-millimeter wave band signal power measurement

over this band using a single instrument. One proposed method to achieve this is to convert input signals to multiple-band signals using a precisely-designed filter bank, and then measure all of them at the same time using frequency combs as local oscillators. In FY2016, we demonstrated a filter bank operating as designed in the 400 GHz band, and in FY2017, we prototyped an intermediate-frequency (IF)-amplifier-integrated mixer able to down-convert signals from the filter bank to intermediate frequencies. In FY2018, we developed a sub-millimeter-wave frequency comb generator using the precision optical frequency comb (Fig. 3).

International standardization

Spectrum identification above 275 GHz has been studied by the relevant ITU-R Working Parties (WPs) under WRC-19 agenda item 1.15, which considers identification of frequency bands for use by administrations for land mobile and fixed service (LMS/FS) applications operating in the frequency range 275-450 GHz, in accordance with Resolution 767 (WRC-15). This agenda item was originally proposed by NICT at the 4th and 5th meetings of the APT Conference Preparatory Group for WRC-15 and was finally input to WRC-15 as an APT Common Proposal. As a responsible group of WRC-19 agenda item 1.15, ITU-R WP1A has developed Report, ITU-R SM.2450, which summarizes possible identification bands for LMS/FS applications. Although the Conference Preparatory Meeting (CPM19-2) was held before the completion of Report ITU-R SM.2450, CPM Report on agenda item 1.15 was finalized based on contributions from Japan, Germany, USA, Canada, China and IUCAF, and seven Methods to satisfy agenda item 1.15 were included for further discussion at WRC-19, to be held in October and November, 2019. A new footnote and modified RR No.5.565 to identify frequency bands for LMS/FS applications will be agreed upon, with consensus among administrations, and included in Radio Regulations at WRC-19.

We are also continuing to participate in discussion of regulations for future terahertz radio devices in the Institute of Electrical and Electronic Engineers (IEEE) 802 standardization committee. As of July 2018, The Technical Advisory Group Terahertz (TAG THz) is in charge of this, and HOSAKO Iwao, Director of the Terahertz Research Center, is continuing to participate as the Vice Chairman of the group.

Advanced ICT device Laboratory

To promote R&D on challenging and advancing device technologies, we have formed the Advanced ICT Devices Laboratory to function as a platform for open innovation among industry, academia, and government in the field of devices.

A wide range of basic R&D activities is being done at the Advanced ICT Devices Laboratory on innovative device technologies, including integrated optical and electronic devices in the millimeter-wave and THz wave bands, deep ultraviolet optical devices, and on highly functional devices based on new materials, such as nanofabrication materials, organic photonic materials, superconducting materials, and gallium-oxide materials. Latest R&D results are being created based on organic exchange of technologies and human resources including researchers and trainees, from different organizations in Japan and overseas.

Open Innovation

Innovation Promotion Department

Executive Director YANAGISHIMA Satoru

The Innovation Promotion Department, cooperates with governments industries and academias, makes great efforts in the following mission with the aim of maximizing research and development (R&D) achievements.

- *Promote efficient and effective R&D by making effective use of external research resources through collaborative research, commissioned research, and funded research.*
- *Promote open innovation by implementing R&D achievements in society through appropriate securing and effective use of intellectual property and effective standardization activities.*

Promotion of collaborative research with companies, universities, public research institutions, etc.

NICT conducts collaborative research, using capabilities of both external research facilities and NICT to achieve R&D synergies and promote research. In FY2018, this included 559 instances of collaborative research (Fig. 1). These also include instances of collaboration with overseas research facilities, totaling 56 instances and 60 facilities in FY 2018.

In addition to ordinary collaborative research, NICT promotes "funded collaborative research" in which NICT accepts the provision of research expenses from the collaborator. In FY2018, a total of 42 "funded collaborative research" projects were conducted.

Regarding collaboration with universities, in the past, NICT has operated the "Tohoku University-NICT Matching Research Support Project," based on an agreement to cooperate and collaborate with Tohoku University. Starting in FY2018, we also began the new "Waseda University-NICT Matching Research Support Project" with Waseda University and conducted joint research on 14 topics selected by NICT and the two universities. In December 2018, we also formed a comprehensive agreement to promote collaboration with Kyushu Institute of Technology, agreeing to start the "Kyushu Institute of Technology-NICT Matching Research Support Project," in FY2019.

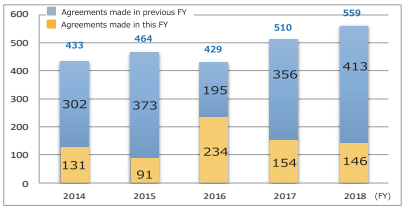


Fig.1 : Trends in numbers of joint research contracts

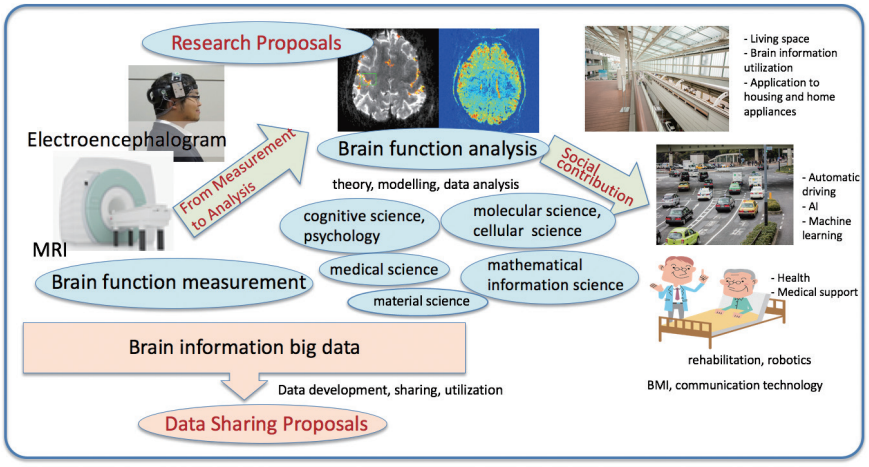


Fig.2 : Collaborative research in computational neuroscience

Promotion of researcher exchanges with outside institutions

NICT promotes researcher exchanges for mutual cooperation with universities and other institutions in diverse areas in the information and communication field. NICT also promotes research exchanges with academia, e.g., by concluding agreements with graduate schools based on the Joint Graduate School Program and provides research opportunities with guidance by NICT researchers for graduate students.

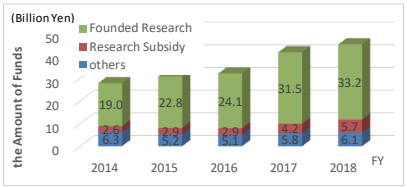


Fig.3 : Trends in amount of external research funds

Deep ultraviolet semiconductor photodetectors	SUN mesh module	Multilingual Translation
Type: Researcher/corporate collaboration **Transferred To**: Electronics Manufacture **Summary**: Compact, high-output, deep-ultraviolet LED light sources have been realized through significant improvement in efficiency of deep ultraviolet LED light production. The output of this deep-ultraviolet module has wavelength of 265 nm, which is optimal for disinfectant properties, so it is promising for realizing drug-free clean sterilization systems. It has prospects for replacing existing mercury lamps and creation of other new markets.	**Type**: Researcher/corporate collaboration **Transferred To**: Systems Integrator **Summary**: SUN is a low-power radio communication scheme that achieves long distance communication using multiple hops. It is expecting various types of data collection in fields such as agriculture, transportation, and fire prevention. This product equalizes energy consumption among radio terminals by improving an algorithm for selecting multi-hop communication channel.	**Type**: Researcher/corporate collaboration **Transferred To**: Electronic equipment manufacturers **Summary**: NICT's highly accurate speech recognition, translation, and speech synthesis technologies can be used in diverse areas including tourism, commercial complexes, and healthcare as an app on smartphones and other devices. The number of supported languages is being expanded to 31. This technology is used by companies that needs long sentence translation, and patent/document translation companies.

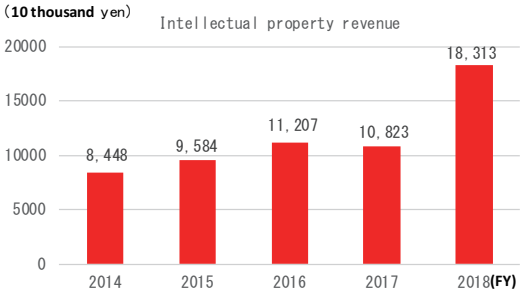


Fig.4 : Trends in revenue from technology transfer and intellectual property in FY2018

Promotion of efficient and fruitful commissioned R&D by effective use of external research resources

In FY2018, NICT worked on 15 research projects continuing from the previous fiscal year and began 17 new research projects. From the research projects solicited in FY2018, NICT researchers oversaw commissioned research as project officers, for improvements to enable the R&D to be integrated with NICT R&D. In international collaborative research, we also began "Collaborative Research in Computational Neuroscience" (Fig. 2) and "R&D for Trustworthy Networking for Smart and Connected Communities" based on an MOU between NICT and the U.S. National Science Foundation (NSF).

Research results included publication of 283 research papers, 415 oral presentations, and 62 industrial property rights applications (47 in Japan, 15 overseas). As for standardization activities, 21 proposals were submitted to standardization organizations, and 12 proposals were adopted by oneM2M.

Promoting acquisition of external funding

Expanding commissioned research and research support funding received from other facilities contributes to utilizing NICT's technical superiority for government policies and the needs of society, to enhancing NICT's R&D capabilities, to strengthening collaboration with other research facilities, and to creating the seeds of new technologies (Fig. 3).

Effective promotion of technology transfer

NICT promotes appropriate securing and use of intellectual property by providing end-to-end intellectual property services from the time of an invention to technology transfer, thereby helping to expand its own revenues and foster open innovation.

In particular, expanding new licensees for semiconductor deep-ultraviolet light-emitting devices and licensees for our multi-lingual translation software has contributed to deployment of NICT R&D results in society (Fig. 4, top). Recent trends in intellectual property revenues are shown in Fig. 4 (bottom).

Promotion of standardization activities

To reflect R&D results in international standards, we are actively participating in meetings of various international standardization organizations, and in FY2018, we submitted a total of 229 document contributions based on R&D results. In FY2018, 39 NICT personnel were working in roles such as chairperson or editor, in various committees related to standardization and in meetings of international standardization organizations. Through these efforts, we contributed to establishing three International Standards based on results of NICT R&D, such as ITU-T G.9803. G.9803 is the first ITU-T recommendation regarding Radio over Optical Fiber (RoF) and was established and published in November 2018. This recommendation includes a system for detecting foreign objects over runways (Fig. 5), which utilizes RoF technology from NICT R&D.

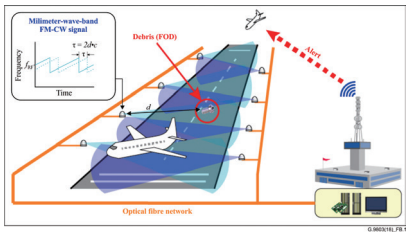


Fig.5 : Concept of airport runway foreign-object detection system incorporating radio over fiber systems conforming to the International Standard, ITU-T G.9803, established in FY2018

Open Innovation
Global Alliance Department

Executive Director NAKANISHI Etsuko

The Global Alliance Department promotes international collaboration in NICT R&D activities and international development of R&D results, and by promoting open innovation with a global perspective, it also contributes to strengthening Japan's international competitiveness in the field of information and communications technology.

Promotion of international research collaboration

We have exchanged memorandums with overseas universities and research institutes (5 renewals and 10 new additions). Furthermore, 18 joint research contracts and 8 non-disclosure agreements (NDAs) have been examined by the Security Export Control Review Board, and we have established and maintained appropriate international cooperative relationships by welcoming 4 foreign visits for the purpose of research cooperation (IMT Atlantique, France; National Radio Research Agency (RRA), South Korea; Urban Development Authority, Sri Lanka; Posts and Telecommunications Institute of Technology (PTIT), Vietnam). As of the end of FY2018, we have the capability to perform research exchanges with 99 institutions in 31 countries and regions (a total of 103 memorandums) (Fig. 1).

