Building a World Where Everyone Can Enjoy Abundance and Well-being through Innovative Social Infrastructure Technologies

The novel coronavirus pandemic (COVID-19) is changing the world dramatically, and the digital transformation (DX) of social infrastructure such as public services, broadcasting systems, and airports is quickly escalating. In recent years, natural disasters have become more serious and more frequent, driving the need for sensors to enable the provision of more appropriate warnings and directives. To achieve a continuously sustainable society, where current and future generations can enjoy abundance and well-being, NEC believes it is essential to establish DX and sensing technologies as well as to promote advancements in future-focused network and infrastructure technologies. This paper presents a broad view of NEC's wide-ranging research and development (R&D) into innovative social infrastructure technologies — which extend from the present to the future and from the bottom of the sea to the far reaches of space.

NAGANO Hiroyuki
Senior Vice President

1. Introduction

Society is like a living organism, which is constantly evolving and changing. Today, we are experiencing revolutionary changes that are creating the need for us to rebuild the social infrastructure that has supported our society. Based on NEC's R&D philosophy that society should be a place where all people can enjoy abundance and well-being, NEC is pushing forward with research and development in pursuit of solutions to not only the challenges we currently face, but also to those we will potentially face in the future. This special issue highlights NEC's various activities.

2. Technologies Supporting Digital Transformation in Social Systems

2.1 Digital transformation in public services

The digital transformation (DX) of the government is underway and has been quickly escalating in recent years. NEC believes that the key enabler is the set of agile government approaches that will enable the government to deliver solutions promptly without coding. In the framework developed by NEC, various basic services are offered as blocks which can be stacked and/or recombined as necessary to quickly respond to different social issues, allowing the government to quickly build an optimal service under the cloud environment.

Digital transformation of local governments is also important because it can significantly improve interfaces between citizens and public administrators. These contact points are often beset by lengthy procedures, time-consuming paperwork, and the use of handwritten signatures and stamps for verification. In Japan, this process has been customary for so long that it now represents an adherence to tradition rather than efficiency. Local governments now plan to reconstruct this process, and then all governmental information will become paperless and digitized. The digitization of information will dramatically increase its convenience and usability, while utilization of big data and artificial intelligence (AI) will almost certainly create new value. Deployment of these technologies will break through the logjam of bureaucracy and significantly improve the efficiency of local government operations and the convenience of

residential services.

Social changes are also significantly impacting educational areas. The digitization of education has been well underway for many years, but the COVID-19 pandemic has accelerated many of those trends, while also forcing children, teachers, and education service providers to shift to a new way of studying and teaching. As one of the learning modules in NEC's Smart Schools, the Collaborative Learning Support Solution supports remote online group activities such as active learning and promotes the enhancement of teacher-student interaction by analyzing and visualizing various behavioral characteristics such as oral communication between students and teachers. This will make it possible to customize learning solutions for each student.

2.2 Digital transformation in broadcasting systems

Video libraries are not only digitalized, but are also evolving into a service platform that realizes safe, secure digital video distribution with functions, such as quality check, preview, and online video transmission. NEC's Video Platform Service is expanding its applications from video management for improved operational efficiency within a business (inB) to creative business-to-business (B2B) video distribution.

Video's large data footprint makes data compression especially important in this field. Since the amount of video data that must be managed and distributed is expanding exponentially, the importance of the technology for video codecs continues to increase. NEC continues to tackle DX technologies in broadcasting systems, including making basic improvements.

2.3 Digital transformation at airports

2.3.1 DX technology for passengers using airports

Everyone who has traveled abroad knows that the customs area at airports is usually crowded and the lines move slowly. To solve this problem, NEC provides various airports in Japan with electronic declaration gates (e-Gates) at customs checkpoints. Using excellent space design and NEC's proprietary face recognition technology, which is ranked number one in the world[1)], the e-Gates facilitate safe, quick, and efficient customs procedures for visitors and returning residents to Japan.

