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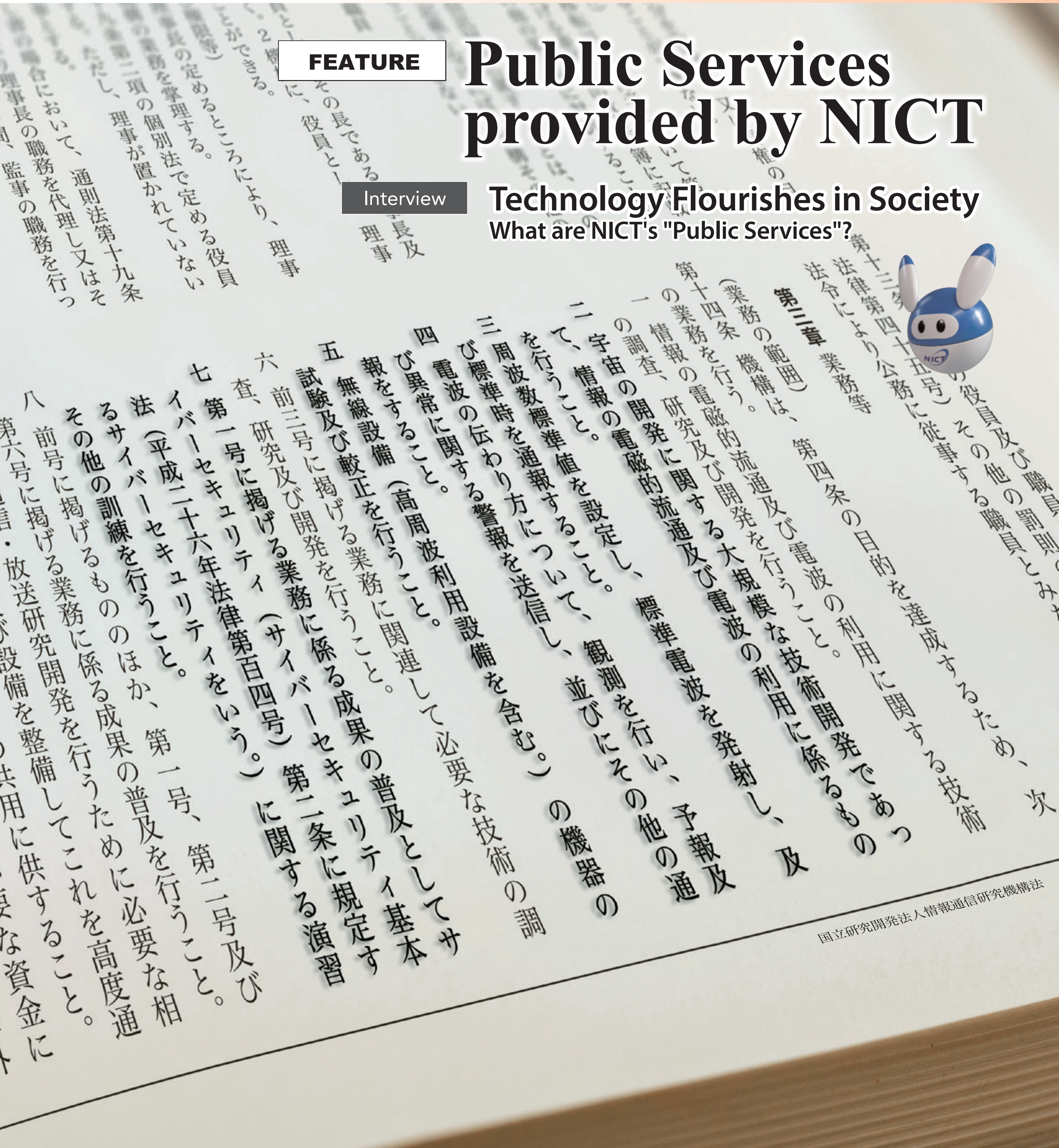

FEATURE

Public Services provided by NICT

Interview

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What are NICT's "Public Services"?

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Information and Communications Technology

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FEATURE

Public Services provided by NICT

Cover Photo:
"Act on the National Institute of Information and Communications Technology, Independent Administrative Agency" that prescribes the organizations, operations, etc. of NICT and the provisions related to NICT's public services specified in the act (in boldface type).

Interview

INFORMATION

FEATURE Public Services provided by NICT

YASUI Motoaki
Executive Director, NICT

He joined CRL of Ministry of Post (currently NICT) in 1996. After he had engaged in research of remote sensing technology, he became assistant manager of Technology Policy Office, ICT Strategy Policy Division, Ministry of Internal Affairs and Communications, Director of Sensing Fundamentals lab at NICT, director of social innovation unit, Executive Director, Strategic Planning Department, then Senior executive director. Current position from 2023. Ph.D. (Science)

NICT conducts cutting-edge research and development in a wide range of fields, from networking, communications and cybersecurity to brain information and neural networks, but NICT has the goal of making the results of its research useful to the world. NICT's major operations include "research and development," "funding to external research institutions," and "public services." Among these operations, "public services" is specifically the one that directly links NICT's cutting-edge research and development results to society, where they are implemented in the daily lives of the general public. What are NICT's "public services" and how do they support social infrastructure? We sat down with Executive Director YASUI Motoaki, who has been engaged in this field for many years.

Interview

Technology Flourishes in Society

What are NICT's "Public Services"?

——What are NICT's "public services"?

YASUI NICT is Japan's only public research institution that specializes in the field of information and communications technology, and provides some of its research results as services that support social infrastructure. Those are NICT's "public services."

One of the most representative examples is Japan Standard Time (JST). Radio controlled clocks that employ radio waves to set the time are widely used in social activities and daily life, and it is NICT that generates the basic time for such radio-controlled clocks.

——Is time something that can be generated?

YASUI Time in the past was determined by measuring the rotation and the orbital motion of the Earth. But with the development of science, technology, and business, more accurate time determination was demanded, and since 1967, the duration of the unit "second" has been defined based on cesium atomic clocks, and NICT began operating cesium atomic clocks as well. Currently, NICT has 18 cesium atomic clocks that generate time with high accuracy to within 1 second over 20 million years. The generated time is transmitted on low-frequency radio waves from two Low Frequency Standard Time and Frequency Transmission Stations in Japan (*Ohtakadoya-yama* in Fukushima Prefecture and *Hagane-yama* located at the border between Fukuoka and Saga prefectures). In addition, there are two other ways to transmit Japan Standard Time: Hikari Telephone JJY, which uses fiber optic lines to distribute time, and the NTP server, which adjusts Internet time; thus, there are three ways in total to transmit JST without a break. Although atomic clocks are extremely accurate, there are slight variations in accuracy from one individual clock to another. For this reason, we not only compare and calibrate the atomic clocks owned by NICT but also those owned by overseas institutions to generate more accurate time.

Japan Standard Time generated by NICT contributes greatly to today's social infrastructure, as it is used in radio-controlled clocks, daily TV and radio time signals, and even in sharing accurate time when communicating with smartphones and other devices. Furthermore, research on the optical lattice clock, which is expected to change the definition of the second in the future, is also underway at NICT. If this clock is put into practical use, we can aim for a world in which time is determined with ultra-high accuracy of within one second over 30 billion years.

——I see NICT's "public services" are contributing to the familiar daily lives of the public.

YASUI Speaking of the familiar daily lives of the public, the same is true of smartphones. NICT's technology is the reason why mobile communication and Wi-Fi signals are stable and of high quality. For example, there is a "Technical Standards Conformity Certification" system for wireless equipment. Since wireless equipment with this certification mark means that it has passed a highly reliable inspection using highly accurate and calibrated measuring instruments tied to NICT's standards, it will not interfere with communication with other wireless equipment. Technical Standards Conformity Certification was established in 1981, and right about that time, radio waves began to be used for various purposes. Now, various wireless services are widespread, but wireless devices can be used with ease because of the calibration technology that guarantees Technical Standards Conformity Certification.

When the Beyond 5G/6G era arrives in the future, radio waves in the terahertz band, which are even higher than the frequencies currently used, will be used for communication. Even in such an era, with Technical Standards Conformity Certification based on solid calibration technology, we can use communication devices with ease.