Promotion of projects in cooperation with foreign governments

By implementing projects proposed and selected by APT in cooperation with other organizations, such as the Sri Lankan Disaster Management Center (Fig. 2), we have performed a feasibility study of an early warning system aimed at using the NerveNet disaster-tolerant network technology developed by NICT to reduce landslide disasters in places such as Sri Lan-

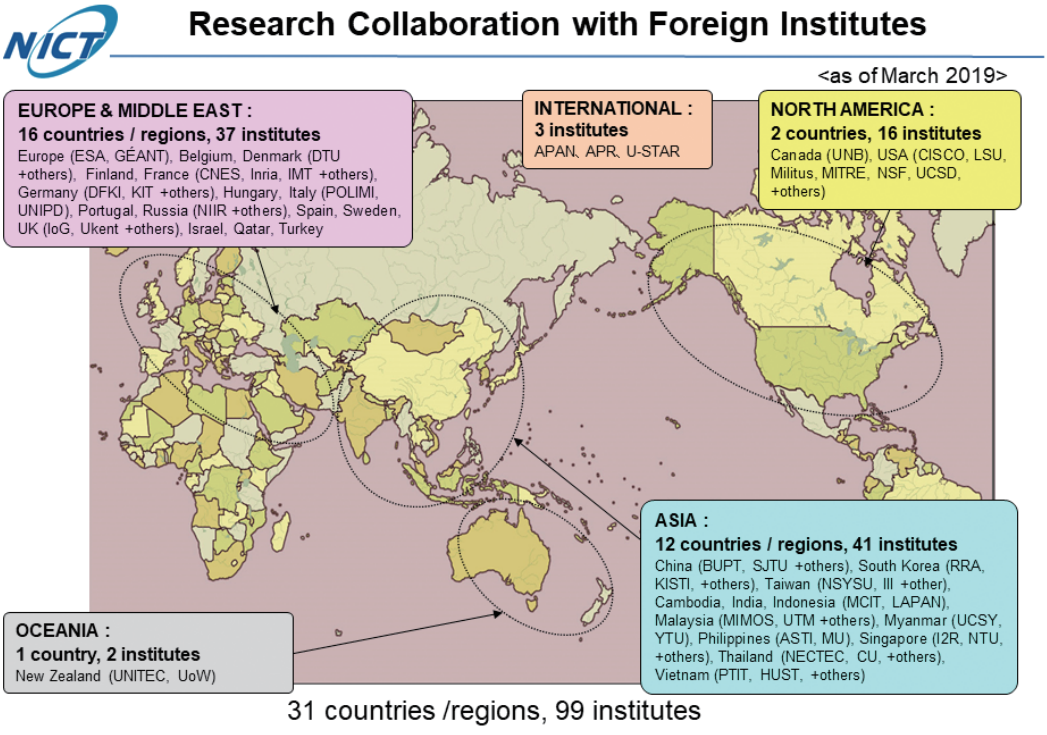


Fig.1 : Universities and research institutes with which we have exchanged research memorandums (as of the end of March 2019)

Fig.2 : Pictures from the Sri Lankan APT project "Feasibility Study to Establish a Comprehensive 'Sensor Based end to end Early Warning System' Utilizing 'Resilient Communication System'" (title abbreviated). Clockwise from top right: the Japanese team visit a landslide site and are briefed by a geology professor from the University of Peradeniya (two photos); a briefing and a demonstration by the dean of the university; a demonstration for the research team and university professors; briefing with the Sri Lankan Prime Minister's senior advisor.

ka's Kandy District. This study included discussions with related government bodies, inspection visits to disaster sites, and consideration of corporate collaboration measures for the practical implementation of this system in the future. At the same time, we worked on the formation of new projects, and we began research on this subject when the APT adopted a joint proposal to study the configuration of emergency medical systems for ambulances in Thailand, involving organizations like the Thai emergency medical service and ToT (formerly the Telephone Organization of Thailand). We plan to study system configurations that incorporate body area network technology developed by NICT (which was inherited by an NICT venture called Goleta Networks).

Promotion of international joint research with the USA and Europe

Under the Japan-US Network Opportunity 2 (JUNO2) program, a network area research program jointly run by NICT and the US National Science Foundation (NSF) and successor to the JUNO program, 5 joint studies (one of which was allocated to NICT) on the theme of highly reliable networks were started in September. A Principal Investigator (PI) meeting was held in Tokyo to share ideas between researchers in Japan and the US. In parallel with this, researchers from the US (NSF and National Institutes of Health (NIH)), France, Germany, Israel, Spain, and Japan (NICT) are participating in an international research program called CRCNS (Collaborative Research in Computational Neuroscience), under which 2 Japan–US joint research projects were started in September 2018.

Regarding the Japan–European international joint research that is being jointly organized by the European Commission and the Ministry of Internal Affairs, 2 studies were started in July in 2 different fields (IoT security and Beyond 5G) by taking synergy with NICT research into consideration. In September, reviews of 3 studies (in the fields of public big data and information-oriented networks) were conducted in Brussels. In December 2018, the 7th Japan–European International Joint Research Symposium was held in Vienna with the aim of confirming the progress of ongoing research and discussing research topics for 2020 onwards. NICT proposed a "Human-Centric Trusted AI for Data-Driven Economy" and summarized the future direction of research including this concept.

Promotion of international joint research in south east Asia by ASEAN IVO, and development of research results

NICT has been raising awareness of ASEAN IVO (ICT Virtual Organization of ASEAN Institutes and NICT), a collaborative research organization led by NICT and established and operated with research institutes, universities, and other organizations in the ASEAN region. Our work includes describing the activities of this organization to the Japan ASEAN Science and Technology Cooperation Committee. ASEAN IVO now has 54 member organizations, 14 more than the previous fiscal year. As part of this effort, 17 joint research projects (6 in FY2016, 5 in 2017, and 6 in 2018, respectively) were implemented to pursue ICT solutions to social issues common to ASEAN. Many of these projects build on NICT's achievements such as multilingual translation technology, wireless technology, and disaster resistant ICT. In FY2018, these projects were worked on by 168 people from over a hundred organizations. In FY2019, 5 new joint research projects were launched.

International personnel exchange

In FY2018, as part of our international personnel exchange efforts, we admitted 15 interns from 12 organizations in 9 countries and regions: France, Myanmar, the United States, Vietnam, South Korea, Taiwan, the United Kingdom, China, and the Netherlands (in order of admission). We have now accepted a total of 175 interns.

Overseas Center Activities

Please refer to pp.66–69.

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director HIROSHIGE Kenji

Information communication provides the infrastructure for social and economic activity. We are currently engaged in many activities in this field, such as promoting the commercialization of initiatives such as ventures that give rise to new services, enhancing our infrastructure to facilitate the use of diverse new forms of communication, promoting information barrier-free environments where information communication services can be used by anyone, promoting basic research in the private sector, and supporting international exchanges in research and development. Through these activities, we are helping to stimulate industry and facilitate rich lifestyles that are both safe and secure, and in order to support the adoption of highly convenient information communication services in people's social and economic activities, we are promoting the following initiatives in the field of information communication to efficiently and effectively implement various promotion activities

Inviting overseas researchers and providing support for the hosting of international research conferences

Through NICT's own International Exchange Program and the privately funded Japan Trust International Research Cooperation Program, we are working to invite overseas researchers to research institutes other than the NICT, and we are providing support for the hosting of international research conferences as part of our International Exchange Program.

(1) Invitation achievements

There were ten cases of inviting overseas researchers to Japan in FY2018, as part of our International Exchange Program. There were also two further cases as part of the Japan Trust International Research Cooperation Program. We also provided support to hosting ten international research conferences.

(2) Recruitment achievements

Recruitment of overseas researchers to be invited in FY2019 included five cases by the International Exchange Program, and two cases by the Japan Trust International Research Cooperation Program. In our support of hosting international research conferences, we have selected eight cases to support in FY2019.

Supporting ICT startups

In order to realize a more rich and diverse next generation of information and communication services, there is a need for innovative technologies. Our goal is to produce ICT startups that will be active globally, by providing opportunities for information and interaction that will be useful for commercialization, to ICT startups having difficulty procuring funding or expanding their markets. In this way, we promote commercialization of technologies and services that are promising, innovative, and potentially influential.

(1) Kigyouka Koshien and Kigyouka Expo

We held Kigyouka Koshien to discover and nurture new talent from colleges and universities who will drive ICT startups in the future (Fig. 1) and Kigyouka Expo for

Fig.1 : Kigyouka Koshien

Fig.2 : Kigyouka Expo

ICT startups to announce their innovative new projects and business relationships (Fig. 2).

(2) Silicon Valley Boot Camp

To provide an opportunity for those planning to attend Kigyouka Koshien an opportunity to develop their "global mind," we held the Silicon Valley Boot Camp on the USA west coast (Silicon Valley), including exchange with ICT ventures in the area, and lectures from venture entrepreneurs active in the area (Fig. 3).

(3) Exhibits at overseas conferences

We provided opportunities to exhibit at TechCrunch DISRUPT SF 2018, held in San Francisco, to AISing Ltd. (Minister for Internal Affairs and Communications Award recipient), who appeared at Kigyouka Expo in March 2018, Teslasheet Inc. (a NICT initiated venture), and the Osaka University G+ team (Minister for Internal Affairs and Communications Award recipient), who appeared at Kigyouka Koshien (Fig. 4).

Supporting the spread of information communication infrastructure

We are supporting the spread of information and communication infrastructure in Japan, to make Japan a world-leader in ICT.

(1) Supporting IoT testbed projects and regional data center projects

In FY2018, we accepted applications on two occasions, and selected two IoT testbed projects and seven regional data center projects to receive grants.

(2) Supporting regional communication and broadcasting development projects

For projects contributing to advancing telecommunications in regions outside of the city of Osaka (enhancing CATV, establishing digital terrestrial television relay stations, etc.), we subsidized interest payments for loans from banks and other financial institutions for four projects (three companies).

Supporting people with insufficient access to information

(1) We are providing support for broadcasters producing programs that have captions, sign language, or described video. In FY2018, we provided support for 47,701 programs from 120 companies.

(2) We are providing support for communication services that benefit those with physical disabilities. In FY2018, we provided support for five projects.

(3) We are providing information helpful for people with disabilities, the elderly, and social welfare organizations through a barrier-free information access site (http://barrierfree.nict.go.jp/).

Fig.3 : Silicon Valley Boot Camp

Fig.4 : TechCrunch DISRUPT SF 2018


THINKING!
STOP
LUCK
THINKING!
STOP
LUCK
BUSINESS
LOVE
FIRM
COMMUNITY
TIME
CREATE
TALK
GO!
JOB

Research Highlights

CONNECT

Automatic near-miss avoidance for drones using V2V direct communications

Toward safe flight when operating beyond visual range

With the spread of drone aircraft, there are increasing reports of near misses between drones and between drones and small manned aircraft on the background that industrial fields of drones is becoming mainstream, and flight area is moving from within visual range to beyond it. Therefore, it is highly desirable for drones and other aircraft to share position information to maintain safe distances between each other in the air.

Currently, most drones flying outside of visual range are operated by GPS-based automatic flight control methods with pre-programmed flight paths and command-and-telemetry communication links between the drone and pilot. However, with such flight control methods, it is difficult to maintain safety when the drone approaches other drones or manned aircraft.

As part of the "Tough Robotics Challenge (TRC)" (Program Manager: Prof. TADOKORO Satoshi) in the Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT), which is led by the Cabinet Office Council for Science, Technology, and Innovation; the Wireless Networks Research Center recently used "Drone Mapper®", which was also developed in the TRC, to perform autonomous flight control, realizing safe operation in the common airspace shared by multiple drones and other flying objects. Drone Mapper® shares position information through direct communication between drones using the unlicensed 920 MHz band. Experiments were successful in demonstrating up to three drones autonomously avoiding near-misses as they approached each other. Specifically, the Center developed a technology that links Drone Mapper® and the onboard flight computer for the first time, enabling drones to control their own flight, maintaining a minimum distance to other drones around them without intervention by the pilot. This is achieved by using directly shared position information from other drones, given by Drone Mapper® (Fig. 1). We conducted field tests to verify the performance of the tech-

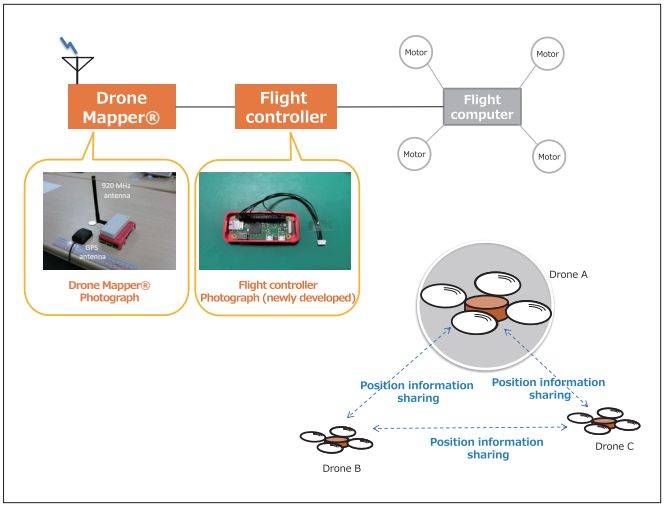


Fig.1 : Configuration of the near-miss avoidance system with Drone Mapper® and flight controller

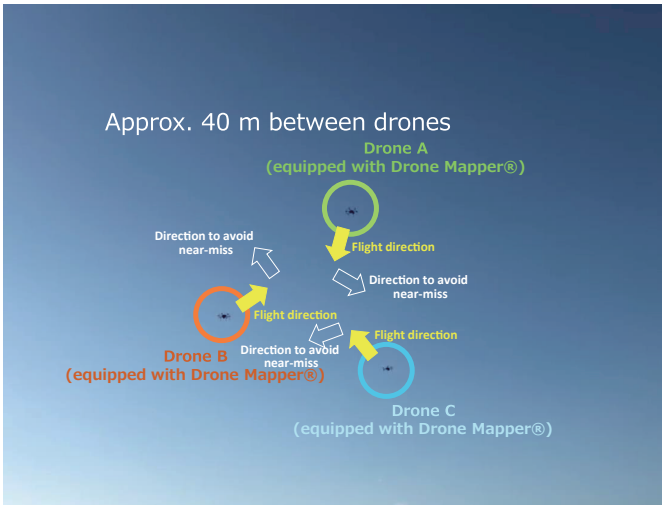


Fig.2 : Flight control test (Near-miss avoidance with three drones) (Dec. 18, 2018, Chichibu City, Saitama Prefecture)

nology and confirmed that up to three drones were able to avoid near-misses autonomously. After avoiding near-misses, the drones returned to their original path automatically, and finally arrived at their own destinations (Fig. 2).