Another problem that needs to be addressed is the inconvenience of boarding procedures. To help solve this, NEC's face recognition system called Face Express will be introduced at Narita Airport. After passengers have registered their faces at the Face Express kiosk, they can proceed to the baggage check-in area and then through the security checkpoint and boarding gate without having to show a boarding pass or passport. Instead, their faces will be scanned and used for identification. This system is ideally positioned to handle the imperatives of the new normal of living in a pandemic because of its contactless properties. NEC is now working to connect this system to peripheral systems and to other airports and to also deploy it at various airports around the world where it can help achieve convenient, contactless airport services that meet today's needs for safety and security.

As more and more people are vaccinated, the COVID-19 pandemic is expected to come to an end. Building on the concept of NEC I:Delight, NEC continues to provide more pleasant ways to cope with changes in the environment in Japan and around the world.

2.3.2 DX technology for air traffic control systems

The troubles of travelers do not end once they have passed through the gate and boarded the plane. They must then hope that their flight will depart on schedule and arrive safely at the destination airport without delay. NEC's technologies support on-time flight services that work behind the scenes and assure a smooth, trouble-free experience for passengers.

One of those technologies is a ground-based augmentation system (GBAS), which uses the global positioning system (GPS) to assist in the safe approach and landing of aircrafts. NEC developed Japan's first practical-use GBAS and supplied Tokyo Haneda Airport with it. GBAS makes possible more precise approach-and-landing support than conventional landing guidance systems. Thus, it can improve flight efficiency by shortening routes and increase the in-service rate by helping achieve safe landings even under adverse weather conditions.

The other technology is an air traffic control system. Safety and on-time service in air traffic are ensured by air traffic controllers. They instruct airplanes to keep intervals between airplanes to maintain safety. This requires a system able to provide them with a flight plan for each airplane and real-time position information. For more than half a century, NEC has been developing and supplying air traffic management systems to assure safer and more efficient air traffic management, minimizing delays and maximizing safety, while supporting the controllers with sophisticated, reliable technology.

3. Sensing Technologies That Support Social Systems

3.1 Invisible sensing

3.1.1 Monitoring of global environment and infrastructure

Sensing technologies play a critical role in the effort to protect people's life and property from natural disasters, which appear to be increasing in severity and frequency, and also help achieve the United Nations Sustainable Development Goals (SDGs). Sensing technologies facilitate global environment monitoring and make it possible to anticipate disasters, limit vulnerability, and increase the ability to respond to disasters when they occur. These technologies can also be used to keep an eye on physical infrastructure, watching for deterioration and alerting us to potential problems.

NEC owns a comprehensive suite of sensing technologies. These include satellite-based observation systems that can support the achievement of the SDGs. Use of the second-generation global imager (SGLI), the hyperspectral image suite (HISUI), the thermal and near-infrared sensor for carbon observation (TANSO), and other optical sensor technology incorporated in Earth observation satellites makes possible global observation of snow and ice, aerosols, ocean colors, and vegetation as well as greenhouse gases such as carbon dioxide and nitrogen, enabling more accurate climate change projection.

Similarly, spaceborne synthetic aperture radar (SAR) can measure ground surface displacement with high precision. Applying various analysis technologies to the SAR measurement data makes it possible to visualize the impact of shield construction and the deterioration of physical infrastructure, such as bridges, roads, and buildings. NEC has developed a SAR infrastructure monitoring service that uses these visualization technologies, contributing to a safer and more secure world.

Although the observation targets are on the ground, they can be observed using elementary cosmic particles called muons, which are part of the cosmic radiation that showers the planet. Muons have extremely high penetrability and make possible the use of muography, a type of non-destructive imaging that shows the inside of objects in much the same way as radiography does. NEC is now working on a muography system for geoscientific applications, including the monitoring of volcanos, tide levels, and soil moisture to estimate the potential danger of mudslides. This same technology can also be used to monitor industrial infrastructure such as blast furnaces, electric furnaces, power plants, etc.