The Importance of Space Weather Forecasting

——I think the electromagnetic environment in space also has a great impact on

Interview

Technology Flourishes in Society
What are NICT's "Public Services"?

the stability and maintenance of social infrastructure.

YASUI One of NICT's "public services" is "space weather forecasting operations." This service analyzes the state of the sun and constantly-observed data on the state of the ionosphere and magnetosphere in space around the Earth to determine whether anomalies such as geomagnetic storms are occurring, and also performs forecast simulations and announces them as weather forecasts.

NICT has been observing the ionosphere since the days of its predecessor, the Electrotechnical Laboratory of the Ministry of Communications (founded in 1891). This is because radio communication at that time, which had just started (Japan's first radio communication experiment was conducted in 1885), was easily affected by ionospheric phenomena. At that time, the shortwave band was used for long-distance radio communications, and such communications were conducted by using the ionosphere (the ionized layer of the atmosphere caused by ultraviolet rays from the sun, etc.) located between 60 km and 800 km above the ground, which reflects radio waves.

However, when large-scale solar flares occurred, the electron density in the ionosphere increased and radio communications were disrupted, which was a serious problem at that time, as the ionosphere was used for important communications. It was therefore necessary to constantly observe changes in the state of the ionosphere.

The disruption of shortwave communications is not the only problem. Geomagnetic storms caused by solar activity threaten to disable our highly advanced information modern society all at once. Modern society is built on the support of huge electromagnetic networks, such as the Internet, and a large-scale geomagnetic storm could destroy power lines and communication networks.

A large-scale coronal mass ejection (a massive explosion) called the Carrington Event occurred at the end of the Edo period in 1859. The event was caused by a solar flare of a magnitude rarely seen in history and is said to have disrupted telegraph lines that were just opened at the time.

One recent example is the 40 Starlink satellites from the U.S. company SpaceX losing functionality due to a geomagnetic storm caused by a solar flare in 2022. In addition, solar flares can disturb the ionosphere and affect radio wave propagation, which in turn affects the positioning accuracy of satellite positioning systems such as GPS.

It is also important to detect disturbances in space as soon as possible in order to protect the crew of passenger aircraft flying at high altitudes from radiation exposure. Space weather forecasts published by NICT are provided to operators as aviation information through the International Civil Aviation Organization (ICAO).

Contributing to Cyber-physical Space

——Are satellites also affected? That is a serious problem.

YASUI It can be said that a modern society that relies on advanced information and communications technology is also a society that is vulnerable to electromagnetic interference. For this reason, EMC (Electromagnetic Compatibility) is internationally emphasized. EMC is the balancing act of ensuring that electromagnetic waves, when used, do not affect other equipment and that the equipment is resistant to being affected by other equipment.

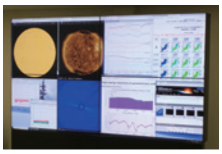
To this end, it is necessary to make standards that apply not only to Japan but also to the international community. NICT's researchers are taking the lead in participating in and contributing to the creation of international standards.

——Technology using electromagnetic waves has become one of the most important infrastructures for a state. I now understand NICT's high level contribution to the field.

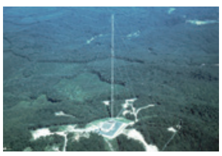
YASUI Today, cyberspace created on

History of NICT's public services

- 1949 ●Standard radio wave emissions start.
- 1952 ●Calibration operations start.
- 1972 ●New UTC (based on the 1967 "definition of the second") is adopted as the reference time for standard radio waves.
- 1988 ●Space weather forecasting operations start.



- 1995 ●Telephone JJY (time transmission via telephone lines) starts operation.
- 1999 ●Low-frequency standard radio wave operation (JJY 40 kHz: *Ohtakadoya-yama*) formally starts.



networks such as the Internet has become widespread, and information exchange and business are being conducted there just as in the real world. We have already entered an era in which various things are happening in cyber-physical space, where cyber space and physical space are fused and integrated. In a situation where society is built on such a system, for example, if a failure, accident, or incident occurs in cyberspace, it will have a tremendous impact on and damage the entire system connected to the physical space. In such a world, in addition to security within the physical space, security within cyberspace, or cybersecurity, has become extremely important.

NICT has a long history of research in cybersecurity technology, the results of which are utilized in the "public services" of developing and discovering security human resources. For example, there is a program called the CYDER exercise, a practical cyber defense exercise for local governments nationwide. This is an exercise designed to develop defensive skills against cyber attacks. The SecHack365 program, which targets young people under the age of 25, seeks to discover and develop security innovators—individuals who bring new ideas to cybersecurity issues. Through these efforts, NICT helps people who make up society in various settings acquire cybersecurity skills, thereby making practical contributions toward the maintenance and development of a stable society based on a sound cyber-physical space.

These are the public services implemented by NICT as specified in the Act on the National Institute of Information and Communications Technology, Independent Administrative Agency. In addition to these public services, we have recently been implementing a program for discovering and developing human resources who will pioneer cutting-edge technologies and support the country's future in the field of quantum technology, where international competition is heating up and there is a serious shortage of human resources. The program is called the “Quantum ICT Human Resources Development Program NICT Quantum Camp (NQC).” Its objective is to develop researchers in new quantum technologies that will become mainstream in the future, such as quantum communication, quantum computation, and quantum sensing.

Transcending the “Limits of Knowledge”

——I now understand that the results of years of NICT’s research are applied to society through its public services.

YASUI NICT conducts research and development, from the most advanced and profound basic research to applied research and social implementation, from a long-term point of view. Furthermore, even in the middle of our research, if we find any technology or idea that can be useful in the real world, we will try to make use of it as much as possible.

It is difficult to systematically proceed with everything looking 20 or 30 years ahead, but as we constantly pioneer new concepts and functions and advance research and development, various applied technologies have been created, and these have revolutionized society, which defines the general course of history. Thirty years ago, it would have been unimaginable to think of a world in which social networking services (SNS) are as widespread as they are today.

NICT is pursuing a variety of research and development areas to pioneer future possibilities. It is exciting to imagine a future in which various studies for the Beyond5G/6G era, as well as brain information and neural networks for even further in the future, create new technologies that are also utilized in a variety of services.

From pioneering cutting-edge science and technology to public services, NICT is committed to opening up the future by seamlessly and dynamically interlocking various activities.

The technological foundations of the future do not come out of nowhere. Nor is there an end goal. Things are constantly moving forward, but technology is also advancing in parallel. Or major technological innovations can change the flow, nature, and values of things. In such a process, NICT creates usable and necessary technologies and provides them as "public services" that support social infrastructure so that they will be widely used by the public. That can be called NICT's “public services.”

NICT's recently released brand statement, "Transcending the Limits of Knowledge, Establishing Social Infrastructure of the Future," expresses this situation well.

I believe that technology is constantly renewing old knowledge into new “knowledge.”

——I see that NICT will continue to advance by transcending the "Limits of Knowledge.” Thank you very much for your time today.

● Low-frequency standard radio wave operation (JJY 60 kHz: *Hagane-yama*) formally starts.

● Time provision via NTP and dissemination service for time business starts.

SecHack365

● Sec-Hack365 starts.

NQC
NICT Quantum Camp

● NICT Quantum Camp (NQC) starts.

2001 2003 2005 2013 2017 2018 2019 2020 ・・・・・・・・・ 2023

CYDER
Cyber Defense Exercise with Recurrence

● CYDER starts.

● Jcss frequency calibration starts.

● Hikari Telephone JJY operation (time provision via fiber optic telephone lines) starts.

● Space weather information provision to the International Civil Aviation Organization (ICAO) starts.

● Kobe Substation operation starts as the main JST station.

Japan Standard Time

Making accurate time usable as a matter of course

MATSUBARA Kensuke

Research Manager, Group Leader, Japan Standard Time Service Group, Space-Time Standards Laboratory, Electromagnetic Standards Research Center, Radio Research Institute

After completing graduate school, he joined the Communications Research Laboratory (CRL, currently NICT) in 2001. Engaged in research on ion optical clocks, high-precision frequency provision by standard radio waves and operation of Japan Standard Time, etc. Ph.D. (Science)

Few people nowadays are likely to wake up in the morning and be completely unaware of the time or hour throughout the entire day. Standard time, which was created to share with others the time that is closely associated with human life, is said to have its historical origins in the development of long-distance railroads in the 19th century. Now that people and information come and go globally, standard time is also maintained through global international cooperation. NICT contributes to this effort and is working to make accurate time and frequency usable in Japan as a matter of course, and is preparing for the future.

