

Scientific and Technological Achievements Which Contribute to Daily Life

Part 2 reported measures taken during FY2017 to promote science and technology.

In this segment, we present scientific and technological achievements contributing to our daily lives.

Listed here are R&D achievements of national R&D agencies, and of companies collaborating with universities, governments, etc., which ministries and agencies selected as those that have contributed, or are expected to contribute in the near future, to our daily lives.

This year, the following ten topics were selected.

- ① Non-Destructive Observation Using Cosmic Rays and Terahertz Waves
- ② Development of Products That Fulfill the Needs in the Nursing Care Field
- ③ New Breed Improvement Techniques
- ④ Treating While Observing: A Nanodrug Delivery System
- ⑤ Infrastructure Development Using a Supercomputer and AI
- ⑥ Development and Recommendation of Shoes for Leading a Vibrant Life
- ⑦ Safer Security Technologies
- ⑧ Various Uses of Geological Information
- ⑨ Utilizing Ocean-Bottom Seismometer Networks for Railway Safety
- ⑩ For More Precise Definition of Units of Physical Quantities

The achievements described in this section are all built upon the legacy of science and technology from the past. For example, if we trace these achievements back to the 19th and 20th centuries, technologies explained in topics ① to ④ tap into the knowledge of the characteristics of radiation discovered in the late 19th century, such as radiation's ionization effects and penetrating power. Topics ⑤ to ⑦ are related to AI and other IT technologies. The science of electricity, which made a great progress in the late 19th century, provides a crucial foundation for IT technologies today. As for topic ⑧, Japan's first geological map was created in the late 19th century. The technology described in topic ⑨ uses optical fibers, which were actively studied in the late 20th century. Topic ⑩ heavily relies on the concepts of quantum physics, a field of science which made great progress in the 20th century.

Scientific and technological evolution is an accumulation of achievements from the past. Today's research may contribute to the lives of people living 100 or 200 years from now.

Scientific and Technological Achievements Which Contribute to Daily Life ①
(Non-Destructive Observation Technique Using Cosmic Rays and Terahertz Waves)

Non-Destructive Observation Using Cosmic Rays and Terahertz Waves

Universities and public agencies that participated in R&D

Nagoya University; Japan Science and Technology Agency (JST); National Institute of Information and Communications Technology (NICT)



Source: Nagoya University (the scan of the pyramid), NICT

Left: The Pyramid of Khufu in Egypt where an unknown enormous space was found inside. An imaginary picture indicating the position of the newly discovered space, created based on the observation data.

Right: The Badia Polyptych by Giotto (1300; housed in Uffizi Gallery, Florence, Italy). The results of non-destructive observations of the painting using terahertz waves. The cross-section revealed that the painting was created using the medieval techniques.

- Nagoya University developed a muon radiography technique to create three dimensional images of the inside of objects using muons, which constantly pass through our bodies (muons are generated by cosmic rays in the atmosphere), by using nuclear emulsion plates as detectors (see ① below).
- In 2017, Nagoya University used this technique in its study on the Pyramid of Khufu in Egypt and discovered an unknown enormous space in the middle of the pyramid. This technology can also be used for inspections of large-scale social infrastructure.
- In 2009, the National Institute of Information and Communications Technology (NICT) revealed the painting technique of Early Renaissance art using the terahertz technology for the first time in the world (see ② below). This technology enabled the non-destructive steric observation of the inner structure of the art piece, including its plaster base, which could not have been achieved with conventional radiography techniques using x-rays, etc.
- The above non-destructive radiographic techniques contribute to gaining a deeper understanding of human culture and history.