"We will be able to demonstrate avoidance of near-misses also between a drone and a manned helicopter."

Principal Researcher, ONO Fumie

has stated that, "These experiments demonstrate that direct communication between drones can contribute to safe flight control of drones in environments beyond visible range. Although the flight speed in these experiments was 1 m/s, we plan further tests of performance at higher flight speeds." Executive researcher in charge of this R&D, MIURA Ryu has said, "In the next step, we will demonstrate avoidance of near-misses not only between drones, but also between a drone and a manned helicopter."

TRC Program manager Prof. TADOKORO Satoshi also added his comment: "This research involves practical technology that can be applied to disaster response using large numbers of aircraft. We look forward to international standardization of the technology and further progress in safety for operating aerial robots in disaster-hit areas."

Reference

Cabinet Office, Impulsing Paradigm Change through Disruptive Technologies program (ImPACT)
https://www.jst.go.jp/impact/

PROTECT

Inter-organizational data utilization via privacy-preserving deep learning

Inviting financial institutions to participate in demonstration experiment to improve detection accuracy of remittance fraud

It is expected that various social problems can be effectively or better solved by integrating a large amount of real-world data held by multiple organizations via the process of collecting, processing, learning, and controlling data across the organizations. However, one of the main challenges is to protect privacy and ensure data confidentiality, which is viewed as a barrier to data circulation among multiple organizations.

NICT Security Fundamentals Laboratory has developed a novel system called DeepProtect, which enables multiple organizations such as banks or hospitals (with personal data) to participate in the process of using deep learning on their data with expectedly better learning outcomes than using machine learning at each organization individually, and importantly without having to disclose their plain data to each other. At its technological heart, DeepProtect employs a central parameter server where ciphertexts produced by the homomorphic encryption at every organizations are securely stored and processed so that the server can see nothing about the plain data. In addition, all plain data items are pre-processed and calculated in a statistical manner before being

encrypted and transmitted, so that no plain data is shared to other organizations.

"Reducing costs while improving performance for detecting remittance fraud"

NICT Security Fundamentals Laboratory, together with Kobe University and Eltes Co., Ltd., in the JST CREST "Artificial Intelligence" (Development and Integration of Artificial Intelligence Technologies for Innovation Acceleration) research area, work on the research and development of privacy protection data analysis technologies such as DeepProtect that can achieve both data utilization and privacy protection at the same time. In addition, the Laboratory is working on verifying and demonstrating the practicality of such technology at large scale. Owing to the cooperation of a few banks, we have conducted experiments on each bank individually to detect fraudulent remittance, which is an issue in the financial industry. Aiming at further improving the automatic detection accuracy of fraudulent remittance by integrating learning outcomes from multiple financial institutions, we are currently recruiting financial institutions participating in this demonstration experiment. Via our privacy-preserving data analysis technologies, it is expected that multiple financial institutions can enjoy benefits such as reducing costs while improving performance for the task of detecting fraudulent remittance.

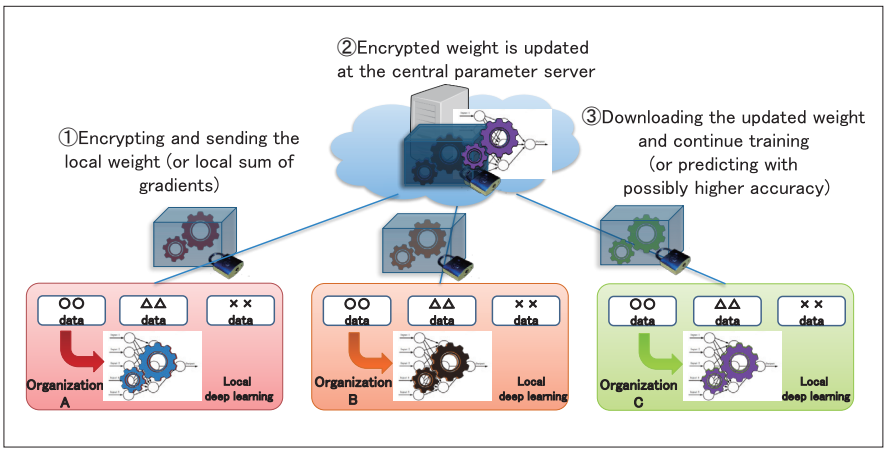


Fig. : DeepProtect system : collaborative deep learning in a privacy-preserving and secure manner

Reference

"Privacy-preserving Data Analytics to Promote Cross-industry Data Sharing" project webpage: https://www2.nict.go.jp/security/crest/index.html (Japanese)

CONNECT

Protecting factories with wireless communication systems

Seven companies collaborate to publish a security deployment guide

Use of wireless communications in manufacturing environments has received much attention recently, but compared with wired-only networks, networks that include wireless communication have more aspects that can be attacked, so attention must be given to them.

In June 2015, the NICT Wireless Networks Research Center launched a Flexible Factory Project with two objectives: coordinating the wide variety of wireless systems installed within factories and ensuring that they oper-

ate safely. During this project, we have been collaborating with many manufacturers across a variety of industries to survey the wireless environments found in actively operating factories. Various issues have materialized as use of wireless in factories has increased, including (1) Radio waves are invisible, (2) Many devices share the same resources of space (signal paths) and frequency, and (3) Wireless communications are strongly influenced by the physical environment such as physical objects and walls. These issues can lead to security threats or trouble due to operational faults, so adequate measures must be taken in order to use wireless communications safely in a manufacturing environment.

With this background, NICT together with six companies participating in the Flexible Factory Project* have published, "FFPJ Security Guide for Factory," to protect factories introducing wireless communication (available in English and Japanese editions).

"We will work to establish technologies and standards for stable, cooperative control of multiple wireless systems."

The guide compiles the main security measures that can be introduced at the factory-floor level in a toolbox with five categories, so that even those that are not specialists in security technologies can easily understand the important issues before implementing them. The figure shows the five categories vertically, and the functionality satisfied by each category horizontally.

Senior Researcher, ITAYA Satoko, has stated, "In the future, this project will work to establish technologies and standards for stable, cooperative control of multiple wireless systems, while actively publishing information regarding utilization of wireless communications."

An outline of this guide was presented, at the Hannover Messe (an international industrial technology trade fair) held April 1-5, 2019 in Germany.

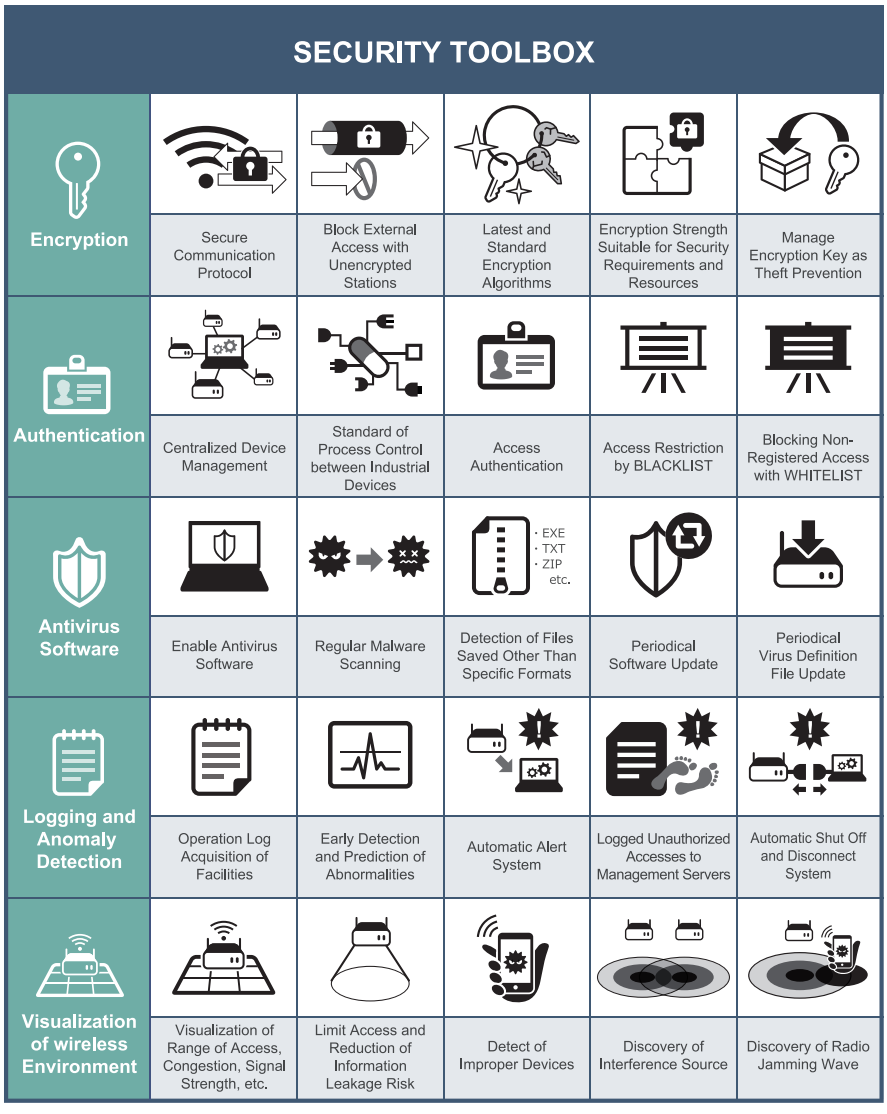


Fig. : Toolbox of protection methods for assets

Footnote

* National Institute of Information and Communication Technology, OMRON Corporation, NEC Corporation, FUJITSU KANSAI-CHUBU NETTECH LIMITED, Sanritz Automation Co., Ltd., KOZO KEIKAKU ENGINEERING Inc., TOYOTA TECHNICAL DEVELOPMENT CORPORATION.

Reference

download: FFPJ Security Guide for Factory
https://www2.nict.go.jp/wireless/en/ffpj.html
(English edition)

CONNECT

Successful high-capacity transmission over multi-core fiber link amplified with 19-core optical amplifier

In order to meet the demand for ever increasing data traffic, research on new optical fiber designs is actively pursued all over the world. In particular fibers using the spatial domain to both multiply the transmission capacity and provide greater efficiency in transmission system design are particularly attractive.

One of the most common new fiber types studied is multicore fibers (MCFs), in which multiple paths (cores) are arranged in a single optical fiber. Optical amplifiers are an important component for long-distance transmission and offer potential for integration and resource sharing in MCF systems. In particular, high core-count multi-core amplifiers offer potential to integrate hardware and significantly reduce the number of pump lasers. Furthermore, they can expect reduction in power consumption and installation space. Previously, high capacity was reached over short distances in a high-core count amplifier or long-distance transmission was achieved with a 7-core-pumped (with 1 pump laser per core) amplifier.

NICT Network System Research Institute (NSRI) and Furukawa Electric Co., Ltd. (Furukawa Electric, President: KOBAYASHI Keiichi) jointly successfully demonstrated transmission of 715 Tb/s data over a distance of 2,009 km using 19-core multi-core fiber and a 19-core amplifier utilizing cladding-pumping technology in order to share electrical power between the many spatial channels (Fig.).

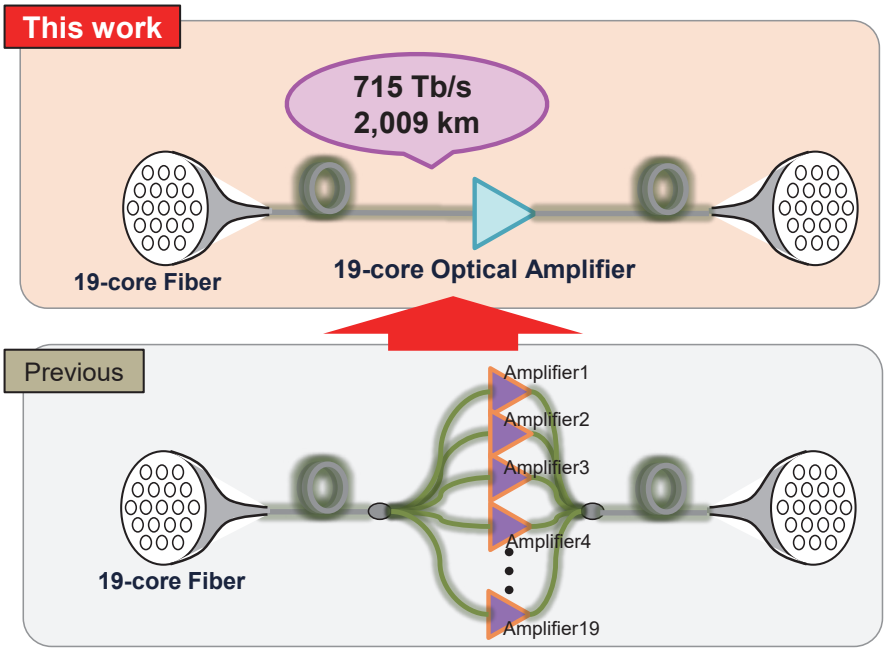


Fig. : 19-core amplifier that reduces power consumption and installation space

"We are promoting innovative technology that enables early adoption of next-generation optical communication infrastructure."

This demonstration showed high-core count cladding-pumping amplifiers are suitable for high throughput transmission over 1,000s km, achieving the highest throughput-distance product of any transmission demonstration using multi-core amplifier experiment of 1.44 Exb/s x km.