Japan Standard Time Closely Related to our Daily Lives

The public most closely relates to NICT-determined Japan Standard Time (JST) by the time adjustment of radio-controlled clocks using low-frequency standard radio waves for time and frequency (JJY). “Ohtakadoya-yama LF Standard Time and Frequency Transmission Station” opened in June 1999, and “Hagane-yama LF Standard Time and Frequency Transmission Station” in October 2001. Both stations have a transmitter with an output of 50 kW to emit standard radio waves, enabling radio-controlled clocks available throughout Japan to not deviate from JST by a single second. Their recent operations have been reported in magazines, etc.[*1].

One way to more reliably set the time to JST without relying on radio wave propagation is to use Telephone JJY, which is a system that uses the public telephone line. Since 1995, the system has been operated and then used by NTT's time signal device and numerous broadcasters, etc., with more than 150,000 accesses per month in 2019. In that same year, the higher-precision Hikari Telephone JJY which uses an optical telephone line started, and users migrated to the new system, bringing the number of Hikari Telephone JJY accesses to more than 200,000 for the month of August 2023. The Telephone JJY from 1995 will cease operation at the end of March 2024.

Other time dissemination services include NTP (Network Time Protocol) and time dissemination for time business operators. NICT's public NTP is available to everyone and is accessed over 10 billion times daily. In addition, NICT is promoting redundancy and decentralization of the NTP servers for more stable operation in the future. For time stamping authentication using dissemination service for time business, a certification system by the Ministry of Internal Affairs and Communications started in April 2021, where NICT is designated as the sole reference for standard time. Figure 1 shows an overview of these Japan Standard Time operations. NICT will continue its efforts to maintain secure and reliable Japanese Standard Time services.

History of Japan Standard Time

NICT, including its predecessor organization, has long been involved in the generation of standard time and the development of frequency standards[*2]. Figure 2 shows an abridged chronological table. Two years after the International Meridian Conference, the standard time system of Japan based on the meridian line at 135 degrees east longitude started in 1886 in accordance with Imperial Edict No. 51. Since around that time, the Ministry of Communications (now the Ministry

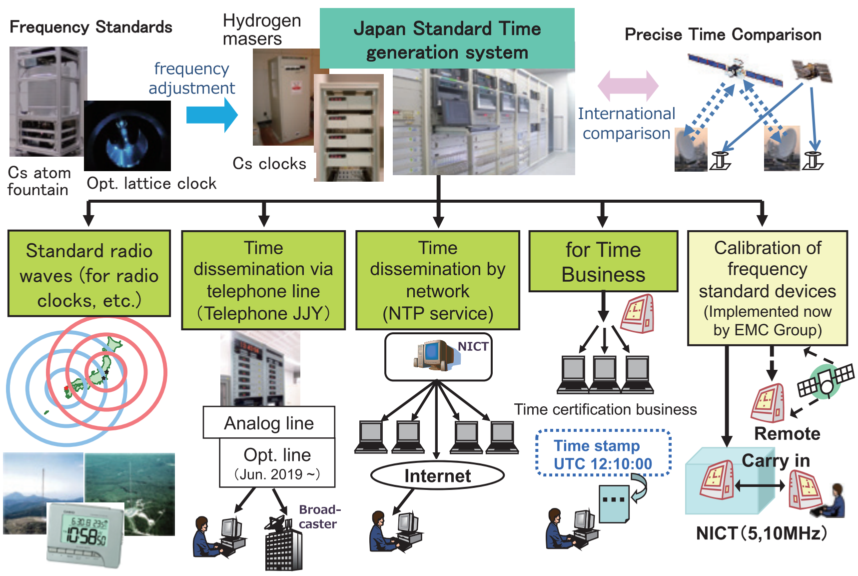


Figure 1 Outline of Japan Standard Time operations

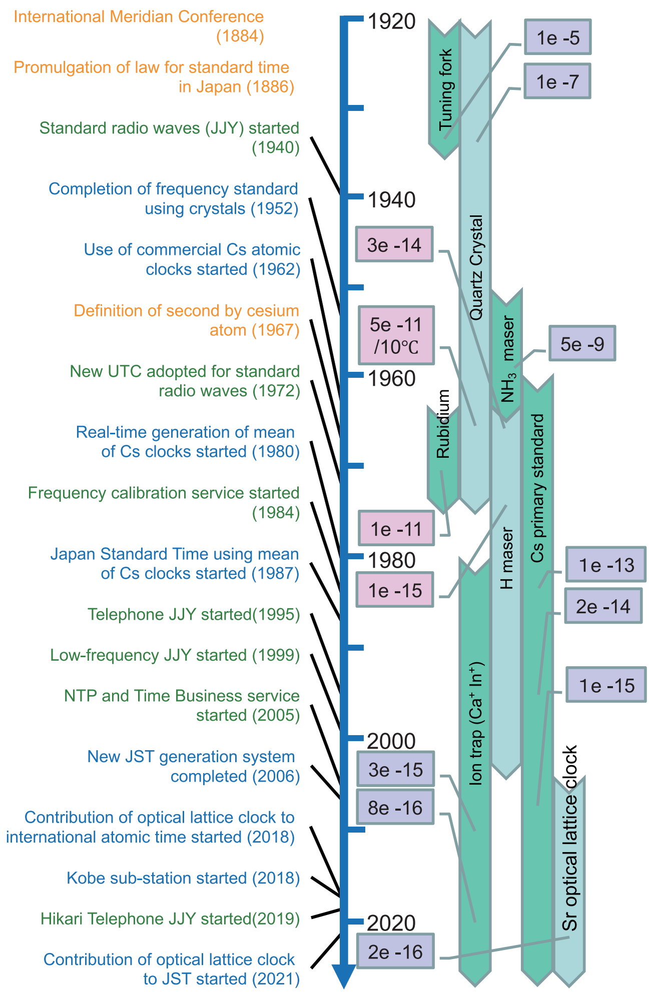


Figure 2 Abridged chronological table of NICT's Standard Time operations and frequency standard development.[*2]

Left: Orange indicates institutions, green indicates JST provision, and blue indicates the history of JST initiatives.

Right: History of frequency standards developed by NICT (including its predecessor) (Purple indicates the accuracy achieved in that period, and pink indicates the stability).

of Internal Affairs and Communications) has been responsible for disseminating standard time.

In 1940, the Ministry of Communications began to transmit high-precision standard frequencies in the shortwave band in accordance with the ministry's Public Notice No. 1, and in 1948, the role of time disseminating was added to standard radio waves with the successful test of superposing minute and second time signals.

With the growing importance of standard radio waves, setting of the frequency standard value, transmission of standard radio waves, and disseminating of standard time came under the responsibility of the Ministry of Telecommunications, which was established in 1949. These responsibilities have been carried over into the content of the current Act for Establishment of the Ministry of Internal Affairs and Communications and the Act on the National Institute of Information and Communications Technology, National Research and Development Agency. In 1952, the Radio Research Laboratory of the Ministry of Posts and Telecommunications was established, where frequency standard equipment using quartz crystals, various atoms, etc. was developed and the operation of standard time was conducted. In 1967, at the 13th Conférence générale des poids et mesures (CGPM), "second," one of the International Standards of Units (SI), was redefined from the previous astronomical definition to one using cesium atom, and in 1970, at the 12th Comité consultatif international pour la radio, a new Coordinated Universal Time (UTC) based on the new definition of second was recommended for adoption. As a result, in 1972, the Communications Research Laboratory at that time changed the base for JST from the previous astronomical time scale (called UT2) to UTC, which is still in use today, and advanced it by 9 hours to be disseminated by standard radio waves.