Detailed information on research results

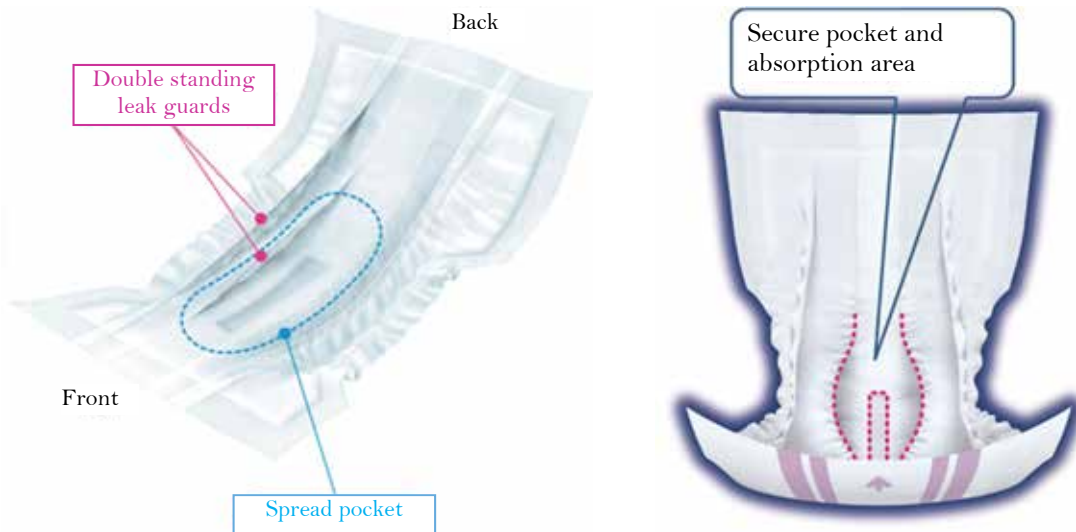
- ① Muon radiography technique: Nagoya University developed this technique as part of the JST-SENTAN Program from 2011 to 2015. The density distribution inside the subject structure can be determined by measuring the distribution of muons which have penetrated the subject structure. One muon penetrates our palm every second.
- ② Early Renaissance painting: Terahertz waves refer to electromagnetic waves of frequencies roughly from 0.1 to 10 terahertz. It was revealed that the painting studied in this project was created during the dawn of the Renaissance; it used the medieval technique using two plaster base layers (a technique that was used back in the days when paintings were mainly used as ornaments of alters), while the painting itself featured realistic depiction of humans, which is one of the major characteristics of Renaissance art.

Scientific and Technological Achievements Which Contribute to Daily Life ②
(Academia-Industry Research Projects to Fulfill the Needs in the Nursing Care Field)

Development of Products That Fulfill the Needs in the Nursing Care Field

Universities and public agencies
that participated in R&D

Tottori University; Daio Paper
Corporation; K.K. Nishiura



Source: Daio Paper Corporation

Left: Diaper with double leak guards and a spread pocket

Right: Diaper with a secure pocket and an absorption area

- In the nursing care field, diaper leaks from the front and the sides, which occur particularly frequently with male users, have been a troubling issue. Leaks tend to occur during the night because of the unique way that the male genital moves as the body rolls over while asleep. This issue has been tough to deal with for both care workers and care receivers.
- In 2010, Tottori University, Daio Paper Corporation, and K.K. Nishiura started to work on the development of disposable diapers to solve this issue. They found out that the cause of diaper leaks was the male genital inhibiting the spread of urine, just like a dam. This phenomenon was also confirmed with X-ray CT scanning. In 2014, they released a disposable diaper that helps the quick spread of urine (see ① below).
- In addition, they also conducted a joint R&D project to produce a diaper that securely contains the genital in the inner leak guards and the pocket. The product was released in 2016 (see ② below).
- These R&D efforts to fulfill the needs in the nursing care field have contributed to the challenges of the changing society.

Detailed information on research results

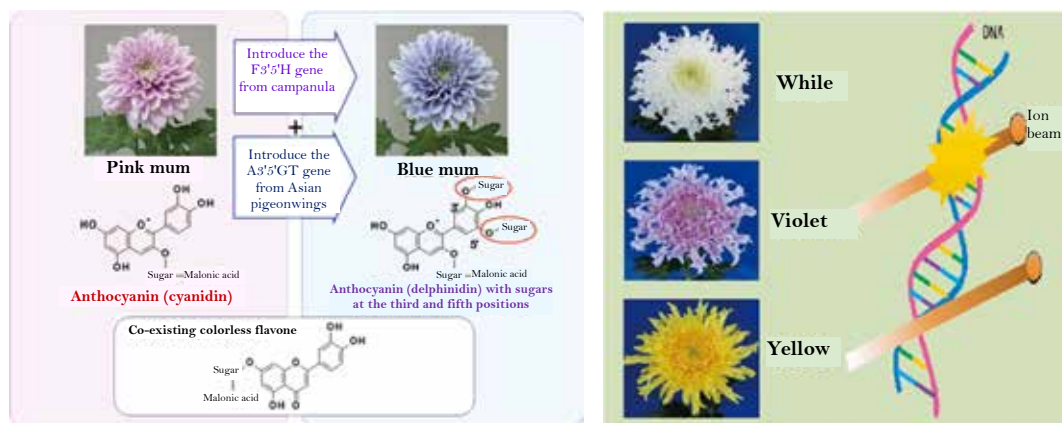
- ① Disposable diaper with double leak guards and a spread pocket: In 2010, Tottori University, Daio Paper Corporation, nurses with expertise in nursing care, and nursing supplies distributor K.K. Nishiura started to work on the development of this diaper based on the needs in the nursing care field. The effectiveness of this product was also verified quantitatively. In this project, they also conducted the world's first demonstrative experiment regarding the spread of urine using X-ray CT scanning.
- ② Disposable diaper with a secure pocket and an absorption area: This diaper was jointly developed by Tottori University, Daio Paper Corporation, and K.K. Nishiura. The product was released in 2016.