The results were selected for presentation as a post-deadline paper at the Optical Fiber Conference (OFC 2019), the world's largest event for optical communications research.

AWAJI Yoshinari and Ben Puttnam,

Research manager and Senior Researcher of the NSRI Photonic Network System Laboratory have stated: "We are promoting R&D of innovative technology that enables early adoption of next-generation optical communication infrastructure technologies which can smoothly accommodate traffic for big data and 5G services and international standardization by industry-academia collaboration."

Reference

Ben Puttnam, Georg Rademacher, Ruben Luis, Tobias Eriksson, Werner Klaus, Yoshinari Awaji, Naoya Wada, Koichi Maeda, Shigehiro Takasaka and Ryuichi Sugizaki, '0.715 Pb/s Transmission over 2,009.6 km in 19-core cladding pumped EDFA amplified MCF link' In Proc. Optical Fiber Conference (OFC) 2019 paper Th4B.1

CREATE

Accuracy improvement for machine translation of automobile laws and regulations using neural technology

*Improving the practicality of English-Japanese & Chinese-Japanese translation through collaborative research with Toyota**

When designing, manufacturing, and exporting automobiles and automobile parts, the requirements in each nation's established laws and regulations such as ensuring safety and protecting the environment must be fulfilled. To do so, they must swiftly and accurately understand the frequently revised laws and regulations of each country, but in our current circumstances, because we rely on human translation, ensuring accuracy takes time. High-speed, high-accuracy translation of information is the key to business efficiency for those in the automobile industry, such as Toyota.

NICT has been working with the

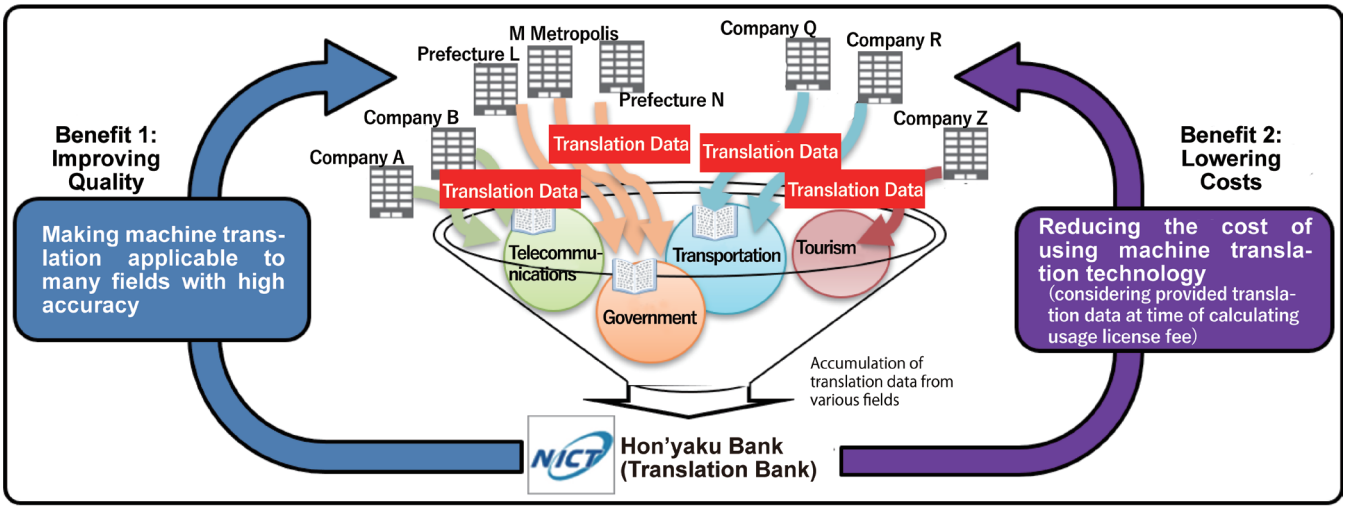


Fig. : Hon'yaku Bank Scheme

Ministry of Internal Affairs and Communications on the operation of Hon'yaku Bank (Translation Bank)[1] since 2017. Hon'yaku Bank accumulates data that is essential for neural machine translation (NMT), an automated translation technology that uses neural networks. Until now, we have received data provided by numerous organizations including pharmaceutical companies and advanced the accumulation and utilization of translation data. In addition, we have conducted collaborative research on the topic of "research and development of machine translation engines for automobile laws and regulations" with Toyota since June 2018.[2]

By using English-Japanese and Chinese-Japanese translation data related to automobile laws and regulations provided by Toyota, NICT adapted (i.e., further adjusted an already trained NMT neural network to improve its accuracy using data that had been added to Hon'yaku Bank) general-purpose English-Japanese and Chinese-Japanese neural network translation engines and improved their practicality.

"Expanding this technology to apply to a wide variety of documents, we will advance its multilingualization."

When Toyota assessed the machine translation engines' practicality for automobile laws and regulations after the adaptation, they found a 24% improvement in the English-Japanese translation, and a 11% improvement in the Chinese-Japanese translation, compared with the pre-adaptation results. With these results, Toyota decided to continue investigating practicality improvement.

Dr. SUMITA Eiichiro, Associate Director General of the Advanced Speech Translation Research and Development Promotion Center, commented, "As we expand this technology beyond laws and regulations to apply to manuals and a wide variety of other documents, we will advance its multilingualization, and aim to broaden its use to the entire automobile industry and export industry, which covers a wide area."

Translations for each nation's language's laws and regulations are not limited to automobiles, but rather exist for all products that are exported, and increasing the speed and accuracy of translations for those products is similarly essential. It is anticipated that Hon'yaku Bank will make this achievable.

Footnote

* Toyota: TOYOTA MOTOR CORPORATION

Reference

[1] Hon'yaku Bank (Translation Bank) http://h-bank.nict.go.jp/index.html
[2] Related press release (in Japanese) (released on April 23, 2019 https://www.nict.go.jp/press/2019/04/23-1.html)

DEVELOP

ITU-T has developed the first ITU-T Recommendation on quantum key distribution network

Researches and developments of quantum key distribution (QKD) have been promoted in all over the world as a method to share cryptographic keys between two parties, which is unbreakable by the third party (eavesdropper) with any computational resources even with quantum computers.

In recent years, there has been a growing demand for standardization of QKD networks, as major telecom companies have been increasing their momentum to expand their investment in QKD ventures.

In Japan, NICT, NEC, and Toshiba have developed the world's most advanced QKD equipment, and have been working on development of network technologies, long-term operation tests, and development of various

security applications on the Tokyo QKD Network since 2010.

These three organizatiuons, NICT, NEC, and Toshiba, have compiled a draft base-line document with the results of the researches and developments works on the requirements, basic configuration and functions of the QKD network and submitted a contribution at the ITU-T SG13 meeting in September 2018, and have led to standardization activities in ITU-T.

"We will accelerate utilization of cryptographic services to establish the international standardization of QKD."

In May 2019, NICT invited an interim meeting at the NICT Headquarters (Koganei) to discuss the draft Recommendation of QKD network intensively, gathering opinions and made a significant progress as the chair of the meeting and contributed to completion of Y.3800.

In consequence of these discussions, Y. 3800 was consented as a new ITU-T Recommendation at the ITU-T SG 13 meeting which was held in Geneva on June 28, 2019.

Thus, Japan's QKD network technologies have formed an international standard as the ITU-T's first QKD Recommendation.

This ITU-T Recommendation will specify the requirements, basic structure and functions of the QKD network, and it is the first ITU-T Recommendation to establish an international standardization on QKD network.

By establishment of the international standard in ITU-T, it is expected that practical applications and utilization of cryptographic services with high confidentiality using QKD technologies will accelerate.

A part of this study was carried out by "Society 5.0 realization technology by utilizing optical and quantum" of Strategic Innovation creation Program (SIP) of Council for Science, technology and Innovation of the Cabinet Office (Management corporation: National Institutes for Quantum and Radiological Science and Technology).

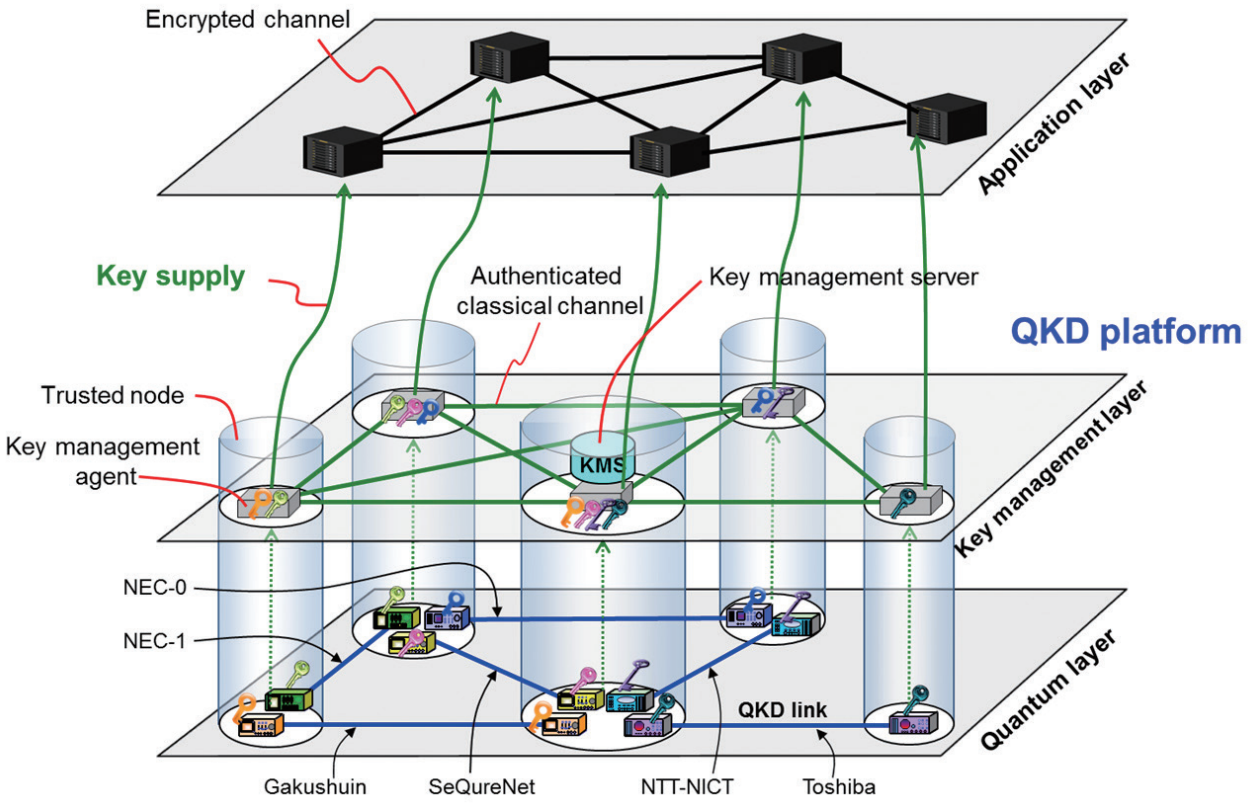


Fig. : Tokyo QKD network architecture and layer structure for key management

CREATE

How your brain remembers motor sequences

Hierarchical, yet flat

The best way to remember/produce long and complex motor sequences is to divide them into several smaller pieces recursively. For example, a musical piece may be remembered as a sequence of smaller chunks, with each chunk representing a group of often co-occurring notes (Fig.). Such hierarchical organization has long been thought to underlie our control of motor sequences from the highly skillful actions, like playing music, to daily behavior, like making a cup of tea. Yet, very little is known about how these hierarchies are implemented in our brain.

In a new study published in a journal Neuron, YOKOI Atsushi, Center for Information and Neural Networks (CiNet), NICT, and Jörn Diedrichsen, Brain and Mind Institute, Western Univ., provide the first direct evidence of how hierarchically organized sequences are represented through the population activity across the human cerebral cortex.

The researchers measured the fine-grained fMRI activity patterns, while human participants produced 8 different remembered sequences of 11 finger presses. Through a series of careful behavioural analyses, the researchers could show that participants encoded the sequences in terms of a three-level hierarchy; (1) individual finger presses, (2) chunks consisting of two or three finger presses, and (3) entire sequences consisting of four chunks. They could then characterize the fMRI activity patterns with respect to these hierarchies using machine learning techniques.