In 1972, JST was generated using the time of a single high-performance cesium atomic clock, but in 1987, accuracy was improved by using the weighted average time of multiple atomic clocks. In 2006, further improvement was made by using a hydrogen maser as the signal source, which has excellent short-term frequency stability, completing a system almost the same as the one that currently generates JST. Currently, as an emergency backup for JST generation at NICT headquarters, a time generation system using a total of approximately 30 atomic clocks distributed to NICT headquarters, the Advanced ICT Research Institute (Kobe substation), and two LF Standard Time and Frequency Transmission Stations is in operation at the Kobe substation.

Japan Standard Time Aiming for Higher Accuracy

Currently, "second" is defined as about 9.2 billion oscillations within a cesium atom (a frequency of about 9.2 GHz). On the other hand, it is envisioned that the "second will be redefined" around 2030 using frequencies in the optical bandwidth of several hundred THz. Therefore, NICT began contributing to national standard time with a "strontium optical lattice clock" in August 2021, the first in the world[*3]. Here, one second of conventional JST, determined mainly by cesium atomic clocks, is periodically corrected by an optical lattice clock to reduce the deviation from UTC. As a result, the deviation of UTC (NICT) (the time 9 hours back from JST generated by NICT) from UTC has been reduced to less than 5 nanoseconds, which is about 1/4 of the previous time. Currently, NICT is attempting to generate JST with even higher accuracy by using hydrogen masers, whose accuracy has been improved by adjustment with an optical lattice clock, in addition to cesium clocks. Atomic clocks, including an optical lattice clock operated by NICT, are currently used directly for UTC determination made at the Bureau International des Poids et Mesures (BIPM). These achievements have made NICT one of the key players in the Asia-Pacific region in the international approval system for the calibration of frequency standards, contributing greatly to the facilitation of imports and exports of measuring instruments, etc.

Prospects for the Future

In preparation for the "second" to be redefined around 2030, improvements will be needed to generate and provide Japanese Standard Time by making the best use of the accuracy of the redefinition. At the same time, NICT is considering to provide JST according to the accuracy required for each communication and communication speed obtained in next generation wireless communication, with the aim of improving the value of use. The operation of JST is also reported on the Web site (https://www.nict.go.jp/sts/index.html).

＊1 CQ ham radio March 2023 issue pp.35-41, NICT News 2023 no.2 pp.10-11, NICT News 2022 no.4 p.12.

＊2 History of standard radio waves, frequency standards, and standard time. https://jjy.nict.go.jp/QandA/reference/chrono_table.html Journal of the Communications Research Laboratory vol. 49 nos. ½ 2003, pp.25-pp.32

＊3 NICT Press Release, "The World's First Use of an Optical Lattice Clock to Keep National Standard Time." https://www.nict.go.jp/press/2022/06/09-1.html

Space Weather Forecast

For safe social infrastructure and prosperous life

KUBO Yûki

Space Weather Forecast Service Group, Space Environment Laboratory, Radio Propagation Research Center, Radio Research Institute

Dr. KUBO joined Communications Research Laboratory (current NICT) in 1998 after receiving a degree of MSc in astronomy.
He has worked for a research on space weather forecasting such as a solar radio observation and cosmic rays, and has also managed space weather forecast operation. Ph.D

SAKAGUCHI Kaori (left)

Research Manager, Space Environment Laboratory, Radio Propagation Research Center, Radio Research Institute

After completing her doctoral program, Dr. SAKAGUCHI obtained a research fellowship for young scientists from Japan Society for the Promotion of Science, then joined NICT in 2010. She has been engaging in research on space weather, such as the forecast of the aurora and radiation belts. She currently developing measurement tools for space environment to be installed in Hiwawari 10. Ph.D. (Science)

NISHIOKA Michi (right)

Senior Researcher, Space Environment Laboratory, Radio Propagation Research Center, Radio Research Institute

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

In recent years, we have increasingly been hearing in the media and other outlets about space weather, which is the interface between astronomy and/or geophysics and social life. As we strive to reduce the impact of solar activity and other changes in the space environment on social infrastructure to maintain its safety and realize innovations such as space travel that can create prosperity for future human societies, we are seeing a rapid increase in the demand for space weather forecasting.

Introduction

The National Institute of Information and Communications Technology (NICT) is the only public organization in Japan that provides space weather forecasting services. Since the early 1950s when NICT's predecessor, the Radio Research Laboratory under the Ministry of Posts and Telecommunications, was founded, the organization has been engaged in radio wave warning services to detect and provide users with advance alerts of shortwave communication interruptions. This service was renamed Space Weather Forecast in 1988 and now provides a wide variety of information including information on solar activity, geomagnetic disturbances, and ionospheric disturbances that can cause interruptions in shortwave communication and an increase in satellite positioning errors, as well as information on radiation belt electrons that can cause satellite disruptions and proton events that can affect the health of astronauts and aircrews from exposure to cosmic radiation in 24/7 (Figure 1).

Space Weather Disasters

In a nutshell, space weather refers to the impact of solar activity on the space environment around the Earth and on social infrastructure that we as Earth's inhabitants rely on.

While we may not have a clear image when they speak of the impacts of solar activity on our social infrastructure, there are a variety of different ways in which we are actually being impacted. For example, one of the most notorious cases of space weather disasters occurred in March 1989 in the vicinity of Quebec, Canada. A disturbance in the space environment caused by a large explosion on the solar surface (solar flare) caused excessive current to flow through the power grid on the ground, resulting in a disaster that caused substation failures and consequent power outages. Space weather is also known to have a significant impact on satellite operations and other activities. In July 2000, as a result of a solar flare-induced disturbance in the space environment, the Japanese scientific satellite ASCA lost control of its attitude, and hence lost its ability to generate electricity from its solar cells, eventually falling out of orbit.

As for the impact of space weather on satellite operations, the incident in February 2022 where around 40 Starlink communications satellites fell out of orbit due to disturbances in the space environment is still fresh in our collective memory.

As a recent example of impact on our wireless infrastructure, we can point to the solar flare on September 2017 that increased GPS positioning errors. During this event, GPS positioning accuracy deteriorated as a result of delays in radio wave propagation from GPS satellites that were caused by solar flare-induced disturbances in the space environment. This prompted the Geospatial Information Authority of Japan (under the Ministry of Land, Infrastructure, Transport and Tourism), which operates Japan's GPS receiver network, to issue a flash report stating, "With respect to the positioning system used by the general public, such as in car navigation systems and smartphones, there were times during the daytime on September 8 when users experienced significant deterioration in positioning accuracy." (https://www.gsi.go.jp/denshi/denshi40001.html). It was within this time window that super hurricane Irma hit coastal areas of the Caribbean Sea, and it is known that the solar flare caused a total loss of radio communications, which hampered hurricane rescue efforts.

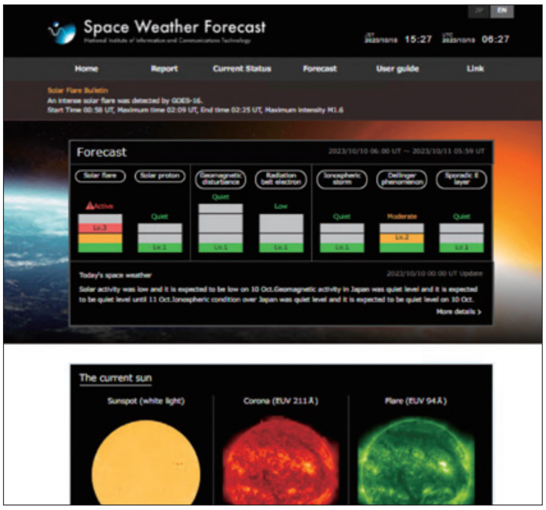


Figure 1　Space weather website（https://swc.nict.go.jp/en/）

Figure 2　Annex 3 to the convention on international civil aviation (left), and the space weather information manual (right)

Real-World Use of Space Weather Information

In the previous section, we gave examples of space weather disasters that have actually occurred in various areas of our lives. Aviation is an industry that has been quick to incorporate space weather information into real-world operations to reduce the impact of such space weather disasters. In fact, space weather information has already been in use for some time in commercial aircraft operations. The aviation industry recognizes the importance of the following three key aspects of space weather information in their commercial aircraft operations. The first is to avoid shortwave communication interference between aircraft and ground control, the second is to prevent increases in electronic navigation measurement errors in aircraft positions, and the third is to reduce aircrews' exposure to space radiation. The International Civil Aviation Organization (ICAO), a specialized agency of the United Nations, added “space weather information” in the amendment 78 (2018) of Annex 3 to the Convention on International Civil Aviation (commonly known as the Chicago Convention), which provides for "meteorological service for international air navigation." In response to this move, the use of space weather information in commercial aircraft operations began on November 7, 2019 (Figure 2).