Scientific and Technological Achievements Which Contribute to Daily Life ③
 (New Breed Improvement Techniques)

 Universities and public agencies
 that participated in R&D

National Agriculture and Food Research Organization (NARO); National Institutes for Quantum and Radiological Science and Technology (QST); Tokyo University of Science; Aichi Prefecture; Suntory Global Innovation Center Limited

New Breed Improvement Techniques



- A blue color is expressed because of the mutual interaction of anthocyanins modified with two introduced genes and mums' inherent colorless materials (flavones). (Left) (Source: NARO)
- Varieties of wagiku with rare petal shapes developed by Aichi Prefecture and the QST (photos on the right; taken from the press release of the Aichi Agricultural Research Center and the QST dated November 24, 2017). Ion beams were used to artificially induce mutations (right figure).

- Since the discovery of Mendel's law in the 19th century, breed improvement has been conducted by inbreeding or crossbreeding plants with superior traits and growing mutant plants with advantageous traits.
- In 2017, NARO and Suntory Global Innovation Center Limited succeeded in producing a blue chrysanthemum: which had been difficult to produce with conventional variety improvement techniques, by introducing pigment biosynthesis genes using genetic engineering techniques (see ① below).
- QST developed a breeding technique using ion beams to artificially induce mutations, which can accelerate breed improvement (see ② below). The Aichi Agricultural Research Center selected three varieties from chrysanthemums produced with this technique and filed applications for their variety registration in 2017.
- This project was successful not only in that varieties with gorgeous colors which would be perfect for celebrations were developed, but also in that it replicated the process of biological evolution and contributed to a deeper understanding of the mechanisms of evolution (see ② below).

Detailed information on research results

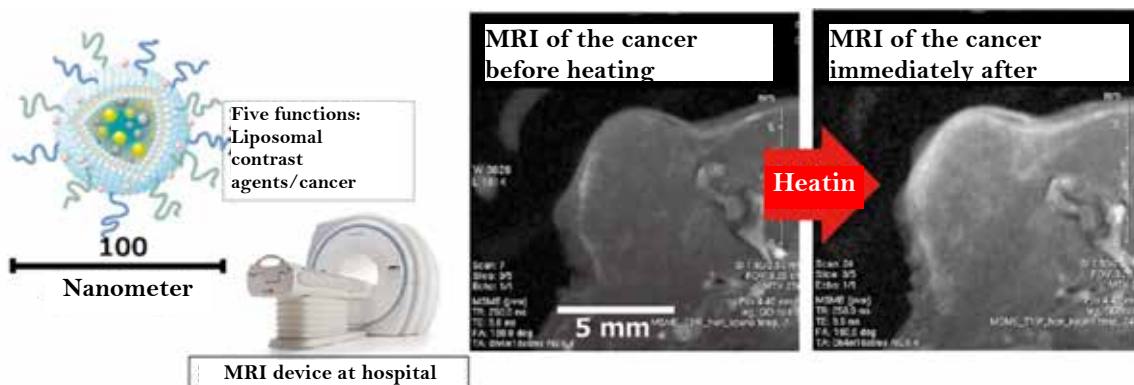
- ① Technique to give chrysanthemum a blue color: A blue color was obtained by introducing the flavonoid 3',5'-hydroxylase gene from campanula and the anthocyanin 3',5'-glucosyltransferase gene from Asian pigeonwings. Blue chrysanthemums with different flower shapes (decorative, pompon, etc.) have already been produced. Efforts for developing blue chrysanthemums cross-sterile with wild species are promoted with an eye to commercialization.
- ② Ion beams proved to be effective in drastically modifying genes: In 2017, a study by QST and Tokyo University of Science demonstrated for the first time in the world that carbon ion beam irradiation drastically changes the chromosomes of the model plant of this study, *Arabidopsis thaliana*. After irradiation, the plants grew and reproduced normally, but became cross-sterile with the original variety and showed different traits as if they were a different variety.

Scientific and Technological Achievements Which Contribute to Daily Life ④
(Treating While Observing: A Nanodrug Delivery System)

Treating While Observing: A Nanodrug Delivery System

Universities and public agencies that participated in R&D

National Institutes for Quantum and Radiological Science and Technology (QST); Osaka Prefecture University



Source: QST

A nanoparticle that has five functions, including the visualization and treatment functions (upper left). Anticancer agents are released inside the tumor when heated. The progress can be observed through MRI. When the heat of 42.5 °C, a temperature close to that of bath water, is applied for ten minutes, the anticancer agents spread across the target area, which can be observed as MR signals (right).