3.1.2 Sensing technologies for defense applications

The Indo-Pacific region, to which Japan belongs, is one of the more tumultuous parts of the world and faces a variety of threats such as piracy, terrorism, and the proliferation of weapons of mass destruction. As a supplier of defense equipment, NEC has been supporting the mission of the Japan Self-Defense Forces to protect the life and property of Japanese citizens. This special issue introduces a variable depth sonar system and a ship-based tactical air navigation (TACAN) system, two advanced defense systems we supplied to the Japan Maritime Self-Defense Force (JMSDF).

The variable depth sonar is an acoustic sensor used to detect underwater threats such as submarines. Because light and radio waves have a short propagation distance underwater, acoustic waves are used instead. However, the nature of the medium varies considerably depending on conditions such as water temperature, salinity, the effect of currents such as the Kuroshiro Current, and pressure changes in depth direction. For this reason, the propagation path of sound waves fluctuates in complex ways. Under certain conditions, this can create a blind zone where it is impossible to detect a submarine. By adjusting the sensor depth in accord with the environment, the variable-depth sonar eliminates blind zone to ensure the detection of underwater threats to support the missions of the JMSDF, which protects the life and property of the citizenry.

The TACAN acts as a lighthouse for aircraft, providing range and bearing information. TACAN for ships serves as a beacon for shipboard helicopters. Because an omnidirectional beam is required, the antenna of a conventional ship-based TACAN system is usually installed at the top of a mast where an unobstructed view can be obtained. As threats become increasingly sophisticated, space at the topmost part of the mast is now needed for the installation of other devices able to detect those threats and improve JMSDF's defense capabilities. That's why NEC has developed the world's first TACAN antenna that can deliver omnidirectional services even when it is mounted on the middle of a mast. This assures aircraft safety while allowing a more robust response to other evolving threats and enables us to help the JMSDF with their missions.

3.1.3 Labor-saving technology to compensate for a declining workforce

The decrease in the labor force due to declining birthrates and aging populations is already a major social issue in Japan. Adapting to this requires increased in-

vestment in labor-saving technology. The railway industry, for example, is now shifting its inspection operations from a manual system to an automated track patrol support system that combines onboard cameras and AI to automatically detect and visualize any object that could potentially obstruct train services. We plan to convert the onboard track patrol support system to a cloud-based subscription service that will be easier to deploy and thereby attract business from more railway companies.

3.2 Detection and recognition sensing technology

3.2.1 Helping attain more efficient and sophisticated criminal investigations

Reducing crime is one of the surest ways to help make society safer and more secure. NEC has been working to improve the efficiency and sophistication of criminal investigations for many years. This special issue takes a look at some of those efforts. These include radio fingerprinting, which uses the characteristics of radio emitting devices such as smartphones to identify an individual, and biometrics, which identifies a person by specific physical features such as fingerprints, palm prints, or facial features.

Smartphones and other wireless devices are now ubiquitous. Almost everyone has one and most people carry it with them wherever they go. This makes wireless devices ideal for quick identification of individuals, because in most cases identifying the device identifies the individual. This makes it possible to track suspicious persons and sources of interfering waves. The radio identification system developed by NEC uses unique features extracted from the signal waveforms produced by the device itself to identify it. It cannot be fooled by counterfeit or randomized addresses and, because it applies only to data in the physical layer and not to actual communications, it provides a level of personal data protection that other systems do not. NEC continue to refine this technology to help make the world a safer and more secure place.

The AI technology known as deep learning has greatly increased in use in recent years and is now applied in ever more areas of modern life, propelling many of the innovative breakthroughs that are transforming the world we live in. One of these areas is the field of biometrics.

As the undisputed pioneer and still the world's top player in the field of fingerprint matching technology, NEC started researching and then developing technology for fingerprint matching more than forty years ago and has since developed and refined impressively sophisticated technologies based on minutia. While this remains our core technology for fingerprint matching, the advent of deep learning has massively impacted the field. We are currently engaged in applying deep learning to our matching systems to achieve higher speed and higher precision.