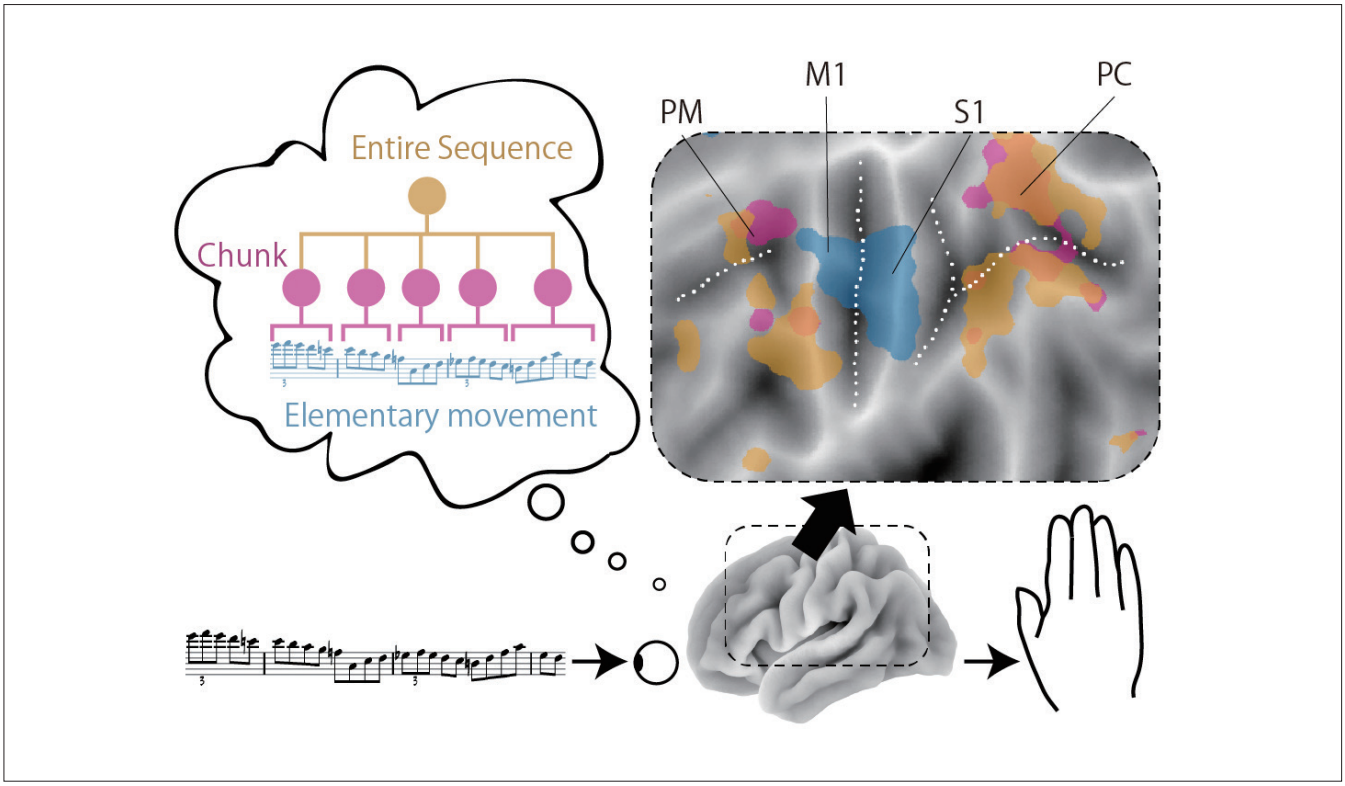


Fig. : Hierarchical organization of motor sequence
M1: primary motor cortex, S1: primary sensory cortex, PM: premotor cortex, and PC: parietal cortex.

"Searching for more sophisticated algorithm to reconstruct complex motor behavior"

Contrary to the common assumption, the researchers found that overlapping regions in the premotor and parietal cortices represent the sequences in multiple levels of motor hierarchy (e.g., chunks of a few finger movements, or chunks of a few chunks), whereas the individual finger movements (i.e., the lowest level in the hierarchy) were uniquely represented in the primary motor cortex. These results uncovered the first detailed map of cortical sequence representation in the human brain.

"Although its functional role is still unclear, the anatomical overlap between chunk and sequence representations may suggest these representations in upper movement hierarchy may influence with each other to support flexible sequence production. This needs to be tested in the future study," CiNet Researcher Dr. YOKOI concluded.

The results may also provide some clue for locating new candidate brain areas as signal sources for motor BCI application or developing more sophisticated algorithm to reconstruct complex motor behavior.

The study was conducted under an international collaboration between NICT (Japan), UCL (UK), and Western University (Canada).

Reference

Journal: Neuron
Title: Neural Organization of Hierarchical Motor Sequence Representations in the Human Neocortex
Authors: Atsushi Yokoi, Jörn Diedrichsen
DOI: https://doi.org/10.1016/j.neuron.2019.06.017
URL: https://www.cell.com/neuron/fulltext/S0896-6273(19)30567-7

Open Innovation

Wi-SUN-based social infrastructure enabling loosely-connected things for "Local production and consumption of data"

Field trials of community-based local monitoring and digital circulation notices in Kurobe City

There is a trend toward aging and shrinking populations, and a growing social issue is how to maintain systems that can efficiently support the lives of elderly people that do not use smartphones or other ways to access the Internet. Social welfare councils and other organizations in each municipality are working to provide the supports needed for their lives, but there is a strong need to increase the efficiency of this work and activity through ICT.

As such, the Social ICT System Laboratory of the NICT has developed a technology for building Wi-SUN*1-based social infrastructure for "local production and consumption of data*2", in which things are loosely connected, using a combination of Wi-Fi and Wi-SUN technology. Wi-SUN is an international radio standard for IoT that does not require licensing. A concept of this technology is to create a "loosely connected" regional society that can transmit, exchange, and utilize information related to regional resources—such as people and objects—in a casual, safe, secure, and convenient way without imposing too much mental or technological responsibility. Specifically, a new, compact, "in-passing" IoT wireless router called "WiWi-Stations" has been developed, which can be placed in

homes or in local commercial vehicles to easily build a platform for gathering, distributing and sharing local information, without being dependent on mobile phone networks or the cloud.

"We have started trial service of local monitoring and digital circulation notice in Kurobe City."

Recently, in April 2019, NICT entered into a three-party agreement with the Kurobe City Social Welfare Council and Nissin Systems Co. Ltd., to research ICT utilization in the area of local social welfare in Kurobe City, and on systems and operations for watching over residents. Based on this agreement, we set a goal of conducting trials of local monitoring and digital circulation notices using the network building technology described above, for elderly households in Kurobe City (up to 40 households) for three months from October.

For the local monitoring trial, a mechanism was introduced that is able to notify of the frequency of outings or a decline in social interactions at households being monitored, using Wi-SUN radio in commercial vehicles that pass nearby by chance while performing their ordinary work. This enables changes in the conditions of those being monitored to be detected early, so that monitoring services requiring visitation can be operated more efficiently. The digital circulation notice trial involves a digital circulation notice service that delivers notices from the social welfare council, including video content, utilizing local commercial vehicles while they carry on their regular duties.

Footnote

***1 Wi-SUN**
An International radio standard for IoT being promoted by the Wi-SUN Alliance (https://www.wi-sun.org/ja/). Common in Japan for its use in smart meters. Over 90 million devices globally. Communication speed approximately 100 kbps. Features the ability to build broad service areas with relay networks using multi-hop communication.

***2 Local production and consumption of data**
The idea of using data to create new value by sharing and consuming locally detected sensor data on the local network, rather than storing it on the cloud.

Fig. : Observing the city while driving on business

CREATE

Preventing anxiety-induced decrease in motor performances

A new method for sport and music training

Athletes, musicians, and other performers, be they professionals or amateurs, are required to conduct rapid complex movements that can be affected by anxiety. Influential self-focus theory postulates that the motor skills required for these actions become automatic and unconscious during learning, but anxiety causes an interference between conscious and unconscious processing that can negatively impact the performance. However, no behavioral or brain data has confirmed the theory. Such data would provide therapeutic targets that negate the effects of anxiety on motor performances.

Principle Investigator HARUNO Masahiko (Center for Information and Neural Networks (CiNet), NICT), with Dr. Gowrishankar Ganesh (CNRS) and Dr. Takehiro Minamoto (Shimane University) conducted fMRI by designing a novel behavioral task and found a correlation between activity in the dorsal anterior cingulate cortex (dACC) and the motor performance deterioration due to anxiety. The application of TMS to suppress dACC activity rescued the deterioration, providing the first direct evidence that suppressing anxiety-stimulated regions could reduce performance deterioration.

In general, specific motor skills, such as those used in tennis or playing the piano, require repeated practice to memorize the motions and their order. In the new study, the researchers simulated this practice on a computerized

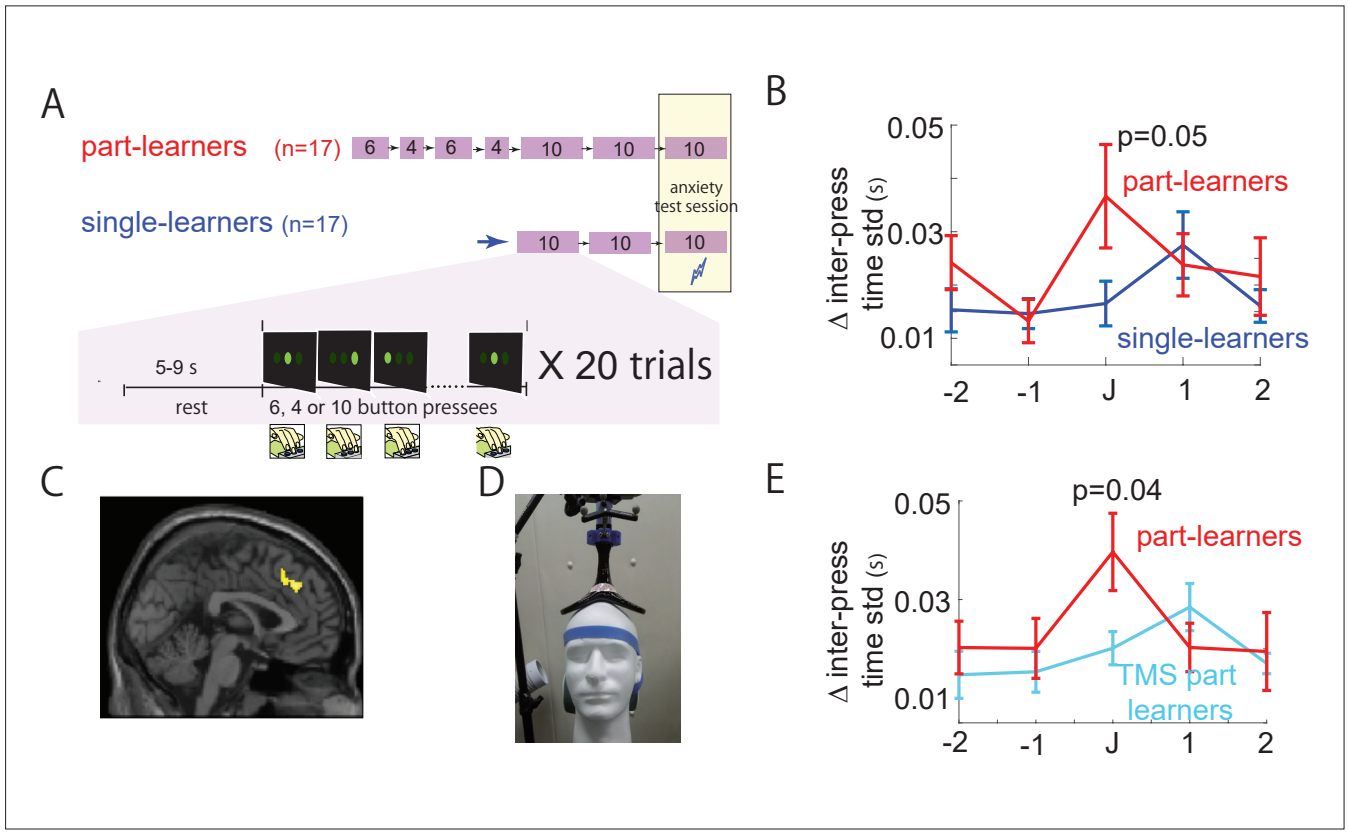


Fig. : Reduced performance under anxiety correlated with activity in the dACC.

10-step rapid button press task. Part-learners learned the task in two parts, one 6 steps long and the other 4 steps long. Finally, they practiced all 10 steps at once. Single-learners, on the other hand, learned the 10-step rapid button presses together without breaking them into parts. After the learning, both groups of learners were asked to conduct the entire 10-step task and given an electrical shock if they made a mistake during the performance (Fig. A, anxiety test session).

Part-learners proved more adept at learning the task in the training sessions based on the speed and number of errors with which they completed the task. However, when the anxiety test session started, their performance dropped noticeably to a level worse than single-learners (Fig. B, J represents the junction of the two parts). This finding is consistent with the self-focus theory, which would expect performance to decline with anxiety.

"Investigating the relationship between regional brain activities and performance of athletes or musicians"

fMRI revealed that the part-learners showed increased activity of the dACC at the time of the junction in the test session (Fig. C). Applying TMS to this region for 5 minutes (1 Hz) prior to the test session (Fig. D) eliminated the performance degradation in part-learners (Fig. E). On the other hand, part-learners who received sham TMS did not show improvement.

These experiments show for the first time the brain region responsible for performance degradation caused by anxiety and a possible therapeutic strategy using TMS. "In addition to more study of the dACC neural circuits that connect anxiety to performance degradation, the group will investigate how TMS can enhance the performance of athletes, musicians, and other performers," CiNet PI Dr. HARUNO stated.

This research was funded in part by JST-CREST and JSPS KAKENHI grant.

Reference

Journal: Nature Communications
DOI: 10.1038/s41467-019-12205-6
URL: https://doi.org/10.1038/s41467-019-12205-6
Title: Activity in the dorsal ACC causes deterioration of sequential motor performance due to anxiety
Authors: Gowrishankar Ganesh, Takehiro Minamoto, Masahiko Haruno

CONNECT

First demonstration of a 1 Petabit per second optical switching node

Optical networks have become an indispensable infrastructure underpinning the digital economy and supporting the intensive data networking needs of industry, commerce, academic institutions, governments and individuals worldwide. Since the amount of network traffic has increased dramatically over recent years, the capacity limits of conventional optical networks based on wavelength division multiplexing (WDM) technologies has been concerned. To extend the current capacity limit, spatial division multiplexing (SDM) technologies using multi-core fibers (MCFs) and/or various spatial-modes have been recently studied and developed.

