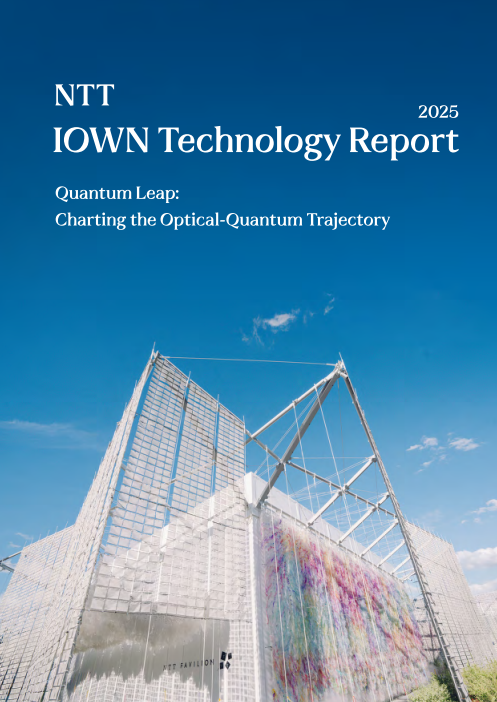
NTT
IOWN Technology Report

2025

Quantum Leap:
Charting the Optical-Quantum Trajectory



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Advancing IOWN through Layered Social Implementation

NTT has pursued research and development across a wide range of technologies, from networks to AI, in order to bring the Innovative Optical and Wireless Network (IOWN) concept to fruition.

Since announcing the concept in May 2019, steady progress has been made in both networking and computing, and in 2023, NTT launched the next-generation network service "All-Photonic Connect powered by IOWN." While the evolution of foundational technologies continues, social implementation is also advancing in parallel.

Among this year's most emblematic developments is the Osaka-Kansai Expo 2025, which began in April. At the Expo, NTT is presenting a vision of future communication through its pavilion, while also organizing numerous events that connect the Expo venue with locations in Japan and abroad via IOWN. Furthermore, IOWN is contributing to the safe and secure operation of the Expo. NTT's involvement goes beyond showcasing cutting-edge technologies, offering a glimpse into the experiences that may define next-generation society.

Beyond the Expo, proof-of-concept trials and social implementation efforts using IOWN are underway in a variety of fields. In video production, including applications in television programming and sports broadcasting, remote production leveraging IOWN networks is progressing. Application is also expanding in foundational infrastructure such as data centers, as well as in advanced sectors like the space industry. NTT is also working to build an environment where diverse AI systems can collaborate with humans through an initiative titled "AI Constellation." As interest in AI continues to grow, IOWN is expected to play an increasingly significant role in these areas.

Quantum computing is another area attracting attention. Building on its longstanding expertise in optical technology, NTT is developing a photonic quantum computer with the aim of realizing a fundamentally new computational platform. As these various lines of technological and service development converge, IOWN's potential social impact continues to expand.

This year's NTT IOWN Technology Report presents NTT's wide-ranging initiatives, from the Expo to data centers, AI, and quantum computing. The growing body of IOWN implementations across these domains reflects NTT's unwavering commitment to realizing a sustainable future society.

The Road to IOWN

Innovative Optical and Wireless Network

Where is the IOWN Initiative Headed?

Entering the Seventh Year of the IOWN Initiative

NTT unveiled its IOWN (Innovative Optical and Wireless Network) initiative in May 2019, as a vision for next-generation ICT infrastructure. By harnessing the optical technologies NTT has developed over many years, the initiative seeks to overcome the limitations of conventional electronic systems and deliver breakthrough capabilities in ultra-high speed, high capacity, ultra-low latency, and ultra-low power consumption. IOWN is steadily progressing toward realization. Its three core technological pillars are the All-Photonics Network (APN), Photonics-Electronics Convergence (PEC) devices, and Data-Centric Infrastructure (DCI). Since the initiative's announcement, these technologies have continued to advance, with APN already moving into commercial deployment as the IOWN APN framework.