- Cancer is the most common cause of death for Japanese people. Major treatment methods for cancer include surgical operation, chemotherapy (anticancer drugs), and radiation therapy. Chemotherapy is often practiced in combination with other therapies and the side effects cause great discomfort in patients.
- In 2017, QST and Osaka Prefecture University developed a nanodrug delivery system using multifunctional nanoparticles (see ① below), which allows physicians to observe and treat cancers at the same time. Since the accumulation and release of anticancer agents at the target tissues are visualized with high precision, a treatment with reduced side effects and enhanced effectiveness is possible.
- However, this method may not be very effective when the tumor is particularly large, as it is harder to deliver the agents to its core. To address this challenge, the research team carried out an experiment with model mice with implanted colorectal cancer cells. As a result, it was confirmed that the nanoparticle treatment is highly effective for large cancers when combined with heavy particle radiotherapy (see ② below).
- This achievement is the first step toward a more effective cancer treatment with less adverse effects on patients' bodies.

Detailed information on research results

- ① Multifunctional nanoparticles: Multifunctional nanoparticles jointly developed by the QST and Osaka Prefecture University in 2017 (liposome). They have the following functions.
 - Accumulation: The drugs are accumulated at the target tissues and the severity of side effects is reduced.
 - Visualization: Some types of cancer develop barriers which impede drug delivery. By observing the cancer and drugs through MRI, physicians are able to understand the characteristics of the cancer they are treating.
 - Triggered release: By heating only the target part, the side effects can be reduced.
 - Sensor: Magnetic resonance signals increase when the drug is released.
 - Effective cancer treatment: Effective treatment can be achieved by releasing the low molecular agents locally in high concentration and letting them penetrate into the tumor.
- ② Combined use with heavy particle radiotherapy: Each cancer treatment method has types of cancer it is effective for and those for which it is not. The treatment method using nanoparticles is ineffective for particularly large cancers, while heavy particle radiotherapy is ineffective for metastatic cancers. These types of cancer can be effectively treated with the combination of the nanoparticle treatment and heavy particle radiotherapy. Today, various sensors and treatment techniques combining MRI and nanotechnology are being developed.

Scientific and Technological Achievements Which Contribute to Daily Life ⑤
(Infrastructure Development Using a Supercomputer and AI)

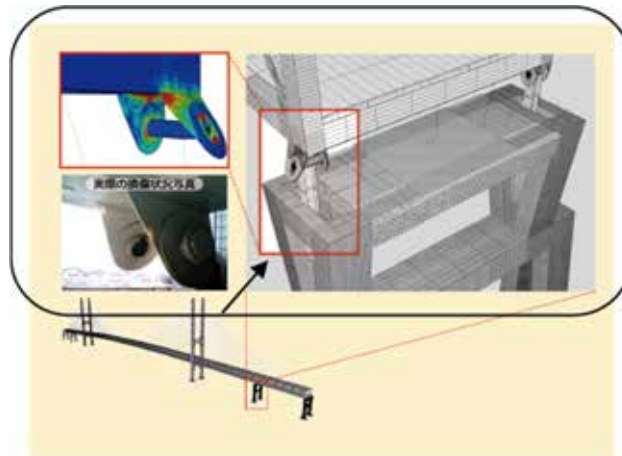
Infrastructure Development Using a Supercomputer and AI

Universities and public agencies that participated in R&D

Kobe University; Tohoku University; Riken; Hanshin Expressway Company Limited; Cabinet Office; Ministry of Land, Infrastructure, Transport and Tourism



Source: Tohoku University



Source: Hanshin Expressway Company Limited

Left: Spherical drone jointly developed by the Cabinet Office and Tohoku University

Right: Damage to a large expressway bridge in the Great Hanshin Earthquake simulated by supercomputer K Computer.

- Ensuring the security of aging infrastructure and enhanced disaster reduction measures are urgent issues today.
- The Riken Center for Advanced Intelligence Project (Riken AIP) introduced highly anticipated AI technology for inspections of bridges, which have particularly complicated structures compared to other components of infrastructure. Riken AIP has been working with the Cabinet Office and Tohoku University to develop a spherical drone using AI technology. This project aims to achieve automated detection of damaged bridge parts, using deep learning technology and images captured by the drone, as well as automated drone operation using the UAV position estimation system (see ① below).
- Kobe University and Hanshin Expressway Company Limited simulated the damage caused by the Great Hanshin Earthquake by reproducing the behaviors of large bridges with complicated structures, using supercomputer K Computer (see ② below). Thanks to the results of this study, it is now possible to set appropriate and reasonable strength and flexibility standards for bridge components.
- These technologies clarify the safety status of bridges located across the country and contribute to the maintenance of critical infrastructure and preparedness for massive earthquakes that may occur in the future.