NICT has collaborated extensively with academia and industry to develop various types of MCFs and provide high-capacity communications for short and long reach backbone networks as well as datacenter networks. These included achievements such as the record Petabit-class transmission in a single fiber and the longest link using SDM amplifiers. However, Petabit-class transmission requires Petabit-class switching technologies to manage and reliably direct large amounts of data through complex networks. Up to now, such technologies have been beyond reach because the existing approaches are limited by complexity and/or performance.

NICT Network System Research Institute (NSRI) has developed and dem-

onstrated the first large-scale optical switching testbed capable of handling 1 Peta-b/s optical signals. 1 Peta-b/s is equivalent to the capacity to send 8K video to 10 million people simultaneously. This testbed made use of state-of-the-art large-scale and low-loss optical switches based on MEMS technology, multi-core joint switches for protection and three types of SDM fibers such as 22-core single-mode fibers, 7-core single-mode fibers and 3-mode fibers. This network used a hierarchical architecture consisting of SDM layer and WDM layer so that low-loss spatial switches in SDM layer can reduce the node cost and enable long-distance transmission. This demonstration included the optical path switching with capacities from 10 Tera-b/s to 1 Peta-b/s and practical requirements of real networks, such as protection switching. The system was demonstrated in 4 fundamental scenarios that constitute the building blocks of the next-generation optical fiber networks (Fig.).

1. Optical switching of 1 Peta-b/s SDM path
2. Redundant configuration to support network failures or fiber breaks and protection switching
3. Management of lower-capacity WDM path (10 Tera-b/s) within the 1 Peta-b/s network
4. Branching of 1 Peta-b/s SDM path into different types of optical fibers with various capacities

"This is a major step forward toward Petabit-class optical networks."

This has been the first demonstration of an SDM network node with capacities comparable to recent Petabit-class SDM transmission experiments. Petabit-class networks correspond to more than 100 times the capacity of currently available networks.

FURUKAWA Hideaki, Director of the NSRI Photonic Network System Laboratory have stated: "We succeeded in 1 Peta-b/s switching demonstration on prototype optical network testbed using various MCFs and large-scale spatial optical switches. This result is a major step forward toward the early implementation of optical networks capable of supporting the increasing requirements of internet services such as broadband video streaming, 5G mobile networks or Internet of Things. We will continue to pursue the advancement of ultra-high capacity communication networks in collaboration with the industry, academia and government."

Reference

International conference:The 45th European Conference on Optical Communication (ECOC2019)
URL:https://www.ecoc2019.org/programme.html
Title: Demonstration of a 1 Pb/s spatial channel network node (Post Deadline Paper)
Authors: Ruben S. Luís, Benjamin J. Puttnam, Georg Rademacher, Tobias A. Eriksson, Yusuke Hirota, Satoshi Shinada, Andrew Ross-Adams, Simon Gross, Michael Withford, Ryo Maruyama, Kazuhiko Aikawa, Yoshinari Awaji, Hideaki Furukawa, and Naoya Wada

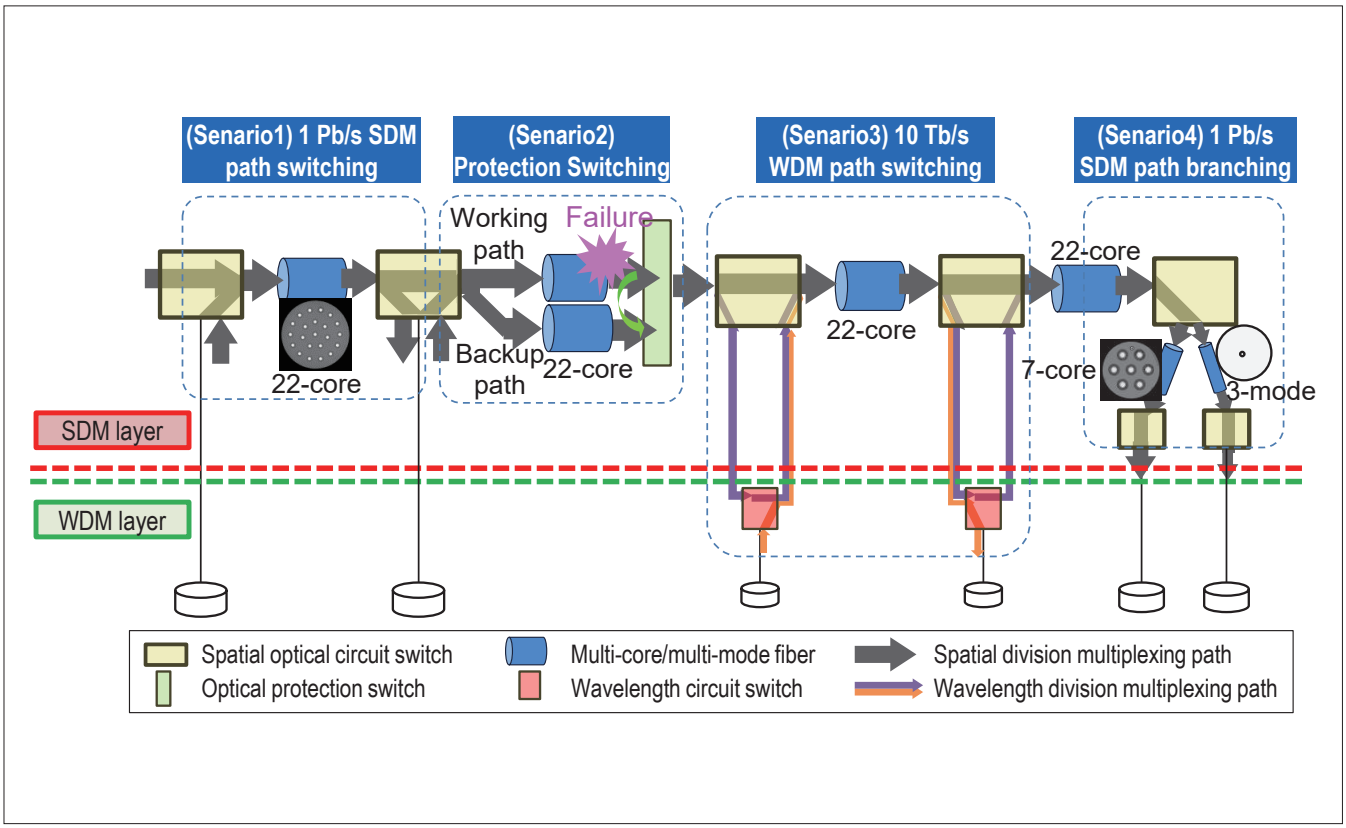


Fig : Experimental SDM network testbed and network scenarios

WATCH

WASAVIES

Warning System for Aviation Exposure to Solar Energetic Particles

Recently, the need for space weather information is increasing in various fields. A notable example of this is the International Civil Aviation Organization (ICAO)'s decision in 2011 to use space weather information for flight operation.

ICAO is concerned with increases in radiation exposure caused by cosmic rays,*1 as well as disruption of high-frequency (HF) communication and increases in errors in global-navigation-satellite-system (GNSS) measurement caused mainly by solar activities. Therefore, ICAO requires information on radiation doses caused by cosmic rays as space weather information. In addition, cosmic ray exposure is recognized as occupational radiation exposure, so civil aviation companies require radiation-dose management for aircrews. NICT was the only Asian center elected for the ICAO space weather center, and its service started on November 7, 2019.

A research group led by NICT, the Japan Atomic Energy Agency (JAEA), and the National Institute of Polar Research (NIPR) succeeded in developing the Warning System for Aviation Exposure to Solar Energetic Particles (WASAVIES), which can estimate the radiation dose caused by solar energetic particles in real-time immediately after a solar flare*2 occurrence.

WASAVIES can estimate a radiation dose up to 100 km above the ground anywhere on Earth and monitor an aircrew's radiation dose in real-time. This system enables information on the aircrew's radiation dose to be given as space weather information used for aviation-operation management.

"NICT strives to contribute to safer air operation by providing cutting-edge information on space weather to ICAO."

This study is a successful example of interdisciplinary research achieved through collaboration among researchers in various fields such as space weather, solar physics, upper atmosphere physics, nuclear physics, and radiation protection.

WASAVIES will further evolve, not only to provide real-time estimation but also to improve the accuracy of its radiation-dose prediction up to end of the radiation event. We will push the development of the system forward to apply radiation-exposure management for astronauts of manned space missions, such as missions to the moon and planet explorations, which will take place frequently in the near future.

NICT is starting to provide information on HF communications, GNSS positioning, and radiation exposure as the only Asian center among ICAO space weather centers. The system will provide information necessary for the operation of the ICAO center.

Footnote

***1 cosmic ray**
Cosmic rays are composed of galactic cosmic rays (GCR), which constantly come from far from the solar system, and solar energetic particles (SEP), which sporadically come from the Sun when large solar flares occur.

***2 solar flare**
Explosive phenomena on the solar surface. Almost all solar flares occur at sunspot areas. When a large solar flare occurs, sometimes solar energetic particles are emitted along with electro-magnetic radiations, such as radio waves, visible light, UV light, and X-rays.

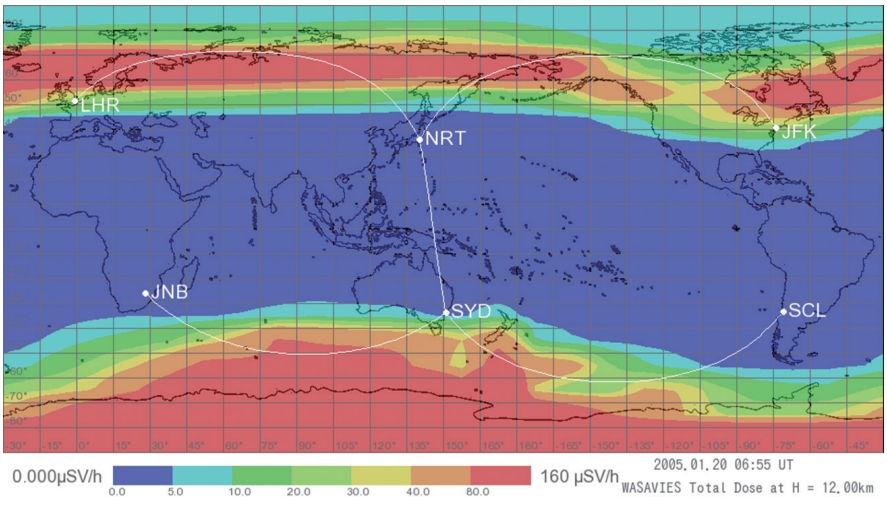
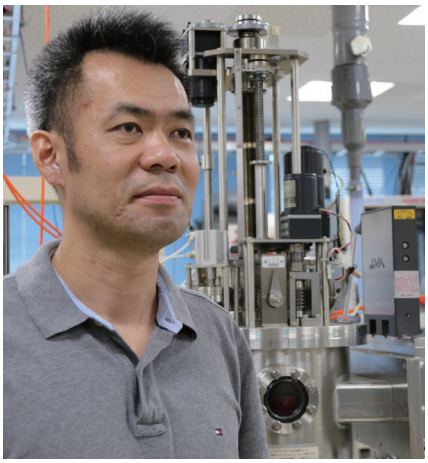


Fig. : World dose map estimated by WASAVIES on the occasion of a past large SEP event. White lines show flight routes, along which WASAVIES can specifically estimate the radiation dose.

Researchers
Person 1



HIGASHIWAKI Masataka

Director of Green ICT Device Advanced Development Center, Advanced ICT Research Institute

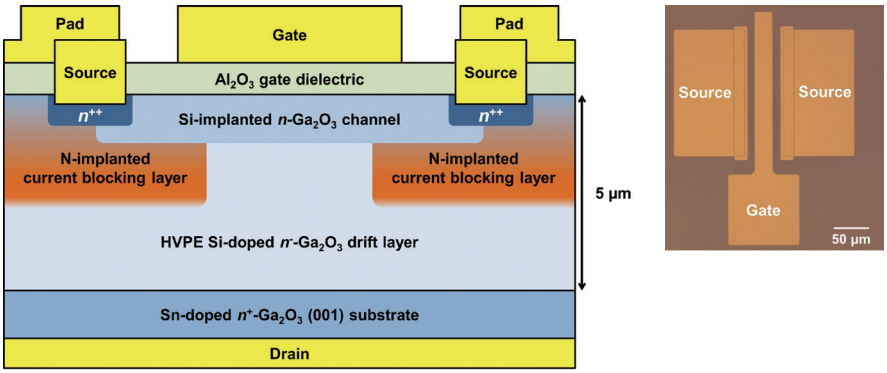
After completing graduate school and Postdoctoral Research as a Fellow of the Japan Society for the Promotion of Science, he joined the Communications Research Laboratory (currently NICT) in 2000. There, he engaged in research on semiconductor crystal growth, device processing, and characterization. Ph.D.(Engineering).