Currently, four space weather centers appointed by ICAO (the United States, European Consortium, Australia-Canada-France-Japan Consortium, and China-Russia Consortium) take turns disseminating space weather information to various aviation-related organizations via weather information networks. NICT is part of the space weather center as a member of the Australia-Canada-France-Japan Consortium.

Figure 3　Solar radio telescope and ionospheric observation antenna installed at the Yamagawa Radio observation facility

Space Weather Forecasting Services

The most critical and indispensable aspect of space weather forecasting is the uninterrupted 24/7 monitoring and analysis of solar activity and the state of the space environment surrounding our planet.

At NICT, we conduct our own observations of solar radio waves, geomagnetic field, and the ionosphere (Figure 3), collect and analyze observational data from other domestic and overseas organizations, and distribute various space weather information 24 hours a day. While our space weather forecasts rely on a large amount of data from observations made overseas, some space weather phenomena are localized to regional domains. In order to provide highly accurate information on these phenomena, we need observational data not only from overseas but Japan's vicinity. To this end, NICT is developing systems that allow us to observe the space environment on our own by mounting space environment sensors on board the next-generation of meteorological satellites Himawari which will be parked in geostationary orbits over Japan.

Our space weather forecasting service includes twice-daily reports as well as special bulletins that are sent out when large-scale phenomena occur. This information is distributed via e-mail and websites (Figure 1) to a wide variety of users beyond the aviation industry, including the wireless communications, satellite positioning, satellite operations, and power industries, as well as the media. We also continue to exchange views with various users to be advanced in space weather forecasting and enable more user-friendly information distribution. NICT provides space weather forecasting services every day so that we are able to maintain the safety of our current social infrastructure and realize innovations such as space travel that can create prosperity for future social life.

Calibration Service

Calibration services for measuring instruments of radio equipment and frequency standards

SAKAI Kojiro

Research Engineer, Standard Calibration Group, Electromagnetic Compatibility Laboratory, Electromagnetic Standards Research Center, Radio Research Institute

He joined in NICT in 2014. He has been involved in calibration works on radio measuring instruments for high-frequency electric power and is currently the ISO/IEC17025-based technical supervisor for NICT's calibration services.

SUGIYAMA Tsutomu (left)

Senior Researcher, Standard Calibration Group,Electromagnetic Compatibility Laboratory, Electromagnetic Standards Research Center, Radio Research Institute

SEKIDO Mamoru (right)

Research Manager, Space-Time Standards Laboratory/ Standard Calibration Group, Electromagnetic Compatibility Laboratory, Electromagnetic Standards Research Center, Radio Research Institute

The Standards Calibration Group at NICT provides calibration services for instruments for radio equipment and frequency standards. "Calibration" is the process of determining the difference between the correct value (reference value) and measurements taken by a measuring instrument as the subject of calibration. Whereas "校正" (kosei) is the generally used term, the kanji (Chinese characters) used in the Radio Act are "較正" (kosei), which are phonetically pronounced the same. The original meaning of "較正" not only includes determination of the deviation from a reference value, but also adjustment of the instrument to output the correct value. However, this adjustment process is usually performed only by the manufacturer. Therefore, "較正" and "校正" practically refer to the same task, and since NICT is the top-level organization for calibration based on the Radio Act, we primarily use the kanji "較正."

NICT's Role under the Radio Act and Measurement Act

In principle, because radio frequencies are a finite resource, a radio station license is required to use (emit) radio waves used for cellular phones and TV broadcasting, etc. In order to obtain this license, inspections (checks) of radio equipment are performed under technical standards set forth in the Radio Act. In order to carry out fair inspections, correctly calibrated instruments for radio equipment are essential. As shown in Figure 1, the Radio Act stipulates that the measuring instruments used for inspections of radio equipment by registered inspectors shall be calibrated by NICT or a designated calibration agency. Furthermore, it is stipulated under the Ministry of Internal Affairs and Communications Ordinance that measuring instruments used by designated calibration agencies must be calibrated by NICT. In other words, the quality standards of radio waves at radio stations nationwide are tied to (traceable to) NICT's calibration operations, and the smartphones that we use also follow these quality standards. In addition, to support International Mutual Recognition (International MRA)* of the calibration of instruments for radio equipment, we perform JCSS calibration based on the Measurement Act which conforms with the international standard ISO/IEC17025. Also, NICT maintains the national measurement standard of UTC (NICT), which is synchronized with Coordinated Universal Time (UTC) as the world's common time system. And we provide accurate time and frequency as the Japan Standard Time nationwide. As illustrated in Figure 1, NICT is the primary calibration institute under the Measurement Act, and also we use these national frequency standards to perform calibration services for frequency standards.

Calibration Categories and Items

Calibration categories at NICT are grouped as shown in Table 1. We cover calibration for a wide range of items including frequency standards, frequency counters, RF (Radio Frequency) power meters, RF attenuators, standard voltage/current generators, volt ammeters, antennas, and specific absorption rate (SAR) measurement probes. In terms of frequencies, we support a wide range of calibrations covering frequencies from DC to 330 GHz, which are further subdivided according to the power and input impedance that is used.

Actions for Millimeter and Submillimeter Wave Band Frequencies

In recent years, the frequencies used for wireless applications have been expanding from the microwave band (3-30 GHz) to the millimeter wave band (30-300 GHz) and even to the submillimeter wave band (300 G-3 THz), and the uses of radio waves are no longer limited to communications and broadcasting but have diversified to include wireless power transmission and in-vehicle radar, resulting in rapidly growing markets. To support these new applications of radio waves and R&D such as Beyond 5G/6G, a new calibration procedure at frequencies above the millimeter wave band are needed. In particular, NICT provides calibration services at the frequency range of 110-330 GHz band, which is difficult for the private testing laboratory to implement it because of the problems of costs and technology, and is currently getting ready to additionally provide the services at the submillimeter wave band.

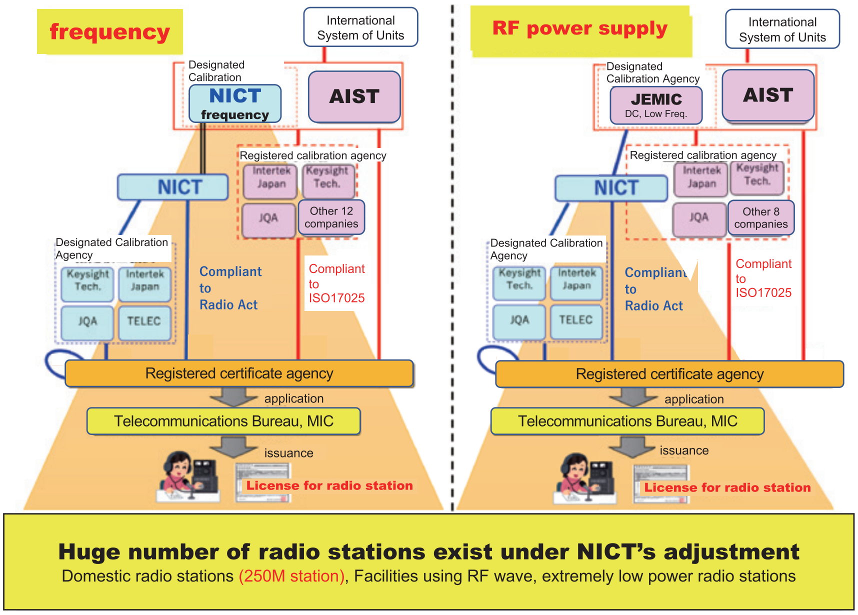


Figure 1 Organization of the National Calibration system

Table 1 List of NICT calibration services

Category of calibration services	Overview description
Calibration service for measuring instruments for the Registered Inspectors	Calibration services provided for "Registered Inspectors" as defined in the Radio Act, Article 24-2
Calibration service based on the Measurement Act (jcss)	Calibration of frequency standards provided to "JCSS registered operators (calibration service providers)" as stipulated in the Measurement Act, Article 143
Calibration service based on the Measurement Act (JCSS)	Calibration of RF power meters, etc., in accordance with the Measurement Act, Article 144 (International MRA compliant)
Calibration service based on the accreditation system of the National Institute of Technology and Evaluation (ASNITE)	Calibration of frequency standards (International MRA compliant) based on the accreditation system of the National Institute of Technology and Evaluation (NITE) (ASNITE)
Commissioned calibration	Calibration of measuring instruments and other equipment used for inspections, etc. of radio equipment (including RF use equipment) in accordance with the National Institute of Information and Communications Technology Act