Detailed information on research results

- ① A joint study by the Cabinet Office, Tohoku University, and Riken AIP: The application of Riken AIP's AI technology was promoted in cooperation with the Cabinet Office and Tohoku University. This study aims to realize cost-effective, highly precise inspections through automated inspections by autonomous spherical drones.
- ② Enhanced precision of a large-scale model of large bridges on the Hanshin Expressway in massive earthquakes: Hanshin Expressway Company Limited conducted a simulation as an industrial project using the K Computer in 2016. The company started a joint study with Kobe University and others to carry out wide-area simulations to study the impact of massive earthquakes regarding all the expressway routes managed by Hanshin Expressway Company Limited.

Scientific and Technological Achievements Which Contribute to Daily Life⑥
(Development and Recommendation of Shoes for Leading a Vibrant Life)

Development and Recommendation of Shoes for Leading a Vibrant Life

Universities and public agencies
that participated in R&D

Okayama University, Chiba University,
Okamoto Seiko Co., Ltd., Flicfit Inc.



Source: Okamoto Seiko Co., Ltd. (left), Flicfit Inc. (right)

Left: Tabi walking shoes "Lafeet"

Right: Matching 3D measurement data of feet and shoes using AI

- It is said that Western shoes began to be worn in Japan between the end of the Edo period and the beginning of the Meiji period (around the late 19th century). Today, they have become indispensable in our daily lives.
- We wear shoes in our daily activities and during exercise, but if you wear shoes that do not fit your feet properly, they could hinder your movement, deform your feet such as causing bunions, or lead to unexpected injuries.
- In 2006, Okayama University and Okamoto Seiko Co., Ltd. started evaluation of tabi shoes (shoes with split toes similar to those of Japanese traditional tabi socks) from the viewpoint of sports medicine, using gait analysis equipment. In the following year, they created baseball shoes called "VALTAIN-X" (see ① below). They continued to make efforts to further improve the foot comfort and the sole thickness, and developed walking shoes "Lafeet," which are lighter-weight and enable a steady gait (see ② below). They are expected to suppress the development of bunions and are optimum walking shoes for the elderly due to their highly stable design.
- Flicfit Inc. and Chiba University started joint research in 2015 to study techniques to measure three-dimensional (3D) images of feet and shoes and to process the measurement data, and developed an original algorithm in 2017 (see ③ below). By matching the measurement data of feet and shoes taken using a high-accuracy 3D scanner, it is now possible to instantly recommend shoes that fit each customer's feet perfectly.

Detailed information on research results

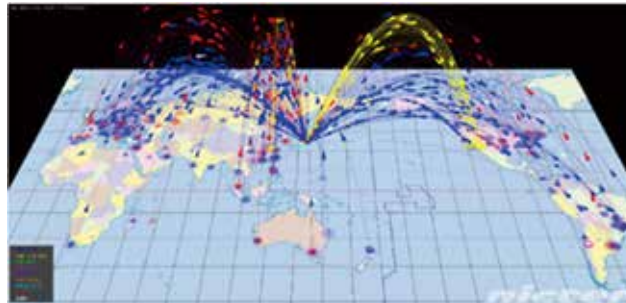
- ① Tabi shoes: The results of the gait analysis experiment revealed that tabi shoes allow a walking experience that is similar to barefoot walking, with walkers' stability, power to push off from the ground, and agility enhanced compared to normal walking shoes.
- ② Effect to prevent bunions: Tabi shoes contribute to the prevention of hallux valgus, since they have a separate compartment for the big toe and allow the free movement of the big toe joint. They also prevent the progression of symptoms by reducing the load on the toe.
- ③ Special technology using 3D scanning and AI: This technology was developed in a joint research project launched in 2015 by Flicfit Inc. and Professor Yoshitsugu Manabe at the Graduate School of Advanced Integration Science, a pioneer 3D technology researcher. It was the first technology that enabled the obtainment of internal shoe measurements, which is crucial in recommending shoes that best fit individual feet.

Scientific and Technological Achievements Which Contribute to Daily Life⑦
(Security Technology)

Safer Security Technologies

Universities and public agencies
that participated in R&D

Ministry of Internal Affairs and
Communications; National Institute of
Information and Communications
Technology (NICT)



Source: NICT

Figure: Unauthorized accesses observed by the NICTER

- Our information and assets are protected by various security technologies. To improve security technologies for safer data utilization and to understand trends of ever-more-sophisticated cyber attacks using combined cyber attack techniques are important challenges in realizing Society 5.0.
- In 2015, NICT developed a homomorphic encryption scheme (see ① below), which allows for arithmetic processing of encrypted data. In the medical field, this technology allows data mining to be carried out in a way that ensures data privacy (see ② below). For example, it allows researchers to analyze data collected from a massive number of subjects while protecting their privacy. This can contribute to the early and efficient development of new treatments and therapies.
- In addition, NICT has been monitoring cyber attacks that occur on the Internet since 2005 in order to grasp general cyber attack trends (see ③ below). It is known that accesses related to cyber attacks have been increasing in recent years (see Figure). DAEDALUS, an access alert system built on the NICTER's observation networks, is available for use for local public organizations which wish to receive alerts if any suspicious access from their organizational networks is detected.
- These achievements contribute to a safer security environment and protection of our important information and privacy. In addition, companies have also been actively working on the development of secure authorization methods using biometrics, etc.