To realize IOWN, NTT is pursuing a phased roadmap for integrating optical technologies from networks to the core of computing systems. This roadmap comprises four major stages. IOWN 1.0 achieves full photonic interconnection between data centers. IOWN 2.0 extends photonic links to communication between boards within servers. IOWN 3.0 advances this further by enabling photonic connectivity between packages on a single board. Finally, IOWN 4.0 reaches into the chip itself, bringing optical integration to the innermost layer of ICT infrastructure. The APN, PEC, and DCI technologies are evolving in tandem with this roadmap.

Progress and Applications of APN

The All-Photonics Network (APN), the foundational network technology of IOWN 1.0, delivers a dramatic leap in performance by transmitting all information optically. APN is expected to evolve in three stages. The first phase began when APN 1.0 services launched in March 2023, followed in December by a new generation of services offering significantly expanded bandwidth and interface options. This enhanced service guarantees bandwidth of up to 800 Gbps, among the highest levels globally, and is available across wide-area networks linking major cities. Alongside the conventional OTU4 optical interface, the rollout has also included Ethernet interfaces more familiar to enterprise users. By relocating terminal equipment previously installed at customer sites to NTT facilities, the service reduces the burden on user systems and enables power savings of up to 940 watts.

APN supports a wide array of applications. In late August 2023, a direct APN connection between Japan and Taiwan was successfully established, covering a distance of approximately 3,000 kilometers. Despite the distance, the link achieved ultra-low latency of just 17 milliseconds. Considering that optical transmission delay within the fiber accounts for around 15 milliseconds, it is a remarkable accomplishment to have reduced all other delays to just 1 to 2 milliseconds. In experiments utilizing this international APN connection, high-speed data backup between data centers in Japan and Taiwan was demonstrated. While conventional wide-area Ethernet (I-WAN) using 10G configurations achieved effective transfer speeds of 2.8 Gbps, APN nearly doubled this, reaching close to 5 Gbps and reducing backup time by two-thirds. The system shows promise for rapid data recovery in the event of large-scale natural disasters. APN has also been proven to enable new types of experience in the entertainment domain as well. At the Osaka-Kansai Expo 2025, a live performance was successfully delivered by connecting the Expo venue with Taiwan. In the field of television broadcasting, APN is supporting remote production workflows. This allows for a significant reduction in the use of large broadcast vehicles and on-site production crews. Video captured by cameras is transmitted via APN to the cloud, where editing software is operated remotely from the production base, enabling highly efficient content creation.

On-Demand APN Connections

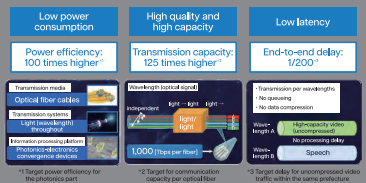
In addition to enterprise applications, APN is also highly effective for interconnecting data centers. Proof-of-concept trials have already been conducted in the United Kingdom and the United States, and more recently, experiments have been carried out between NTT data centers in Mumbai, India. APN also holds significant promise for achieving "watt–bit coordination," which seeks to improve energy efficiency by shifting workloads from regions with low renewable energy output to those with higher generation capacity, thereby increasing the overall utilization of renewable energy. As machine learning becomes increasingly central to AI development worldwide, the efficient allocation and use of distributed GPU resources has emerged as a critical challenge. Trials are now demonstrating that GPUs located across multiple geographically distant data centers can be used as if they were part of a single, unified GPU cloud via APN. While conventional internet connections resulted in a 29-fold increase in latency, APN limited the increase to just 1.006 times, enabling distributed learning with performance nearly equivalent to that of a single data center.

Building on the progress made in steps 1 and 2, step 3 envisions a further 125-fold increase in transmission capacity compared to seven years ago when the concept was revealed, along with improved power efficiency through deeper photonic integration. APN will also be extended to a broader geographic area. A key enabler of this expansion is on-demand connectivity. Rather than relying on persistent dedicated lines, users will be able to automatically configure APN nodes via a controller to establish end-to-end connections as needed. NTT is currently developing technologies such as optical path design and wavelength and spectral band conversion, allowing multiple wavelengths to coexist without collision and enabling seamless end-to-end connectivity.

