What's IOWN?
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Introduction

Creating the Smart World and Natural Technology

Technological evolution is bringing about great changes in the world. Various technologies including artificial intelligence (AI), the Internet of Things (IoT), and blockchain are entering practical use as many companies focus on digital transformation to create entirely new systems using information and communications technology (ICT).

How should companies of the future use technology to transform the world? We want to build a future in which the Smart World is supported by natural technology.

As the Smart World and natural technology become reality, how will industries such as mobility, healthcare, and finance change? How will various technologies make the world smarter and become more “natural” to us? Alongside innovative research and development, we are also increasing investments into basic research originating abroad, research collaboration with other organizations, and new growth areas.

“NTT Technology Report for Smart World” is a map of the future that depicts the world that we envision. Without a map, many people are uncertain of where to go or where they are. That is why we created a map to capture the current state of technology and point the way forward.
The Smart World is not just some imaginary ideal. It is a future that will inevitably arrive. The more that technology advances, the more data, work, people, and industries that were once separate will become intertwined and “smart.” Collaborative connections will enable new co-creation that could not have occurred before, accelerating the Smart World even more.

The term Smart World refers to many different things, as smart technology is introduced in fields including smart cities, smart mobility, smart manufacturing, smart entertainment and smart healthcare. For example in the manufacturing sector, work is underway on an industry-wide platform to tap into the knowledge of skilled workers and construct a connected value chain, and investments are being made in a variety of AI and speech recognition, sensing, and networking technologies.

Building the Smart World is a vital step for solving many of the social challenges confronting society today. Contemporary social issues such as food waste and environmental destruction span a wide range of fields, and cannot be solved simply by reforming one company. In order to solve social issues and create a richer society, we should strive for a smart world that enables co-creation across corporate and industry boundaries.

We have been working for some time on a “B2B2X” business model that will accelerate the creation of the Smart World. This model aims to create new value by having major industry players take advantage of new technologies that we have developed together with our partner companies. We want to accelerate the necessary transition to the Smart World in order to achieve a more sustainable world and richer lives.
In the Smart World, it is essential that people of all ages, genders, occupations and ethnicities benefit from technology. This is why technology must be natural. Using current cutting-edge technologies such as virtual reality (VR) requires clear awareness, and sometimes specialized knowledge. This leads to disparities between those who can benefit from technology and those who cannot. Accordingly, technology must become so natural that people are unaware of its presence.

The advent of natural technology also promises less stressful lives. AI that can converse naturally like human beings would make it possible to communicate beyond simple questions and answers, while more natural everyday devices could eliminate the need to worry about various settings and operations. Natural technology is a crucial concept for eliminating stress in all fields and for people to live comfortably.

In the past, we have understood technology as something in conflict with humanistic things and nature. Accordingly it has sometimes been seen as lacking humanity or warmth. However, as technology grows more natural in the future, it will overcome this opposition and become integrated into what we we have thought of as human values and emotions, contributing to a good environment for both the Earth and human beings.

As technology becomes more natural, it should grow better at supporting human activities on a deeper level. Technology must be natural in order for human beings to display their creativity and increase their own value—to truly expand human potential and unleash groundbreaking innovation.
The basic abilities of artificial intelligence (AI) to see, listen, and speak are reaching practical levels. However, this only means that separate functions can derive standardized outputs, and are still unsuited to dealing with complex problems. AI is being developed that can handle more complex problems by streamlining learning and creating "white box" algorithms. In addition, we believe that AI needs to be able to process human values. AI that can present a number of options tailored to diverse values will deepen human thought by offering multiple solutions, even for more complex problems. AI that can "think" in accordance with people's values is technology with the tolerance to accept diversity, and the sincerity to respond to different ways of thinking.