Detailed information on research results

- ① Homomorphic encryption scheme: A technology that enables addition and multiplication operations with encrypted data. Since this technology is capable of combining addition and multiplication operations and carrying out various types of encrypted data calculation, it can be used for data mining with privacy protection. Conventionally, the key length could only be changed either by decoding and re-encrypting the data or by dividing cipher text into blocks and encrypting them; however, the first method entails a risk of data breaches, while the second method also has the issue that data processing becomes impossible. (*1)
- ② Data mining: A process to extract useful information with a computer from massive data that cannot be processed by humans, such as users' browse and purchase history of shopping websites, passengers' travel data concerning transportation systems, relationships between genetic information and disease, etc. (*1)
- ③ NICTER: A system that observes and visualizes unauthorized accesses arriving at unused IP addresses on a real-time basis. According to the observation results from January 1 to December 31, 2017, accesses related to cyber attacks increased by about 17% from the previous year, of which 54% targeted IoT devices. (*2)
- (*1) Source: NICT press release, "NICT Develops a Homomorphic Encryption Scheme Capable of Both Security Level Update and Arithmetic Operations" (January 19, 2015).
- (*2) Source: NICT press release, "NICTER Observation Report 2017 Published" (February 27, 2018)

Scientific and Technological Achievements Which Contribute to Daily Life ⑧
(Utilization of Geological Information)

Various Uses of Geological Information

**Universities and public agencies
that participated in R&D**

National Institute of Advanced
Industrial Science and Technology
(AIST), Geonet Online Co., Ltd.

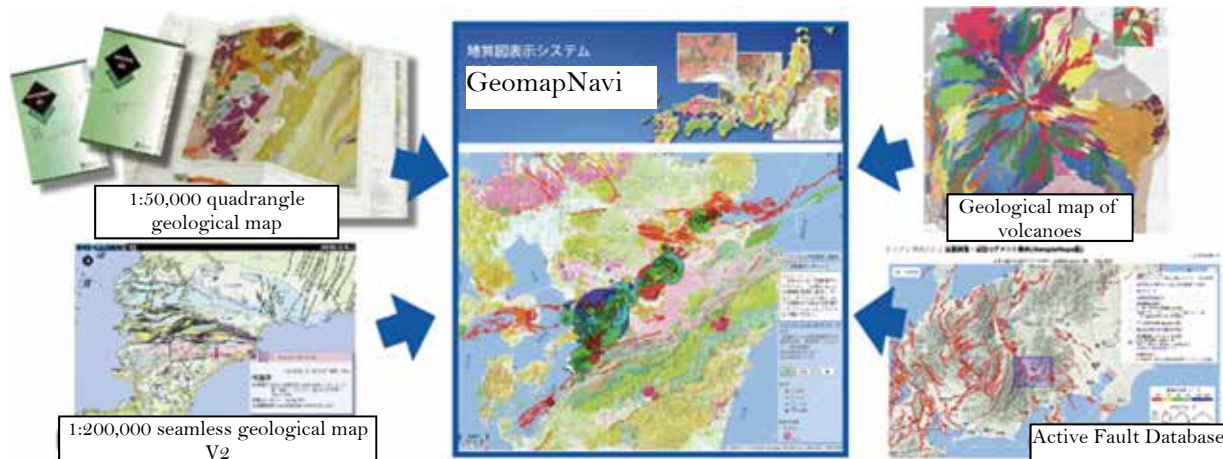


Image: GeomapNavi (see ① below).

Source: AIST

- What does the underground world beneath our feet look like? The Geological Survey of Japan, AIST, collects and analyzes various geological information obtained underground and publishes the results in print and online.
- Geological information reveals the geological structure of a given location, such as the characteristics, geological age, and distribution of strata and rocks scattered among them. Geological information is basic data which is used in various fields, such as civil engineering and construction, disaster prevention, resources development, and environmental conservation.
- Public organizations use geological information as basic data when creating basemaps and hazard maps, when making earthquake predictions, and when determining suitable locations for nuclear waste repositories (see ② below).
- Private entities use information available on the Active Fault Database and geological maps for such purposes as corporate facility planning and real estate assessment (see ③ below).
- The geological map created based on the results of on-site investigations and geochronological assessments conducted in the Kannonji region, Kagawa Prefecture from 2009 to 2013 (the map was issued 2017) revealed that this area has geological features that are suited to wheat farming, which explains why Kagawa Prefecture has a rich *udon* culture (see ④ below).