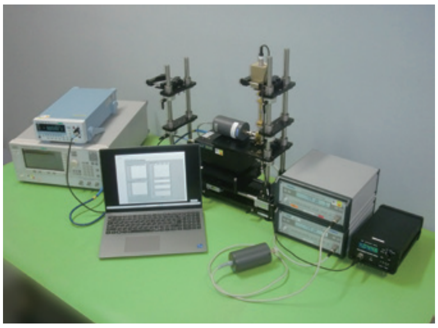


Figure 2 Millimeter-wave power meter calibration system

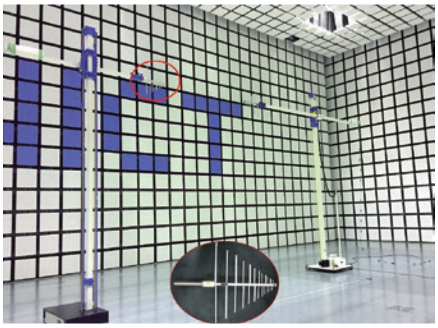


Figure 3 Calibration of log-periodic antennas in radio anechoic chamber

Figure 4 Measurement facility of local calibration service for frequency standards

Expansion of our Antenna Calibration Services

Radio waves radiated from radio equipment include desired signals and, spurious and unwanted emissions. Their acceptable intensity tolerances are respectively set by the Radio Act. In addition, electronic equipment may emit undesired radio waves (electromagnetic interference) that possibly affect other radio equipment, hence the International Special Committee on Radio Interference (CISPR) has established acceptable tolerances for such undesired radio emissions. To verify compliance with such standards, measurement by using properly calibrated antennas is needed. NICT has carried out calibration of loop antennas, dipole antennas, horn antennas, etc., and has obtained JCSS accreditation (International MRA compliant) for years. In addition, calibration of log-periodic antennas has been newly recognized by JCSS this year.

Calibration of Frequency Standards Based on National Frequency Standards

Frequency calibration services that issue calibration certificates include "local calibration" (Figure 4), where the frequency standard as subject to be calibrated is brought to NICT for direct comparison with UTC (NICT), and "remote calibration," where a frequency standard at a remote site is compared with UTC (NICT) via GPS satellite signals. The "local calibration" method has the benefit of a small uncertainty (5×10^{-14}), but its drawback is that the validity of measurements values are strictly limited to the time of calibration. An advantage of remote calibration is that comparative monitoring is possible at all times, although the degree of uncertainty will be somewhat larger (5×10^{-13}).

In recent years, NTP servers and sources of standard frequencies that are equipped with GNSS (Global Navigation Satellite System) receivers are commercially available. Although some of them provide time and frequency close to UTC, the signal provided by these devices are not always regarded as being traceable to UTC. The “traceability” requires an "unbroken chain of calibration" of evaluation and propagation of uncertainty from the primary standard. And the uncertainty and deviation of the output signal must be evaluated by a calibration laboratory. As the use of time and frequency sources that use the GNSS satellites is growing, there may be a need for public calibration services to ensure the traceability for such devices.

Summary

The NICT Standards Calibration Group will continue to be the basis of radio wave utilization through the calibration services of instruments of radio equipment and frequency standards for accurate measurement of radio waves, and will further support advancements in radio wave utilization toward the B5G era going forward. In the next fiscal year, we plan to launch a RF power verification service in the 330-500 GHz frequency band (Compliant with the Special case of a license for a specified experimental radio station).

* International Mutual Recognition Agreement (International MRA): An arrangement whereby multiple countries mutually recognize the equivalence of inspections and confirmations of compliance with technical requirements for the certification of equipment.

CYDER: CYber Defense Exercise with Recurrence

Cyber defense exercise for government agencies, local public institutions, etc.

Figure 1 Key members of the National Cyber Training Center's CYDER program operations

NAKAGAWA Tetsuya

Research Engineer, Cyber Training Laboratory National Cyber Training Center, Cybersecurity Research Institute

After graduated from graduate school, he worked for a big Japanese electric company as a researcher and a project manager. He joined NICT in 2018, been engaged in development of CYDERANGE (NICT cyber training platform) and in management of CYDER training.

The National Cyber Training Center implements the “CYDER” program, a practical cyber defense exercise that functions as a public service for human resource development. CYDER is an exercise mainly for IT system personnel who work at government agencies, independent administrative agencies, and local public institutions. Many such personnel who are on the front lines of ensuring the security of personal information, including the Individual Number, take the course every year on a continuing basis. Thus, the center is making a direct contribution to improving the capability to respond to security incidents in Japanese society as a whole.

Background

CYDER was launched in 2013 as a Ministry of Internal Affairs and Communications demonstration experiment, and the initiative was then transferred to NICT. It has been operated to date in 47 prefectures throughout Japan, approximately 100 times a year, with a capacity of more than 3,000 attendees, and the number of participants has reached a total of 20,000. In addition, by utilizing R&D outcomes of the independently developed exercise platform CYDERANGE, the center has been able to offer online exercises in addition to group exercises as an exercise method from FY2021.

Exercise Content of CYDER

"CYDER" is a practical cyber defense exercise that teaches how to respond in the event of a cyberattack. It offers an initial response exercise program that utilizes NICT's cybersecurity knowledge. The CYDER exercise provides a series of initial response steps to minimize damage in a role-play format. The center (Figure 1) is responsible not only for operation of the exercise itself, but for all of its aspects as well, including exercise scenario development, exercise platform development, and public awareness activities.

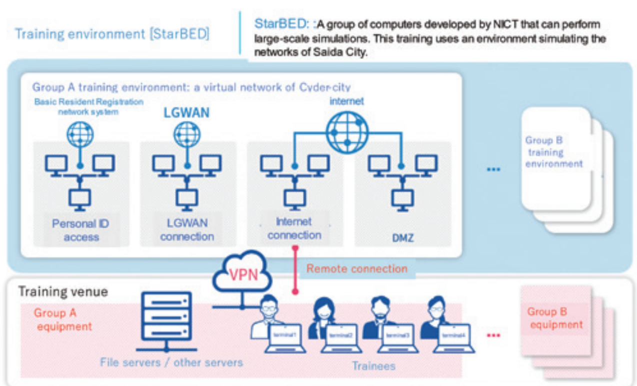


Figure 2 Training environment of CYDER（a network of virtual organization）

In CYDER's exercise system (Figure 2), a virtual environment optimized for each exercise cvourse is created, allowing trainees to experience practical responses through hands-on training using actual tools. The center also thoroughly analyzes the latest trends in real-life cyberattack cases and prepares up-to-date scenarios for each course. It is no longer possible to completely defend against increasingly sophisticated cyberattack methods year after year. Since being victimized by cyberattacks is inevitable, the center expects trainees to repeatedly attend CYDER to learn a series of response measures in order to minimize damage even in the event of the latest and varied attacks.

Future Prospects

For the time being, the center’s goal is to reduce to zero the number of local public institutions that have not yet taken CYDER, as they are the main target of this project. After conducting surveys on the reasons for not participating in CYDER, it was found that some personnel were unable to have sufficient time due to various concurrent duties required in a small municipality, while others missed the opportunity to attend CYDER's group exercises due to geographical and time factors.

For the former group, the center will offer an online exercise program that can be divided into fifteen-munitues sessions to allow participants to learn the minimum required measures to respond to a cyberattack incident. For the latter group, the center will utilize CYDERANGE, an exercise platform that allows hands-on training in an online environment, including log analysis using virtual machines, and will also plan to develop and provide an online exercise program that matches the effectiveness of group exercises.