Paving the way for practical applications of gallium oxide devices

In the mid-2000s, I engaged in development of highly-scaled gallium nitride (GaN) high electron mobility transistors (HEMTs). We successfully demonstrated the capability of GaN HEMTs for applications at frequencies of up to about 100 GHz, which prompted several universities and industries to launch developments of millimeter-wave and/or sub-millimeter-wave GaN HEMTs. At that time, I started to seek a new research topic and came across a new semiconductor "gallium oxide (Ga_2O_3)."

When I started development of Ga_2O_3 devices, I was simply attracted by its basic material properties, which were an extremely large bandgap, controllability of n-type conductivity by donor doping, and existence of melt-grown bulk single crystals. In 2011, I formed a collaborative research team and succeeded in demonstrating the world's first single-crystal Ga_2O_3 transistor as a metal-semiconductor field-effect transistor (MESFET). I strongly believe that the MESFET was the most important breakthrough for the Ga_2O_3 community. Following the development of the MESFET, we have been developing some breakthrough technologies every one to two years and demonstrating milestone devices such as lateral depletion-mode (D-mode) metal-oxide-semiconductor FETs (MOSFETs) and the world's first Ga_2O_3 Schottky barrier diodes with a breakdown voltage of over 1 kV. Recently, we succeeded in developing p-type ion implantation doping process for Ga_2O_3 using nitrogen for the first time in the world. The nitrogen-ion implantation doping technology led to the demonstration of the vertical D-mode Ga_2O_3 MOSFETs [1].

[1] M. H. Wong, K. Goto, H. Murakami, Y. Kumagai, and M. Higashiwaki, IEEE Electron Device Lett. vol.40, pp.431-434, 2019.



(Left) Schematic cross section and (right) optical micrograph of vertical D-mode Ga_2O_3 MOSFET structure

Q&A

What is the most interesting point in your research?

Gallium oxide is a new research field, and thus experimental results are often different from initial expectation and idea. This is most interesting and attractive to me.

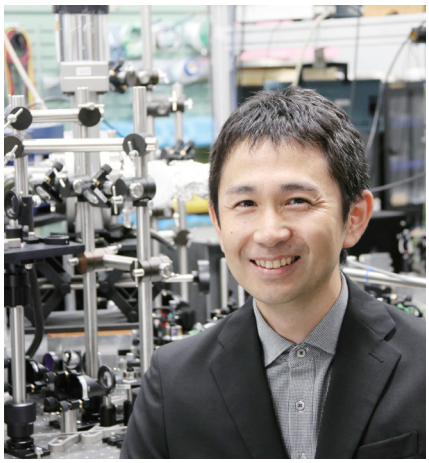
What has been your happiest moment while working on your current research theme?

We succeeded in demonstrating the first gallium oxide transistor in 2011, and the accomplishment galvanized intensive international research activities of this new oxide semiconductor. The gallium oxide community has been rapidly growing. This is the best aspect for me.

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

Gallium oxide devices are expected to be useful for next-generation power electronics. High-efficiency semiconductor power switching devices are under strong demand by the society since they can contribute directly to world-wide energy conservation and reduction of greenhouse gas emission.

Researchers
Person 2



HACHISU Hidekazu

Senior Researcher, Space-Time Standards Laboratory, Applied Electromagnetic Research Institute

After earning a doctoral degree and a Post-Doctoral Fellowship with JST-CREST, he has been with NICT since 2010, where he has been involved in the research and development as well as application of optical frequency standards, specifically optical lattice clocks. Ph. D. (Engineering).

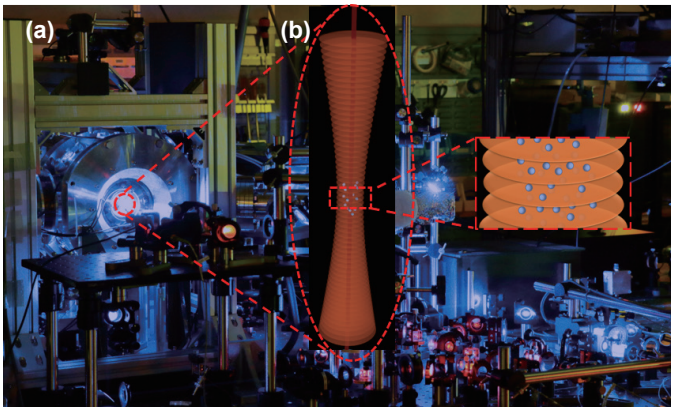
Realizing the next-generation time scale with an optical frequency standard

As the SI unit of time, the second is currently defined by a microwave transition in cesium. A small number of highly accurate clocks based on this transition serve as Primary Frequency Standards (PFSs) and regularly calibrate Coordinated Universal Time (UTC), the international standard time scale maintained by the Bureau International des Poids et Mesures (BIPM) based on data from more than 400 atomic clocks.

We are developing atomic clocks in the optical domain. Such optical clocks are considered as next-generation frequency standards. At this point optical clocks throughout the world - including our own optical lattice clock - have surpassed PFSs in performance, and a redefinition of the second based on an atom's optical transition is being considered.

Recently, NICT started to apply the optical lattice clock to maintain and improve the precision of UTC. After demonstrating that it can evaluate UTC as well as the PFSs, the optical lattice clock at NICT has been recognized as a Secondary Frequency Standard by the responsible international working group. This happened in 2018 and the clock then contributed to the active calibration of UTC - a world first.

We were also first to generate a real time scale signal based on an optical clock. Demonstrated over half a year, this time scale ticked with a scale interval more accurate than that of UTC. Based on our results, we will soon contribute to a more precise Japan Standard Time and will supply accurate reference frequencies when and where needed.



(a)Part of the strontium-based optical lattice clock. (b)A large number of atoms are trapped in the optical lattice (conceptual scheme).
H. Hachisu, F. Nakagawa, Y. Hanado, and T. Ido, "Months-long real-time generation of a time scale based on an optical clock," Sci. Rep. 8, 4243, (2018).

Q&A

What has been your happiest moment while working on your current research theme?

In the field of time and frequency standards, researchers around the world are tough competitors as well as great collaborators, since we share the common goal to unravel nature's mysteries and to improve quality of life by pushing forward technologies such as the global time scale. I am happy to consider every competitor as a nice friend.

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

The second, as the unit of time, is the most accurately realized among the SI units. The advent of extremely precise optical clocks has spurred considerations of a redefinition to make it even more accurate. The realization of a time scale based on an optical clock presented in this work provides important evidence towards a redefinition.

How is your research positioned in the relevant research area?

Previous work has concentrated on a more accurate realization of reference frequencies. Here, we take these results and apply them for UTC calibration and generation of an accurate time scale based on an optical frequency standard (or "optical clock") for the first time in the world.

Researchers
Person 3

YOSHIDA Yuki

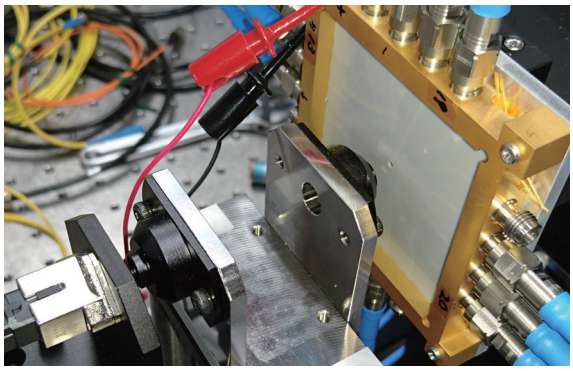
Senior Researcher, Network Science and Convergence Device Technology Laboratory , Network System Research Institute

YOSHIDA Yuki received his Ph.D. in informatics from Kyoto University in 2009. From 2009 to 2016, he was an Assistant Professor at the Graduate School of Engineering, Osaka University. Since 2016, he has been a Senior Researcher in NICT. His research interest is digital signal processing (DSP) for high-speed wired/wireless communications systems.

Bringing extensive optical spectrum resources closer to you with DSP-aided optoelectronic device technologies

My recent interest is in a novel optical coherent receiver technology, known as a phase-retrieving coherent receiver. In recent high-capacity optical core networks, not only the intensity of the optical field but also its phase is exploited as an information carrier for better spectrum efficiency. Such an optical coherent communications technique, however, requires complicated optical circuits at the receiver; photodiodes can only detect the intensity of light in principle, and the received optical field must be properly interfered with a local reference light before the photo-detection to see its phase. Recently, we have proposed a novel coherent receiver solution that utilizes our high-speed two-dimensional photodetector array (2-D PDA) device [A]. The proposed receiver is based on quite a different concept from conventional coherent receivers in that the input optical field is scattered randomly and converted into a random 2-D intensity pattern. The pattern is then detected by the 2-D PDA, and the optical phase information is reconstructed digitally from the intensity pattern by a phase retrieval algorithm known in the image processing field. There is no reference light or complicated optics in the proposed receiver. In [B], we have reported the first experimental demonstration of the phase-retrieving coherent detection of a 40-Gbps-class optical phase modulated signal by the 2-D PDA with a novel low-complexity phase-retrieval algorithm.

In the future, the ultra-compact phase-retrieving coherent receiver may bring advanced optical coherent technology in core networks to your home.



Experimental setup for phase-retrieving coherent detection.
2-D PDA is a tiny black dot at the center of the white plate.

[A] NICT press release (Japanese): https://www.nict.go.jp/press/2017/09/14-1.html
Or, T. Umezawa, T. Sakamoto, A. Kanno, N. Yamamoto, and T. Kawanishi, "High speed 2-D photodetector array for space and mode-division multiplexing fiber communications," J. Lightwave Technol., vol.36, no.17, pp.3684–3692, Sept. 2018.
[B] NICT press release (Japanese) : https://www.nict.go.jp/press/2019/04/25-1.html
Or, Y. Yoshida, T. Umezawa, A. Kanno, and N. Yamamoto, "Coherent detection only by 2-D photodetector array: a discreteness-aware phase retrieval approach," in proc. Optical Fiber Communication Conference (OFC) 2019, paper Th4A.3, San Diego, California, USA, March 2019.

Q&A

What is the most interesting point in your research?

In our laboratory, we develop high-speed optoelectronic devices and DSP techniques for them in tight collaboration. The DSP, developed together with the device, efficiently mitigates the device's impairment, relaxes the requirements on the device, and often affects the device's design. Further, DSP sometimes generates unprecedented value for the device and opens up new applications for it.

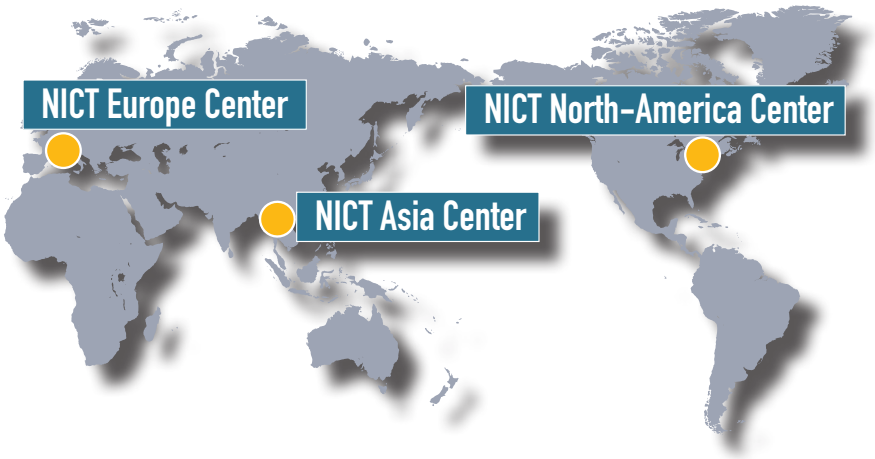
What has been your happiest moment while working on your current research theme?

The very moment we successfully received the first bit transmitted over the optical link based on our home-made devices with the aid of our DSP.

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

The optical spectrum offers a >2000-times broader bandwidth than the radio frequency spectrum. This stupendous spectrum resource is vital to meet ever-increasing bandwidth demand in 5G and beyond. Our DSP-aided optoelectronic devices will provide high-speed, small, and cost-effective optical solutions that bring this incredible optical bandwidth resource closer to end users.

NICT Overseas Centers



Disseminating NICT's Outcome Globally

As hubs to support NICT's international expansion, NICT has established the North-America 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 conducting publicity about 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 in order to support research activities by each department. We also explain NICT's research and development initiatives to each region's government agencies, research institutes, 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 framework between research organizations and universities within the ASEAN region and Japan. We also strive to enhance NICT's presence in the region by participating in exhibits and organizing workshops with our partners' organizations and the relevant departments within NICT. Furthermore, we act as an intermediary for the utilization of NICT's research and development accomplishments on the basis of the research needs of the ICT field in the region.

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

NICT Overseas Centers

Asia Center

Director of Asia Center
KONO Takahiro

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

Collaborating Activities in Highly Diverse Southeast Asia

Work in the Center includes mainly gathering information and promoting and supporting research collaboration in the Southeast Asian region, and making efforts to establish connections with related organizations, as needed to perform this work. As a result, we cannot simply stay in the office; we must go out and visit other areas in Thailand and other Southeast Asia countries. Since my appointment to the Asia Center in August 2018, I have already visited nine ASEAN countries; all except Brunei.

One of the projects we are working on is supporting an ICT project to build a school network in Cambodia, using technologies developed by NICT (Fig. 1). We have become an important bridge between researchers in Japan and Cambodia. In addition, we provide peripheral support for the project, which may not seem exciting at first, such as arranging visits to the project site by parties from the Cambodian government or the Japan embassy. We have made a number of half-day trips from the capital, Phnom Pen, by car and speed boat to the project site, a floating village.