Fundamental Evolution of Photonics-Electronics Convergence Devices

The realization of the IOWN initiative requires not only the advancement of APN but also the development of PEC. As with APN, PEC is planned to evolve through a series of phases from PEC-1 to PEC-4. From fiscal years 2022 to 2024, devices for inter-data center connectivity have been developed under PEC-1. Starting in fiscal year 2025, PEC-2 will introduce optical engines for board-level connections. PEC-3, scheduled for fiscal 2028, will apply photonic integration to chip-to-chip interfaces, and PEC-4, targeted for 2032 and beyond, aims to extend photonic integration within the chip

Benefits of IOWN

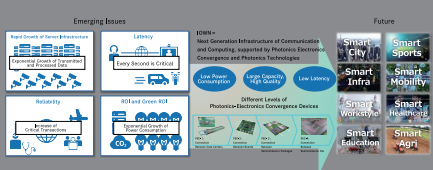


*1 Target power efficiency for the photonics part

*2 Target for communication capacity per optical fiber

*3 Target delay for uncompressed video traffic within the same prefecture

Future Infrastructure Realized by IOWN



itself.

A key current challenge is the rising power consumption of chip-to-chip interconnects. As large-scale integrated circuits (LSIs) continue to improve in performance, the bandwidth for inter-chip I/O is also increasing. It is anticipated that, in the near future, the power consumed solely by inter-chip wiring may surpass the thermal limits of current cooling technologies. Photonic wiring offers a promising solution, as it allows for longer transmission distances on circuit boards without the corresponding increase in power consumption typical of electrical wiring.

In preparation for the transition to PEC-3 and PEC-4, NTT is advancing not only in silicon photonics but also in membrane compound semiconductor technologies. This membrane approach is expected to enable the creation of devices capable of converting electrical signals into optical signals within a compact footprint of just 1.11 mm by 2.75 mm. The critical factors for miniaturization lie in how small the laser can be fabricated, how effectively the light can be confined, and how heat generation can be suppressed. NTT's research laboratories have developed a lateral thin-film fabrication method, as opposed to conventional vertical stacking, and have established world-class manufacturing stability with this technique.

Toward the Next Generation of Computing Infrastructure

DCI is positioned as the core computing infrastructure for the IOWN era. DCI breaks down computing resources into smaller units and operates only the resources needed—such as data—at hand, achieving both high efficiency and low power consumption. Conventional electric wiring has limited connection distances, making it difficult to build truly efficient computing systems. But optical wiring extends connection distances, enabling the construction of large-scale, efficient computing systems.

DCI is expected to be highly effective in scenarios involving massive, diverse, and dynamic data. One example is AI for real-time image analysis using large volumes of video footage. By adjusting resource allocation based on day-night population fluctuations, significant improvements in power efficiency can be achieved.

In the future, DCI will be deployed across geographically distributed data centers in conjunction with APN, realizing high-performance, energy-efficient ICT infrastructure at scale. NTT is currently developing DCI-2 as part of IOWN 2.0, aiming for commercial release around 2026. This version uses PEC-enabled optical switches to interconnect computing resources subdivided at the board level and optimally controls them via a DCI controller, targeting an 8-fold improvement in power efficiency. Like APN, DCI is being used in the operation of the NTT Pavilion at the Osaka-Kansai Expo 2025, where it is already supporting applications such as abnormality detection and facial expression analysis. DCI's deployment is expected to expand into a wide range of use cases beyond the Expo.