The center will continue to develop exercise programs to respond to new social needs in which people can participate according to their convenience.

An introduction of Human Resource Development against Cybersecurity threats in SecHack365 at NICT

Nurturing security innovators

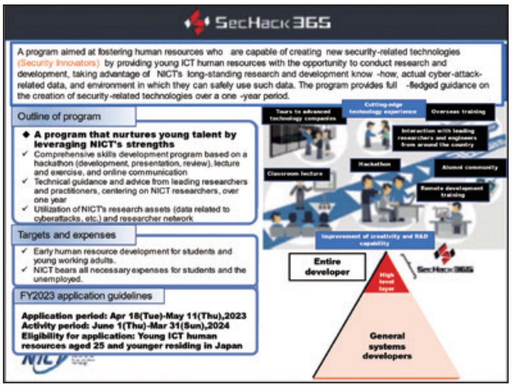
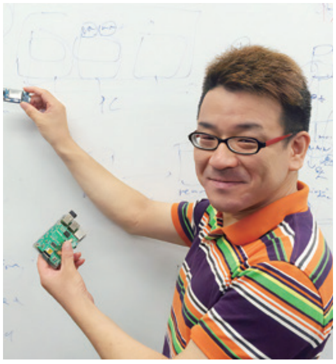


Figure 1 Overview of SecHack365



YOKOYAMA Teruaki

Senior Researcher, Cyber Training Laboratory, National Cyber-Training Center, Cybersecurity Research Institute/ Quantum ICT Collaboration Center

Working for SecHack365 program for cultivating young cybersecurity talent and NQC program for quantum ICT human resource development at NICT. Holds a Ph.D. in engineering. Participated in the IPA Mitou Youth Program. Specializes in internet technology, covering from foundational technologies to practical applications, and has conducted demonstrations, industry-academia collaborations, and educational activities. A member of the WIDE Project and the Cyber Kansai Project.

SecHack365[1] is a human resources development program for young talent aged 25 and younger, aimed at cultivating creative human resources who understand cybersecurity. The NICT Cyber Training Laboratory, National Cyber Training Center [2] has been offering and implementing the course since FY2017 (Figure 1). Those who can create unique technologies and works related to cybersecurity are named security innovators, and the center is working to produce human resources in many fields, including security research and development, general ICT research and development, and others.

SecHack365 Implementation Details

Each year about 40 participants are selected for a one-year security hackathon. Participants can freely decide their creation theme. Some may work on research and development of technologies that can solve security issues, while others may be interested in foundational ICT technologies and work on their reproduction as a white box, or anticipate security threats against various applied services and incorporate countermeasures into them. In all cases, security suggestions and innovations are essential.

Opportunities are provided for all members to gather together, such as at camp-style events or through online activities, bringing and sharing the results of their activities with each other, reviewing them, and communicating with each other. Collaborative creation is encouraged through guidance and advice from specialists in a variety of research and development fields, including researchers and practitioners both internal and external to NICT, as well as through discussions among participants. In order to deliver the newly learned technologies to society in a better form, enhancement of guidance on social implementation and ethics education are also emphasized.

Examples of SecHack365's Works

Many initiatives have been implemented in SecHack365. Some of the unique works are introduced below.

(1) SecHackFuzz, a fuzzing tool for web applications that fits in the development environment
(FY2021 by AKAMATSU Hiroki)

There is a random data entry tool for security verification called Fuzzing.He proposed Fuzzing for unconventional web applications by using genetic algorithms, a form that is easy to integrate into the web development process, to solve the problem of data bloat. He attained results that can be readily used by web application developers and implemented with a high degree of completeness [3].

(2) Security and privacy risk assessment of COVID-19 Contact-Confirming Application
(FY2020 NOMOTO Kazuki)

He focused on the neighborhood notification function of COCOA, the COVID-19 Contact-Confirming Application, and found a number of technical problems, including concerns about the possibility of identifying test-positive individuals by recording the notification signal and the possibility of attacking false close contact persons. He took preliminary measures including notifying the COCOA developer of these concerns, and presented the findings at an academic conference, which resulted in receiving an award; thus, his findings were beneficial to society [4].

Examples of initiatives other than those listed above are found on the SecHack365 Web page.

Future Prospects

During the six years of SecHack365 implementation, many talented individuals have launched into various fields. With the experience acquired through the repeated process of creation, presentation, and review in SecHack365, those people have started flourishing by using their ideas to get to the heart of various security challenges. I look forward to seeing the talent borne from SecHack365 continue to produce security-related deliverables for society in the future.

Reference

[1] Young Security Innovator Nourishing Program SecHack365 (in Japanese) https://sechack365.nict.go.jp/
[2] NICT National Cyber Training Center (in Japanese) https://nct.nict.go.jp/
[3] SecHack365 FY2021 List of works (in Japanese) https://sechack365.nict.go.jp/achievement/2021/index.html
[4] SecHack365 FY2020 List of works (in Japanese) https://sechack365.nict.go.jp/achievement/2020/index.html

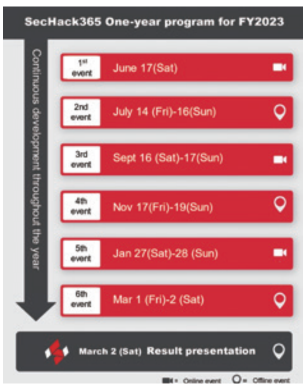
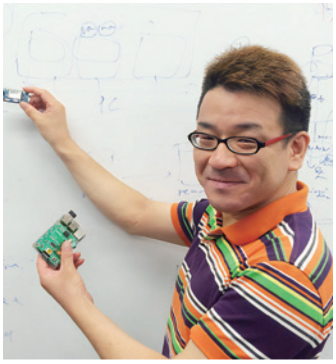


Figure 2 One-year program of SecHack365 for FY2023

An Introduction to NQC

Nurturing quantum ICT natives



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From the perspective of the feasibility of performance and functionality beyond legacy computers and communication technologies, there is great hope and interest in computers and communication technologies based on quantum technology. However, the field of quantum ICT requires a unique perspective on quantum mechanics along with an extremely broad range of knowledge, and there is a need to enhance human resources for the promotion of quantum ICT in Japan [1]. Under these circumstances, in FY2020, NICT started the NICT Quantum Camp (NQC), a human resource cultivation program to cultivate "quantum ICT natives" in order to foster human resources in the field of quantum ICT [2].

About NQC Program

In implementing NQC, we receive cooperation from NICT's quantum-related researchers as well as from leading researchers and practitioners in the field of quantum ICT in Japan. This includes holding lectures and other events [2]. Thanks to such cooperation, we conduct three programs according to the stage of understanding and interest, and the range of interest (Figure 1).

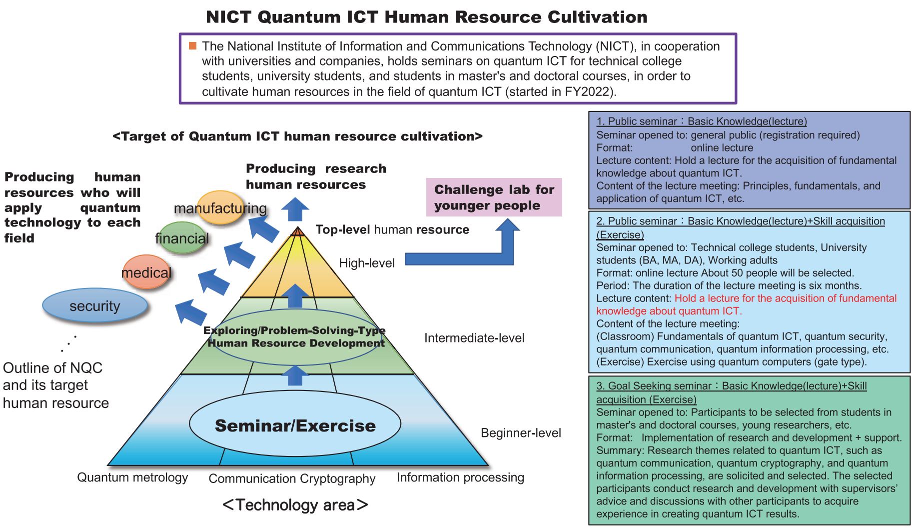


Figure 1 Overview of NQC program

1. Public seminars

Public seminars are online lecture meetings to acquire an overview of the quantum ICT field. Lecturers from academia and industry are invited to provide lectures that serve as a gateway to quantum ICT, including the principle of quantum computers, quantum computing algorithms, quantum communication, quantum cryptography, and the status of practical applications of quantum computers. The public seminars are open to anyone interested, and the program attracts wide participation from academia, industry, students and working adults.