Keywords: Values processing, Values analysis, Values processing model
02. Virtual Reality / Augmented Reality

Creating moving experiences across time and space

Virtual reality and augmented reality (VR/AR) have already been released as part of various services, products, and content, but we want to naturally introduce this technology into an even wider range of fields in the future. For that purpose, we are focusing our VR/AR research not only on enriching qualitative expression but also speeding up processing. Our research includes technology that stimulates senses beyond vision such as hearing, touch, force, and temperature, in addition to technologies such as “Kiraril!” that can transmit entire spaces over distance via real-time high-speed data processing. By reducing latency, Kiraril 2.0 will even overcome time. People’s experiences in the Smart World may evolve into something completely different from today.

Keywords: Zero-latency media (Kiraril 2.0), Personal twin platform, Sixth sense transmission

03. Human-Machine Interface

Deeply understanding humans to naturally integrate with robotics

The Smart World will not only bring updates to products, systems and services. In the future, human-machine interfaces (HMI) will also extend the human body. Brain wave analysis and other methods have unraveled mysteries of brain function, which coupled with much-improved understanding of the mechanisms of the human body, should lead to the creation of more sophisticated and complex interfaces. Through our HMI research such as Point of Atmosphere (PoA), we aim to naturally integrate humans with their environment and robotic devices. With the new technology we envision, people will be able to substitute lost bodily functions and make use of information that natural senses cannot detect. Just as virtual and augmented reality expand the human senses, human-machine interface (HMI) expands the body’s potential—indeed, the very body itself.

Keywords: Point of Atmosphere (PoA), Ambient assist, Cybernetic UX
04. **Cyber Security**

**Shifting to active defense**

As the spread of networks and IoT increases the risk of cyber terrorism, existing passive cyber security technology tends to result in a back-and-forth battle against constantly evolving attackers. In order to overcome this situation, a shift towards active security centered on the use of AI is underway around the world. Stronger security is essential to our vision of the Smart World where everything is networked. In addition to developing security technologies adapted to a wide range of applications including mobility, plant systems, and healthcare, we are focusing on active defense that actively deals with cyber attacks. The Smart World will show its true value only with the establishment of new security technologies that can head off cyber attacks.

**Keywords**

Active defense, Useable privacy & security, Cyber-physical security

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05. **Information Processing Infrastructure**

**Making strides in real-time, scalable processing infrastructure**

Next-generation information processing technology could be called the infrastructure of the Smart World. Thus, effective utilization of rapidly evolving technology requires building out information processing infrastructure. Attention in this field is focused on technology that can overcome the trade-offs between performance and flexibility or power consumption. We are also hard at work developing new information processing platforms that surpass conventional limitations. Projects currently underway include scalable data processing technology to process large amounts of information in real time, and highly efficient data management technology to promote use of data across industries. Of course, we are also making efforts to improve hardware itself and develop new technology that can overcome Moore’s Law. The fruits of this research are leading to the emergence of new infrastructure.

**Keywords**

Scalable data processing, Next-generation data management, Virtual integration of distributed data (iChie)
06. **Networks**

**Creating a breakthrough all-photonic network**

New networks are key to realizing the Smart World, where rich flows of data will connect numerous actors and products across industries. We are embarking on the creation of new networks that surpass the 5G technology entering use in the near future. These networks must be higher capacity, lower latency, stronger and more flexible, as well as energy efficient in order to address the explosive increase in energy consumption. That is why we are working hard to convert to an all-optical network and pursuing creation of new networks. We will lead the way to a new world as these new networks spur innovative collaboration.

**Keywords** Function-specific Dedicated Network, Cognitive Foundation, Digital Twin Computing

07. **Energy**

**Realizing an intelligent energy network**

As various advanced technologies enter practical use and the world’s population increases in the future, the energy needed to power systems in every industry is a key part of the social infrastructure of the Smart World. In order to meet growing energy demand while also managing environmental issues, research institutions around the world are trying to improve high-capacity storage batteries. To create this new social infrastructure, we are also hard at work developing energy that is not only environmentally friendly and high capacity, but able to be freely distributed as if it has intelligence. Accordingly, we are conducting efficient energy distribution through virtual power plants that virtually manage dispersed energy, while also embarking on research into new hybrid energy networks. In the Smart World that we are building, energy will evolve into something smart that can circulate almost as if intelligent.