Infrastructure for the Society of the Future

The research and development for the realization of the IOWN initiative is not the work of NTT alone. From the outset, NTT launched the IOWN Global Forum to pursue global development in collaboration with a broad range of partner companies. Today, the forum includes 154 organizations from around the world, including Intel, Microsoft, and Google, spanning Asia, Europe, and North America. The IOWN Global Forum regularly hosts conferences that facilitate active cross-industry dialogue, and multiple working groups have been established within the forum to conduct proof-of-concept trials across various fields. These collaborative efforts are not only advancing the exploration of use cases but also promoting international standardization and widespread adoption of IOWN. As a result, the benefits of IOWN will extend beyond the NTT Group to industries and societies across the globe.

Through the IOWN initiative, NTT has aimed to realize a sustainable and prosperous society. While ICT infrastructure that offers ultra-high speed, high capacity, ultra-low latency, and ultra-low power consumption holds great potential, it is through implementation that this value is truly delivered to society. Now in its seventh year, the IOWN initiative is entering a new phase—not only of research and development, but also of real-world deployment.

IOWN Beyond Boundaries

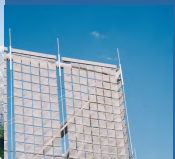
Next-Generation IOWN Experiences at Osaka-Kansai Expo 2025

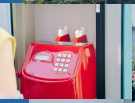
The Osaka-Kansai Expo 2025 was held from April 13 to October 13, 2025. NTT participated under the theme of "NATURAL," unveiling a pavilion that offered architecture responsive to human emotions and experiences transcending time and space. Through the implementation of IOWN, it delivered innovations ranging from large-scale live entertainment connecting remote locations to the control of autonomous vehicles navigating the Expo grounds. What, then, was happening behind the scenes?

PART 1 The Role of IOWN in Supporting Expo 2025 Osaka, Kansai
PART 2 A New Era of Experiences Created by APN
PART 3 The Potential of IOWN Optical Computing

PART 1: How IOWN Works in Expo 2025?

The Role of IOWN in Supporting Expo 2025 Osaka, Kansai





The NTT Pavilion stood out among the many architectural showcases at the Expo. Draped in soft, watercolor-like pieces of fabrics that shimmered and swayed in the wind, its blurred contours evoked a sense of softness and ambiguity.

The experience theme of this pavilion was "Parallel Travel." Powered by IOWN, which connects distant places and spaces, the pavilion embodied a journey through time and space. It was not merely about traveling from one location to another, but about sharing existence across temporal and spatial boundaries. NTT's goal, to create future communication that feels as if someone is sitting next to oneself, offered a new approach to the fundamental human desire to connect.

This philosophy is rooted in historical context. At Expo 1970 in Osaka, NTT (then Nippon Telegraph and Telephone Public Corporation) introduced the "wireless telephone." Fifty-five years later, NTT once again returned to Osaka to present the future of communication technology. However, this initiative was not just a demonstration of technological advancement. It sought to answer a deeper question of how technology can align with human emotions and senses, and expand what it means to be human.

The pavilion also embodied three concepts: "co-creation," "circularity," and "living architecture." These were not merely architectural themes, but reflections of values that society should strive toward. For example, the "co-creation" concept emphasized the importance of interactive communication. Around 300 NTT Group employees who joined workshops across Japan wove together small pieces of fabric to form a large canopy, while during the Expo, children visiting the pavilion could select pieces from among 30,000 colored fabrics and attach them to the building's exterior. The pavilion's appearance evolved over time through this participatory mechanism.

The concept of "circularity" highlighted a commitment to sustainability. The fabric used in the pavilion was made from 100% biodegradable polylactic acid (PLA) derived from plants. Some of the manufacturing took place in Nakanoto, a town affected by the Noto Peninsula earthquake. This international event demonstrated how regional recovery and environmental consciousness could be achieved simultaneously.

Lastly, the concept of "living architecture" captured the building's dynamic qualities. Described as "architecture that wears emotion," the structure responded like a living being—moving with emotion, vibrating in harmony with visitors' feelings, and changing its appearance with the natural breeze. This dynamic architecture challenged the conventional notion of buildings as static and unchanging. The fabric was designed to sway in response to the smiles of visitors, suggesting that ICT had been fully integrated into the architecture itself. The building functioned not merely as a physical structure, but as an information processing system.