Face recognition is another area where new technology developed by NEC promises significant gains in speed and accuracy. In most cases, faces that need to be identified are recorded by security cameras. The quality and recognizability of the image can vary enormously, depending on the orientation of the face with respect to the camera and how well the face is illuminated. This can significantly affect the visibility and appearance of the faces in the images. After 3D face data has been preregistered, it can be reproduced under conditions that mimic those captured on video, making it easier for law enforcement agencies to identify faces more quickly and more accurately. This issue highlights NEC's high-speed, high-precision 3D facial measurement technology and describe how it can be used to match and identify faces regardless of the imaging conditions.

3.2.2 Security measures in public transportation systems and facilities

Against a background of increased terrorist threats and urban crimes such as homicides, enhanced security in public transportation systems and facilities where people gather in large numbers has become a matter of great importance. NEC is now researching and developing invisible sensing (IVS) technology that uses the permeability of radio waves to perform noncontact detection of dangerous articles concealed in bags or under clothing without actually having to stop and search people. NEC believes IVS technology is an effective tool that can be used to enhance security at facilities in urban areas because of its high throughput, user convenience, and ability to differentiate between specific dangerous articles and daily use articles. NEC will shortly start doing validation tests in actual environments with the goal of implementing this technology as soon as possible.

4. Leading-Edge Technology That Enhances Communications

4.1 Advanced technology that permeates society

4.1.1 Software-defined radio

Software-defined radio (SDR) refers to a radio that incorporates software or programmable hardware to handle various communications systems such as multi-mode, multi band and/or multi-function wireless commu-

nications without modifying the hardware. This special issue takes a look at a joint Japan-U.S. research project that seeks to achieve intercommunication between the SDRs of both countries. It also discusses the broadband multipurpose radio system NEC developed for the Japan Ground Self-Defense Force based on this research, from prototype phase to full rate production phase and furthermore a software program improvement project that makes the most of SDR characteristics. In the future, NEC will take advantage of SDR's flexibility and extensibility to support more reliable and more effective communications between government agencies and between nations.

4.1.2 Automation and labor-saving technology for satellite operation

NEC has been operating a small high-performance radar satellite known as ASNARO-2 since 2018. To maintain stable operation, we use GroundNEXTAR, our original ground system package. This issue introduces the features of the GroundNEXTAR and findings on the automation of the satellite operation and the labor-saving technology. It also discusses intention learning technology, which is an advanced type of machine learning that learns the decisions of experienced operators so that it can make appropriate decisions as necessary without human guidance and automate the satellite operation when selecting observation candidates. Through the automation of the satellite operation system and the acquisition of automation and labor-saving technology using AI, NEC will help solve social issues and support sustainable social values such as equality and efficiency.

4.1.3 Quantum cryptography — the next generation of light-based cryptographic technology

Quantum cryptography is a cryptographic technique that enables ultra-long-term protection of information with no risk of compromising the data even in the future. This technology is expected to be applied to critical backbone systems on a national level.

In quantum cryptography, a secret key is transmitted and shared in advance by quantum key distribution (QKD) and communication is encrypted by an algorithm called a one-time pad. The key information is placed on a photon, which is a type of light particle, and the keys are protected by their quantum mechanical properties.

NEC has developed a QKD system called BB84 that achieves the world's top key generation speed with wavelength multiplexing and ensures safety in system implementation. It is now conducting research into a new QKD technology called CV-QKD that makes it possible to share communications for key distribution in a single optical fiber cable and distribute keys via satellites.

4.1.4 Robotics technology that saves or eliminates labor in heavy work

Japan's demographic crisis, brought on by an aging population and declining birth rate, has led to severe labor shortages in many fields, particularly those where physically demanding work is involved. In this case, robotics is attracting notice as a technology that can effectively compensate for this labor shortage. In this special issue, we look at two of the robotics systems developed by NEC. One is a high-mobility powered exoskeleton that reduces the apparent weight load, while at the same time providing a high level of agility and usability on rough terrain. The other is a multipurpose autonomous driving robot that can operate on rough terrain without requiring advance map information. Both systems are now undergoing trials at the Japan's Acquisition, Technology and Logistics Agency. In this special issue, we will examine the configurations and main technologies of these systems and speculate on where these technologies may go in the future.