**Keywords** Virtualized energy flow optimization technologies, New hybrid energy networks, Disposable and transparent batteries
08. Quantum Computing

Innovation with post-Moore’s Law technology

Quantum computing technology, which is expected to vastly outperform conventional computers, is likely to be used in nearly every industry. Quantum computing is often discussed in relation to solving optimization problems that require the testing of endless numbers of choices, but in the future it may also result in breakthroughs in the energy and drug discovery fields. Our quantum computing research has made remarkable progress in recent years, with technologies such as LASOLV introducing new concepts distinct from conventional quantum computing including gate type and annealing type. At the same time, we are also pursuing research on quantum computer hardware utilizing quantum gates, and significant advances in both software and hardware are expected in the future. Quantum computing does not merely provide extremely fast computing technology, but has the potential to transform information processing itself. In the Smart World, quantum technology will change the way information is handled.

Keywords: Topological quantum computing, LASOLV, Quantum repeating with all photonics

09. Biotechnology / Medical Care

Evolution of biosensing leads to precision medicine

Hand-in-hand with advances in biology and chemistry, biotechnology is also steadily evolving. Biotechnology is mainly being introduced in medicine, as well as agriculture, forestry and fisheries, but amid the changing nature of information today, biotechnology actually reveals new possibilities for communication. We are also approaching biotechnology from a number of directions spanning the fields of chemistry, biology and physics. In particular, research is ramping up in recent years in the field of biomedical care. In addition to our development of functional materials such as “hitoe,” in 2019 we entered into research partnerships with Australian institutions including Deakin University and Western Sydney University. We will accelerate our activities going forward as part of our vision of “a society where elderly people can live independently and safely.”

Keywords: hitoe, Precision medicine, Biosensing
10. **Advanced Materials**

Innovative production expands the concept of materials

In the future, instead of conventional fixed materials, multifunctional materials that change flexibly in response to the environment will become commonplace. In fact, research into new materials such as nanomaterials is making steady progress, and numerous materials are beginning to enter practical use. In order to further advance research and development of new materials, we are using AI and other methods to speed up the development process. In order to build the Smart World, rapid development of materials is essential to meet demand for development of personal functions tailored to people’s diverse needs. We plan to pursue development of these new materials, and are already making progress with some technologies such as advanced thin films that will be used to create more flexible and functional materials.

**Keywords**
- Atomically thin functional films
- Nitride semiconductors
- Creation of new materials with superior performance

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11. **Additive Manufacturing**

Personalized production in every field

Additive manufacturing, frequently symbolized by 3D printing, will become an indispensable technology in the Smart World by enabling greater personalization. Additive manufacturing makes possible more than just items such as industrial products and building materials. In the future, even parts of the human body including bones and organs are expected to be manufactured at will. Currently, interest is growing in the field of bioprinting. We are also working on research and development of artificial cells in a layered structure. Another technology to watch is 4D printing, which could incorporate information on changes in time and condition to enable self-healing. As this technology evolves, it will be possible to manufacture more personal products.

**Keywords**
- 4D printing
- Multilayering technology
- Multilayering acceleration technology
To start, let’s think about how the lives of individuals will change. Services and production in all industries are likely to be personalized in the future. The evolution of additive manufacturing and advanced materials will make it possible to create products that meet the individual needs and body of each person, and will change the way we interact with products. It may become possible for people to easily create their own goods, from small everyday items and digital devices to huge items such as houses. The concept of “shopping” by choosing from among items prepared by companies will become a thing of the past.