2. Experience human resource cultivation

This is an online program that provides lectures and exercises related to quantum ICT to those who wish to learn in the field of quantum ICT (Figure 2). We select 50 diverse participants based on comprehensive judgments that not only include their prerequisite quantum knowledge but also their experience in other fields and motivation for the future. Six months of lecture attendance and online communication provide the forum for these human resources to come together and interact.

The lectures offer a wide range of content on quantum ICT according to the expertise of the NQC committee members. We offer lectures by people who are on the front lines, and interaction with questions and discussions. In addition to the lectures, the program includes quantum computer programming exercises using IBM Qiskit[3] to provide participants with the experience of implementing what they learned on simulators and the actual IBM Quantum system, as well as the experience of outputting through the creation of materials and presentations by selecting an arbitrary theme in the quantum field. In this way, the program offers participants a multifaceted quantum ICT learning experience.

3. Exploration human resource cultivation

"Exploration human resource cultivation" is a program that provides funding, introductions to experts, and other support for research and development in the quantum field.

FY2023 NQC experience human resources cultivation course

- The course is held online. (zoom employed)
  - Held on Saturdays: Lectures, discussions, assignments, work, etc.
  - Lectures can be recorded and viewed at a later date, and materials are provided in PDF format.
  - 50 participants, 20 instructors, 11 topics, total of 11 days, 40 hours
  - Only the initial orientation and one lecture are conducted in person.

Figure 2 Images of How the Experiential Program is Offered

Table1 Example of themes in seek type human resource development program

Theme of R&D	Student
Microwave sensing using RF dressed states of Nitrogen-Vacancy (NV) centers in Diamond	OKANIWA Ryusei
Post-quantum hash value generation method using quantum sequential processing	KOJIMA Sota
Simulability of sharp measurements and their physical realizability	KOBAYASHI Kodai, MINAGAWA Shintaro
The power of quantum proof in distributed verification	HASEGAWA Atsuya
Study of catalytic effects of quantum annealing considering problem individuality	HATTORI Tomohiro

Proposals are invited for specialized research and development themes, and up to five proposals are selected by NQC committee members based on the impact of the results and the appropriateness of goals and plans. We provide opportunities for discussion among participants, such as activity reports and information sharing meetings, which are connected to opportunities for learning, emergence, etc.

The contents of the reports are also shared with NQC committee members, researchers within NICT, and alumni, creating opportunities for referrals to experts, individual meetings, consultations and discussions. Through interim and final presentations, participants communicate their research and development to experts in the quantum field and publish their results. In this way, participants aim to achieve research and development results by delving deeply into specialized themes. Theses submitted by participants on the content of activities or the results of activities in NQC lead to subsequent careers such as going on to higher education or studying abroad.

NQC Community

Important goals in nurturing quantum ICT natives in NQC not only include knowledge transfer but creating human networks among instructors and participants as well. For instance, online chat is used for communication outside of lectures. This two-way communication style is also a unique feature of NQC, including lively question-and-answer sessions during lectures, and chat and free time for questions called “Birds of a Feather.” Over the course of the six-month period, voluntary activities such as online mutual teaching among participants, lecturing in turn, study sessions, etc. have emerged.

Alumni are also allowed to continue to use the chat for sharing and consulting about their career path and career status, communicating quantum-related internships and other programs, and sharing their recent activities at an alumni association, thus creating connections that go beyond academic years. In addition, alumni who have come forward to support NQC's activities have been assisting NQC as NQC supporters, providing operational cooperation and other support. NQC supporters are involved in teaching and operations, such as assisting with instruction, providing information, and offering study sessions and supplementary lectures. In this way, NQC supporters gain experience as future core human resources in the quantum field.

Future Prospects

We expect that NQC alumni will continue their relationship with the program to make NQC a hub of quantum ICT human resources in Japan. We have been informed that some alumni went on to higher education in the quantum field or changed careers to the quantum field as a result of their participation in NQC. We feel that NQC has contributed to producing excellent human resources in the field of quantum ICT. NICT has also started an activity called "Young Researchers Lab" at the Quantum ICT Collaboration Center for more specialized careers, and has established a system to be a part of human resource circulation by accepting research assistants, etc. [4].

We also aim to collaborate with other programs by introducing and disseminating the aforementioned programs, as well as publicizing recruitment information within NQC. We have so far invited various organizations to introduce their projects. This includes the MITOU Program of the Information-technology Promotion Agency (IPA), the INNO-vation Program of the Ministry of Internal Affairs and Communications, and corporate internships, which could be the next challenge for NQC participants. We also introduced the Moonshot Research and Development Program of the Cabinet Office and Q-STAR (Quantum STrategic industry Alliance for Revolution), which will be relevant to NQC participants’ future careers as social movements in industry and academia. NICT has also started closer collaborations, including NICT's consortium membership in the Quantum Academy of Science and Technology, a common core program of the Q-LEAP Program of the Ministry of Education, Culture, Sports, Science and Technology.

NQC will expand on the results of these human resource cultivation and collaboration efforts to contribute to the quantum field. We look forward to the participation of those interested in quantum ICT.

Reference

[1] Quantum Technology Innovation FINAL REPORT, Cabinet Office, Jan. 21, 2020 https://www8.cao.go.jp/cstp/tougosenryaku/ryoushisenryaku.pdf (in Japanese)
[2] NQC Official Website: https://nqc.nict.go.jp/ (in Japanese)
[3] IBM Qiskit: https://qiskit.org/
[4] NICT Quantum ICT Collaboration Center: https://www2.nict.go.jp/qictcc/en/index.html

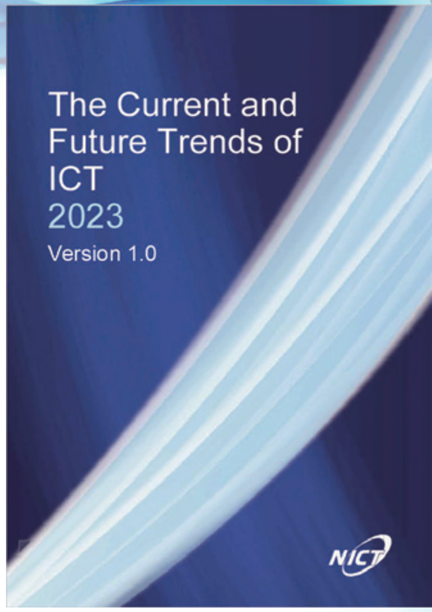
Publication of
"The Current and Future Trends of ICT 2023"

NICT has recently published the Current and Future Trends of ICT 2023, a report on current research and development trends and future prospects in the field of information and communications technology (ICT), which is expected to play a major role in realizing a prosperous future social infrastructure.

The report introduces eight major technological trends ("Foundational cross-cutting technology," "Utilization of electromagnetic waves," "Communication network infrastructure," "ICT device technology," "Cybersecurity," "Quantum ICT," "AI/Universal communication," and "Bio-ICT and brain science for ICT").
https://www2.nict.go.jp/idi/en/#ictrepo

The report consists of two chapters. Chapter 1 begins with an introduction, providing an overview of the global landscape surrounding the ICT field, outlining the latest trends in ICT in the U.S., Europe, and Asia. In Chapter 2, in each specific subfield within the ICT sector, the above notable eight areas of ICT are focused, and the latest research and development trends as well as future prospects are summarized.

We hope that the contents of this report will be utilized by policy makers in Japan' s information and communications, economy, administration, education, and ICT research communities to contribute to the development of ICT and the realization of a safe and secure Society 5.0.



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