As Japan's birthrate continues to plunge and society grows ever older, fewer and fewer young, physically fit people are available to maintain operations in many industries. To counter this, robotics technology is expected to become increasingly prevalent in both defense and consumer sectors. At NEC, we are committed to continuing our efforts to support the evolution of society through the pursuit of robotics technology and the promotion of social solutions.

4.1.5 Development of an efficient wireless power transfer antenna for unmanned underwater equipment

Unmanned underwater equipment is increasingly being used to support research of marine resources and inspection of submarine production facilities. Continuous operation is limited, however, because batteries need to be replaced periodically by humans. To solve this problem, a wireless charging system — just like that used by a robot cleaner when it charges automatically after returning to its docking — is required. This technology has already been applied successfully to electric vehicles, but is more difficult to apply underwater due to current loss resulting from the vibrations of water molecules and by sodium (Na^+) and chloride (CI^-) ions. NEC has developed an underwater antenna with dielectric assist structure which has made possible a 50 W–class underwater wireless power transfer system with high efficiency and

high performance in terms of clearance between the transmitter and receiver antennas.

By improving power transmission efficiency for increased power and checking the resistance to partial discharge, we plan to achieve a kilowatt-class antenna. As applications for underwater wireless power feeds increase, we expect that the internet of things (IoT) will also expand underwater in the not so distant future.

4.2 Cutting-edge technology at work in space

4.2.1 Great achievement of Hayabusa2 asteroid explorer and NEC's technology

Departing Earth in December 2014, the asteroid explorer Hayabusa2 traveled to the asteroid Ryugu where it entered orbit in June 2018. From then until December 2019, the Hayabusa2 conducted various operations in the vicinity of the asteroid, deploying multiple exploration robots to the surface and making two landings itself on the asteroid. On December 6, 2020, Hayabusa2 delivered the samples collected on Ryugu to Earth with courage and hope, where people were suffering from the COVID-19 pandemic. We are sure that everyone was excited to see Hayabusa2's remarkable achievements and are still excited when they look back on them.

In addition to providing its proven technology, NEC was involved in many parts of the project from the design and management of the overall system to integration, testing, and operational support, helping lead the mission to success. This special issue introduces NEC's technologies that supported the great achievement of Hayabusa2 as well as the factors for its success within the context of system design and operation.

Having supported this six-year journey as it had with the first Hayabusa, Hayabusa2's ion engine system (IES) was once again brought into the limelight for its leading role in contributing to the mission's success. But that wasn't the end of the mission. Hayabusa2 is currently underway to a new destination. The IES that drives the spacecraft is a form of electrically powered spacecraft propulsion that has become the key to deep space exploration. This special issue describes how the IES works, how we developed it at NEC, how it performed on Hayabusa2, and also how we plan to improve its performance for Japan's deep space exploration technology demonstrator named Destiny^{+}.

One of the most amazing aspects of Hayabusa2's journey was its successful landing on Ryugu. Hayabusa2 touched down on the asteroid approximately 300 million km away from the Earth with a margin of error of approximately 1 m — a feat made possible by its autonomous navigation, guidance, and control system. This extraordinary performance was made possible by the dedication and commitment of the NEC team that developed this system, which performed at optimal levels throughout the mission despite the severe environmental conditions on the asteroid's surface and the extended delay time in communications. In this special issue, we take a closer look at the technology that made possible this remarkable breakthrough such as the target markers and laser altimeter that enabled the spacecraft to touch down with pinpoint precision. We also highlight the results of the mission itself.

The laser altimeter referenced earlier is called LIDAR, which stands for light detection and ranging. By projecting a laser beam at the surface of the asteroid and detecting the reflected light, LIDAR can measure the distance to the surface of the asteroid, providing support for the autonomous functions of the spacecraft and enabling successful operation without real-time control from Earth or support from satellite navigation systems such as GPS available on Earth. This time it also contributed to the determination of the touchdown location with LIDAR's state-of-the-art 3D modeling capability.

LIDAR also clarified the material structure of Ryugu thanks to its ability to detect the differences between varieties of rocks according to differences in reflectance when light bounces off of the rocks. This capability made it possible to learn what materials constitute Ryugu.