Of course, personalization will proceed not only in the buying and selling of goods but also in intangible areas such as energy. We used to only purchase energy from power companies, but now consumers will produce their own power, sometimes sharing it with others. Furthermore, personalization will proceed in sensitive areas that impact our lives, such as medical care. DNA kits will be commonly used for physical examinations, and everyone should be able to receive treatment based on genomic information. In the Smart World, we will be able to live in a way that properly respects the differences and features of each individual.
Changes such as personalization and the move towards services are certain to have a dramatic impact on individuals and businesses. The result will be more convenient and richer ways of life. But that is not all the Smart World entails. It is by solving solutions to our society’s challenges that we can measure our progress toward a smarter world.

Addressing increasingly severe environmental problems will require changing the way energy is used, with smart energy as part of the solution. For example, optimization of supply and demand forecasting using AI and quantum computing will transform green energy including solar and wind power generation into more practical technology. At the same time, the development of large-capacity storage batteries could make it possible to convert much of our energy supply to renewable energy.

In addition, food shortages and food loss problems confronting the world will move closer to resolution as agriculture and fishing become smarter. The use of IoT technology will make food production more efficient, and accelerating the development of new breeds could result in higher yields. At the same time, producers are likely to make their production processes more transparent, such as by improving distribution traceability using blockchain in order to demonstrate their environmental responsibility.

In this way, the world growing smarter entails individuals, organizations and society changing. Living in the Smart World means solving many environmental problems and creating a sustainable society, and living more like our true selves. This is why the world must become smart, and why we are pressing forward with smart technology.
NTT R&D engages in research and development of new technologies as we aim to improve industrial competitiveness and address social challenges. For that purpose, we work together with partners in various industries to boost productivity and overcome issues including safety and disaster preparedness, and must build a sustainable environment for all individuals to thrive.

To create such a world, technology must become more natural. For that purpose, we must make it possible for people to unconsciously benefit from advanced technology, and create an environment in which every person can use technology tailored to their distinctive traits.

On the other hand, companies demand something different from technology: the ability to quickly grasp changes in customers’ behavior and environment; use data processing to transform business processes, create new value and make decisions; and offer new services that enrich quality of life instead of provide tangible goods. Meeting these needs could allow technology to forge deeper connections between customers and companies.

As a step towards this vision of the future, NTT R&D is working on our Innovative Optical and Wireless Network, or IOWN, comprised of a Function-specific Dedicated Network, Cognitive Foundation, and Digital Twin Computing. By shifting from the world of electronics to the world of photonics, we are striving to realize IOWN, an innovative network with excellent capacity, low latency, flexibility, and energy efficiency and based on photonic technology down to the level of information processing. Stay tuned to see how we will use IOWN to change the world.
Illusionary contour blocks
Combining these blocks makes it appear as if the separate white lines are connected on the surfaces of blocks and in the gaps between.

Café-wall blocks
Mixing black and white stripes causes physically straight lines to appear to be tilted, and the striped pattern that is actually rectangular to be trapezoidal.

Dazzle camouflage blocks
Combining these striped patterns results in a three-dimensional object that appears to bend and spring outward.

Mosaic blocks
Combining blocks with mosaic patterns causes us to sense depth in flat surfaces, and creates a pattern where the connections appear to be interlock depending on how we look at it.

Shape-from-shading blocks
The patterns drawn on the surfaces of the blocks appear to be three-dimensional impressions or extrusions.

Experiment with "Optical Illusion Blocks"
At NTT, we are collaborating on a research project focused on “optical illusion blocks” with the Art Media Center at Tokyo University of the Arts. Optical illusions occur when the properties perceived by the eyes do not correspond to an object’s physical condition. By freely assembling blocks featuring five types of patterns, it is possible to create strange objects whose appearance fluctuates depending on the position and method of viewing.

We conduct workshops using optical illusion blocks in order to create opportunities to think about the mysteries of vision. Combining scientific methods of observation and analysis related to the psychology of vision, the trial and error process of making things, and collaborative methods of creative expression based on group discussion, the project aims for participants to intuitively as well as physically grasp the mystery of vision. In 2017, this project received the Minister of the Economy, Trade and Industry’s Grand Award for the category of “Design to Unlock Children’s Creativity and the Future” at the 11th Kids Design Awards.