Southeast Asia is very diverse, from country such as Singapore, which have developed beyond Japan in some ways, to countries that still need international support, such as Laos, Myanmar, and Cambodia. They are also completely different in terms of ICT R&D. On the other hand, something they have in common is that they have grown remarkably, economically and otherwise. In rapidly changing Southeast Asia, we will continue to make the best use of our connections and resources to support NICT R&D activities from our base in Bangkok, Thailand.

◀One of the project sites, a floating village

Classroom scene using an education application ▶

Fig.1 Cambodia NerveNet Field Testing project in Cambodia (an ASEAN IVO project)

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

A Cozy Office Located in University Campus

It is now 17 years since the predecessor of the Asia Center, the CRL Asia Research Center, was established in Bangkok, Thailand in 2002. Four years ago, we set up an office in Chulalongkorn University, a prominent national university in Thailand. The center is small, with two Japanese and two Thai staff members. It is located in the center of metropolitan Bangkok, but has a relatively relaxed environment on the university campus, with tasty and inexpensive lunches (150-200 yen) available on campus.

A cafeteria meal at Chulalongkorn University

NICT Overseas Centers

North-America Center

Director of North-America Center
SASAKI Akihiko

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

Networking with ICT Related Oganizations in US

NICT North-America Center has been active for approximately 19 years, starting with the establishment of NICT's predecessor organization's Washington office in October, 2000. The current office, located near central Washington DC, is in walking distance of the White House and federal government organizations. It is very convenient for the three Japanese staff, including myself, to accomplish our daily work.

NICT North-America Center, while acting as a hub of support for the international expansion of NICT's research and development accomplishments, gathers information on research and development policy and research institutions in the field of telecommunications, as well as trends in universities and corporations primarily in the United States, in order to contribute to NICT headquarters.

Specifically, we attend various locally hosted conferences on subjects such as wireless communications, space, quantum communication, AI, and cyber security, introduce NICT's research and development initiatives, gather information and exchange opinions on the initiatives of relevant agencies, and work to build relationships with the other attendees. In addition, by attending various seminars and following news reports, we keep daily watch on the current circumstances of research and development policies and other relevant information in the United States and other places.

Most recently, along with participating in a cabinet-level meeting related to the science and technology cooperation between the governments of the United States of America and of Japan, we also explained NICT's initiatives related to space weather observation at the 6th US-Japan Comprehensive Dialogue on Space, and were able to build and strengthen our relationship with the participants on the US side.

In addition, as a science-related organization located in Washington DC, we also work with the Japanese Embassy, making NICT's initiatives and the conditions of our cooperation with the United States known not only to people involved in politics but also to the general public through various events. In particular, this year, we demonstrated how we observe "space weather," which affects GPS and shortwave transmission, with a large-scale display at an event held in the Japanese Embassy. It made a great impression on many attendees.

In North America, the policies related to telecommunications and its market trends change at a whirlwind pace day by day, moment to moment; we hope to make the best of the intuitive sense gained from being on the ground and our human networks to continue actively supporting NICT's research activities.

Fig.1 Presentation at the 6th US-Japan Comprehensive Space Dialogue

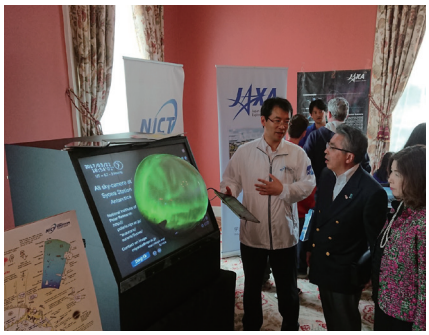

Fig.2 Demonstrating Solar Flare to Ambassador SUGIYAMA

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

National Cherry Blossom Festival

Every spring in Washington DC, a festival called the National Cherry Blossom Festival is held. This festival commemorates the gift of cherry trees to Washington, D.C. from the mayor of Tokyo in 1912, and it has been held annually since 1935. Now, the festival draws over 700,000 people, with the whole city bustling with cherry-blossom-themed events and products for sale. The Cherry Blossom Festival is known in Japan as well, but it is more widely known amongst American people than one would imagine.

One part of the National Cherry Blossom Festival is the Japanese Street Festival. NICT North-American Center utilizes the opportunity provided by this festival to share easily understandable information with many visitors about US-Japan cooperative initiatives in the field of telecommunications.

NICT Overseas Centers

Europe Center

Director of Europe Center
OGI Shintaro

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

Bridging NICT and European Agencies to Promote ICT R&D

Avenue des Champs-Élysées is known as the most beautiful street in the world. One street over in an office district is our Europe Center. Near Paris's main stations, the Europe Center is the base for our two staff members who travel throughout France and Europe.

The Europe Center forms and deepens networks with research institutes, government agencies, and industry groups; spreads information and conducts publicity for NICT's research and development within Europe; and accumulates information on policy and technological development trends related to ICT.

With the complicated state of recent world affairs, there are many agencies that see Japan as an excellent, trustworthy partner. More parties are approaching NICT, too, regarding collaborative research and other types of coordination. The Europe Center plays the role of intermediary between agencies abroad and NICT's headquarters. For the promotion of the shift to wireless communication in manufacturing processes in factories, for example, the Europe Center found cooperative partners and, at large-scale industrial trade fairs such as SPS IPC Drives in November of last year and Hannover Messe in April of this year, conducted joint events on industry 4.0 promotion with European and international industry groups, where specifications independently developed by NICT were introduced.

In addition, the Europe Center actively participates as a public research organization in dialogues between European government agencies, such as the European Commission, and the Japanese government.

Further, so that the rapidly increasing number of foreign tourists in Japan can enjoy pleasant travels, the Europe Center also conducts PR for the multilingual speech translation technology developed by NICT. At the Salon Mondial du Tourisme in March and at Japan Expo in July, both held in Paris, the Europe Center introduced our multilingual speech translation app "VoiceTra" to event attendees interested in Japan.

The Europe Center will continue to work vigorously to establish win-win relationships between NICT, research institutes, and other stakeholders in Europe.

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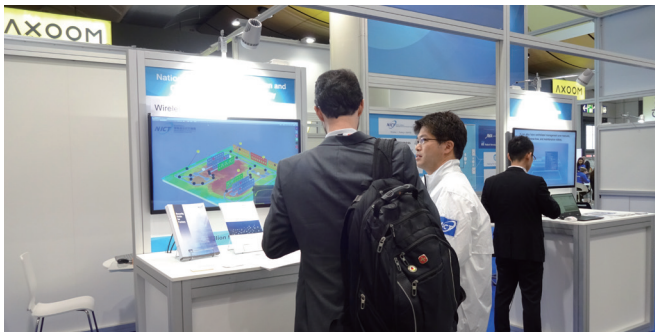


Fig.1 Hannover Messe, held in April 2019

Fig.2 Salon Mondial du Tourisme, held in March 2019

An Air of Vibrancy and Nostalgia

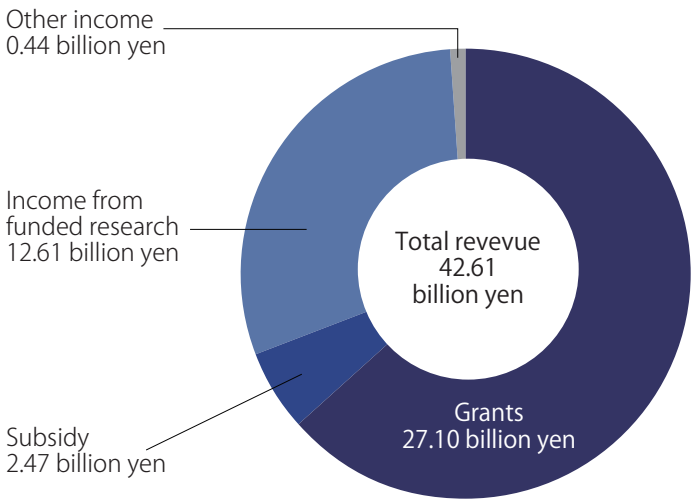
Avenue des Champs-Élysées is constantly bustling with various events, such as the Tour de France, the Bastille Day, and last year, the World Cup victory parade. In addition, there are many telecommunications and device manufacturer shops along the street.

In contrast, around our Europe Center, the street is narrow and one-way, creating an downtown atmosphere. Amidst these surroundings that summon a sort of nostalgia quite unrelated to cutting-edge technology, our two staff members attend to their work.

Budget

The original budget for FY2019

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



Total expenditure for FY2018 was 56.18 billion yen in a reported basis.

Yen-dollar conversion ratio: 111.8yen/dollar (Aplil 2019)

Work Force

1150 (as of April 1, 2019)
(Including fixed term employees)

History

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

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

NICT Primary Facilities

Headquarters

Koganei-shi and Kodaira-shi, Tokyo

Applied Electromagnetic Research Institute
Network System Research Institute
Cybersecurity Research Institute
Open Innovation Promotion Headquarters
ICT Testbed Research and Development Promotion Center
National Cyber Training Center
National Cyber Observation Center
AI Science Research and Development Promotion Center
Big Data Integration Research Center
Terahertz Technology Research Center

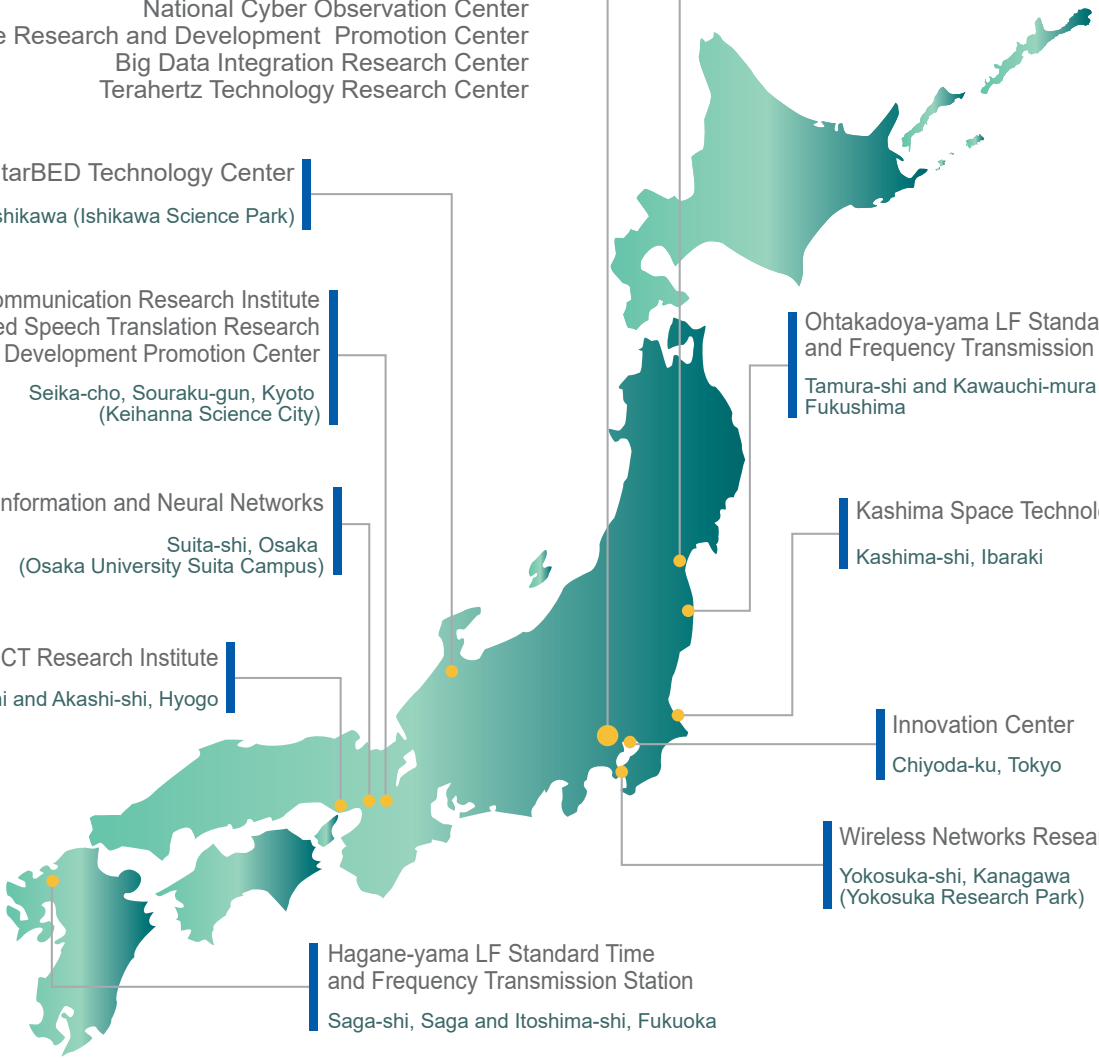
Resilient ICT Research Center
Sendai-shi, Miyagi
(Tohoku University Katahira Campus)

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

Universal Communication Research Institute
Advanced Speech Translation Research and Development Promotion Center
Seika-cho, Souraku-gun, Kyoto
(Keihanna Science City)

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

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



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

Kashima Space Technology Center
Kashima-shi, Ibaraki

Innovation Center
Chiyoda-ku, Tokyo

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

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

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

Overseas bases

Asia Center
North-America Center
Europe Center

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

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