Finally, this special issue takes a retrospective look at the course of NEC's involvement in the Hayabusa2 project from the design and management of the overall system to actual operations as well as the role NEC played in the Hayabusa2 project and this issue also discusses operational scenarios and results in the vicinity of asteroid Ryugu as well as the factors that contributed to the success.

4.2.2 Optical inter-satellite communication technology achieves high-speed, high-volume data communications

NEC is aiming to achieve inter-satellite data communications with higher speed and higher volume than conventional communications by building an optical communications network between satellites to enable the utilization of satellite observation data with increased real-time performance. As a first step, NEC developed the laser utilizing communication system (LUCAS) which was carried on the Japanese data relay satellite (JDRS) launched on November 29, 2020. This successfully established optical links between the JDRS and an optical ground station 40,000 km away. Planning is now underway for an in-orbit validation of inter-satellite optical communications with the advanced land-observing sat-

ellite (ALOS-3) launched by the Japan Aerospace Exploration Agency (JAXA). We are also conducting R&D into developing a next-generation optical communications device with a compact and lightweight design and capable of high speeds for practical use.

4.2.3 High-power X-band transmitter for operation of deep space explorers

Under contract with JAXA, NEC delivered a 30 kW–class X-band solid state power amplifier (SSPA) to the Misasa Deep Space Station in Saku, Nagano prefecture, Japan. Klystrons were conventionally used for high-power X-band transmitters required for deep space explorer operations. NEC developed a 30 kW–class X-band SSPA, the world's first solid-state type, by multi-stage synthesis of power amplifier units using Japanese-made gallium nitride (GaN) elements. This high-power SSPA makes possible more stable operation than the klystron type. However, the klystron type remains superior in terms of size and power consumption, so we plan to continue our efforts to make the SSPA more compact and more energy efficient.

4.2.4 Development of the world's best performing thin membrane solar array paddle

Spacecraft solar cell systems are required to have a lightweight design and high power-to-weight ratio that can supply high power. NEC's extensive experience in solar cell production enabled us to come up with a new concept to reduce the weight. The thin membrane solar array paddle (TMSAP) that was developed in collaboration with JAXA achieves both flexibility and the world's highest power-to-weight ratio. NEC subsequently conducted a deployment demonstration and power generation experiment in orbit, confirming that the TMSAP operated as designed. The TMSAP is expected to play an active role in various space development projects such as deep space exploration and satellite constellations.

5. Conclusion

By working on innovations in social infrastructure that include the promotion of DX technologies and the development of cutting-edge sensing technology, NEC is actively striving to build a better future for everyone. NEC, however, is only one part of these massive projects. Social infrastructure involves the cooperation of the nation as a whole, its government, its businesses, and all the other organizations that compose it. Thus, NEC never forgets that it is only by collaborating with its stakeholders and by discussing and creating together that innovation in social infrastructure becomes a reality. Together with stakeholders, NEC aims to contribute to the achievement of a sustainable society in which current and future generations of people can enjoy the abundance and well-being it has to offer.

Reference

1) NEC Press Release: NEC Face Recognition Technology Ranks First in NIST Accuracy Testing, October 2019 https://www.nec.com/en/press/201910/global_20191003_01.html

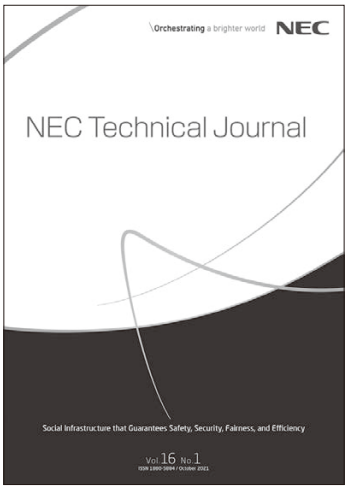
Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese English

Vol.16 No.1 Social Infrastructure that Guarantees Safety, Security, Fairness, and Efficiency



Vol.16 No.1
October 2021

Special Issue TOP

Papers for Special Issue

NEC Information