Detailed information on research results

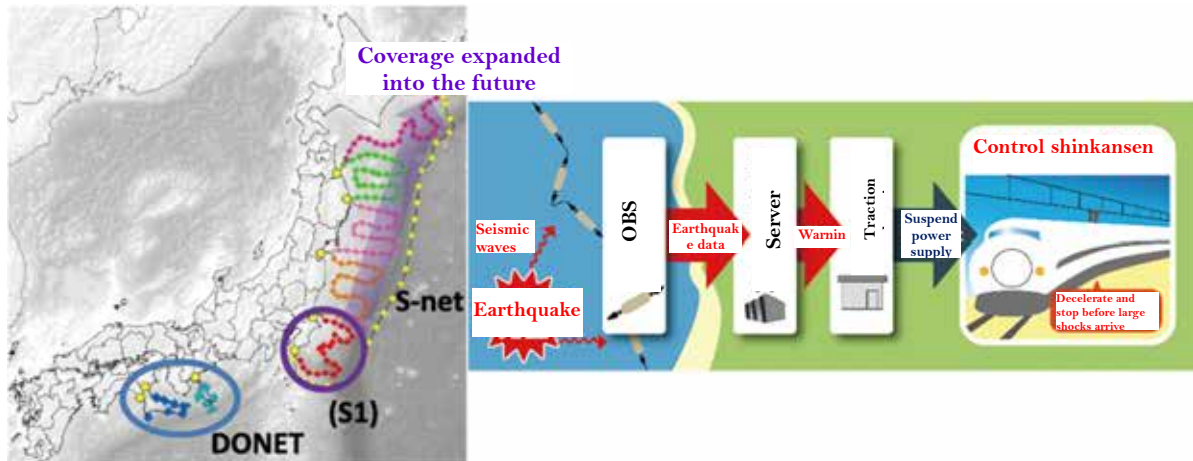
- ① Delivering geological information – GeomapNavi: GeomapNavi is a geological information system, which allows users to view various geological map data distributed by the AIST Geological Survey of Japan along with additional geological information, including locations of active faults and quaternary volcanoes.
- ② Use of geological information by public organizations – Nationwide Map of Scientific Features for Geological Disposal: Published by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry in 2017. In this map, scientific features of individual regions regarding geological disposal are shown based on certain requirements and standards.
- ③ Use of geological information by private entities – Basic Real Estate Information Report: A service provided by Geo-net Online Co., Ltd. Using geological information provided AIST, it can create a geological information report for any given location that describes geological features, seismic history, etc.
- ④ 100 million-year history of Kagawa Prefecture: The first 1:50,000 quadrangle geological map for Kagawa Prefecture was published under the title of “Kannonji” in 2017. This map revealed the history of channel migration of Yoshino River and formation of Sanuki Mountains. The map will be also useful for disaster prevention and mitigation planning.

Scientific and Technological Achievements Which Contribute to Daily Life ⑨
(Utilization of Seismometer Networks)

Utilizing Ocean-Bottom Seismometer Networks for Railway Safety

Universities and public agencies
that participated in R&D

National Research Institute for Earth
Science and Disaster Resilience (NIED)



Source: NIED

The National Research Institute for Earth Science and Disaster Resilience (NIED) operates two OBS networks (left) (see ① below).

The utilization of OBS network data for shinkansen operation control has started (right) (see ② below).

- The past large submarine earthquakes caused massive damage to Japan. Measures against earthquakes off the Pacific coast of eastern Japan, which have been watched with caution since the Great East Japan Earthquake, and the predicted Nankai Trough megaquake are urgent issues for the country. NIED operates ocean-bottom seismometer (OBS) networks (see ① below) in these two areas.
- In order to ensure the safety of shinkansen lines, railway operators deploy seismometers not only along their railways, but also in coastal and inner land areas. Their earthquake disaster prevention system detects earthquakes at the earliest possible point and applies emergency brakes to the trains before large shocks reach them.
- By using observation data captured by OBS in the immediate areas of epicenters, the railway operators will be able to detect earthquakes and apply emergency brakes 10 to 30 seconds earlier than before. Efforts to realize enhanced railway safety are actively promoted.

Detailed information on research results

- ① OBS networks: For wide-area, multipoint monitoring of submarine earthquakes and tsunamis, NIED launched the full-fledged operation of two OBS networks in 2017: one is the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-Net), which covers waters off the Pacific coast of eastern Japan and other areas along the Japan Trench, and the other is the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET), which covers the predicted focal region of the Nankai Trough megaquake.
- ② Utilization of observation data: S-net (S1) data for waters off the Boso Peninsula is already being distributed. East Japan Railway Company has used S-net (S1) data since November 2017. The area coverage of distributed data will be gradually expanded into the future. The pilot distribution of DONET data is scheduled in FY2018. Central Japan Railway Company and West Japan Railway Company plan to start the utilization of DONET data in FY2019.

Scientific and Technological Achievements Which Contribute to Daily Life ⑩
(Precise Physical Quantity Standards)

For More Precise Definition of Units of Physical Quantities

Universities and public agencies that participated in R&D

National Institute of Advanced Industrial Science and Technology (AIST), the University of Tokyo, Japan Science and Technology Agency (JST), Riken

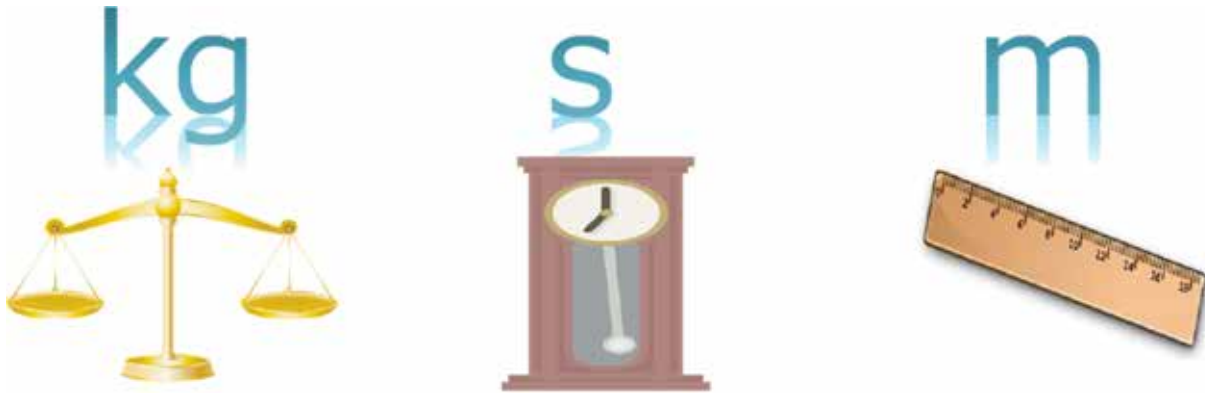


Image: Units of physical quantities used in our daily lives

- Units of physical quantities, such as “kilogram” (weight), “second” (time), and “meter” (length), are defined by certain standards. For example, humans developed calendars according to the moon cycle, and hour, minute, and second were defined as fractions of a day.
- Today, the kilogram is internationally defined by the International Prototype Kilogram (IPK). However, the kilogram is scheduled to be redefined in terms of the Planck constant in 2019. In 2017, AIST succeeded in measuring the Planck constant with the world’s top-class precision (see ① below), making a great contribution to international efforts toward the first-time redefinition of the kilogram in 130 years.
- Professor Katori at the University of Tokyo developed an optical lattice clock, which can be used for the definition of the second (see ② below). The optical lattice clock is nearly 100 times more precise than the cesium atomic clock, which provides the international standard for the definition of the second.
- The meter has been defined by the speed of light since 1983 (see ③ below). In 2009, AIST established a length standard by a measurement method using an optical frequency comb device (see ④ below), which can replicate the definition of length with a high precision. This method is nearly three hundred times more precise than conventional methods.
- R&D activities to improve the precision of definitions of units contribute to various fields. For example, a more precise definition of the kilogram contributes to pharmaceutical development, etc., that of the meter to 3D shapes and distance measurement, and that of the second to geodesy (as it allows the measurement of time gaps derived from very small differences in altitude).

Detailed information on research results

- ① Measuring the Planck constant with the world’s top-class precision: AIST succeeded in measuring the Planck constant with the world’s top-class precision by measuring the Avogadro constant based on the shape of a single-crystal silicon sphere, etc. This method even outperforms the precision achieved with the long-term stability of mass of the IPK.
- ② Optical lattice clock: Professor Katori published his theory in 2001. Multiple atoms are trapped into pockets of an optical lattice formed by laser beams in vacuum. The trapped atoms are cooled to near absolute zero. The second can be defined with a great precision by measuring frequencies of light absorbed by the cooled atoms. Magic wavelengths and laser cooling are the keywords to this technique.
- ③ Definition of the meter by the speed of light: The meter is defined as the length of the path travelled by light in vacuum during a time interval of $1 / 299792458$ of a second.
- ④ Optical frequency comb: A light with a broad, comb spectrum, often generated by an ultrashort pulse laser called “mode-locked laser.” An absolute optical frequency measurement method was developed and won the Nobel Prize in Physics in 2005.