The philosophy behind the NTT Pavilion offered a new vision of communication that transcended a conventional technology exhibition. A modern expo must be more than a showcase for cutting-edge technology. It must serve as a venue for reexamining the relationship between technology and humanity. While architectural design and internal experiences are often treated separately in exhibitions, the NTT Pavilion offered an integrated approach. This embodiment reflected the philosophy of NTT, a company that has historically shaped the Japanese understanding of communication.

NTT in Expo 2025

Ten Experiences Coloring the Expo Venue

NTT Group's efforts at Osaka-Kansai Expo 2025 extend far beyond pavilions and large-scale events. From autonomous vehicles and customer service robots operating within the venue to proof-of-concept programs in collaboration with various institutions, and even remote productions connecting regions across Japan, the scope of NTT's initiatives expands with the Expo. Below are some key highlights.

CASE01: Personal Agent

An AI-powered personal agent app analyzes a wide variety of data to generate a personalized daily itinerary tailored to each visitor. By integrating information throughout the venue, it creates a comfortable and customized experience for every guest.

CASE02: Hydrogen Supply Chain

NTT Anode Energy generates green hydrogen from solar and other renewable sources and supplies it via a pipeline utilizing underground communication conduits. The hydrogen is delivered to the Panasonic Pavilion, located about 200 meters away, realizing a practical, functioning hydrogen supply chain.

PART 2: New Experience through All Photonics Network

A New Era of Experiences Created by APN

Upon entering the NTT Pavilion, visitors found themselves immersed in a space divided into three distinct zones. Over the course of a thirty-minute journey, each guest was invited to reflect on how new technologies might reshape the future of communication.

The experience began with Zone 1: "There are barriers that even the evolution of communication cannot overcome. What emotions and sensations lie beyond technology?" This area traced the historical trajectory of communication technologies while encouraging visitors to contemplate both the inherent limitations and the potential of these tools. Rather than simply celebrating progress, the true intent of this exhibit was to reveal a deeper truth: no matter how advanced technology becomes, a gap remains when it comes to conveying human emotions and sensations. This notion of a "gap" pointed to the deeper, unresolved challenges of modern digital communication. While platforms like social media and video calls now allow us to connect instantly across the globe, true understanding, empathy, and emotional resonance remain elusive. One of the most impactful elements of the exhibit was an audiovisual experience focused on "emotional transmission." Visitors came to realize that some emotional nuances cannot be fully conveyed through words or images alone, but emerge through subtle sounds and expressions. This experience brought a renewed awareness of the human essence that lies beyond technology.

Flowing naturally from this introspective encounter, Zone 2 asked: "What if we could overcome that barrier? When time and space become one, a new kind of sensation emerges." Here, visitors relived a 3D recreation of a live performance by Perfume, experiencing a new form of spatial presence. This was not merely a visual installation. Thanks to IOWN's space transmission technology, the actual space in which Perfume had performed was reproduced inside the pavilion in real time. Using high-precision 3D scanning, intricate spatial data was captured and transmitted via IOWN's large-capacity, low-latency network. Visitors not only saw the performance in three dimensions, but also perceived the breath and movement of the members. It was an experience that transcended time and space, an embodiment of what IOWN makes possible.

Finally, in Zone 3: "Create your own avatar. Another Me, and explore new possibilities of 'us'," visitors created virtual avatars of themselves. In a designated booth, guests were filmed, and AI analyzed their individual characteristics. Based on this analysis, a virtual avatar was generated in real time. These avatars then interacted with others' avatars on screen, displaying expressions not intended by their creators and, at times, initiating movements of their own. This unexpected behavior reflected the diversity and fluidity of identity in today's society. Just as people in digital spaces like social media or online games often present themselves differently than they do in the physical world, Zone 1 suggested that our sense of identity is undergoing a gentle transformation.

The experiences within the pavilion illustrated that technology does more than simply enhance convenience. It has the potential to expand and enrich what it means to be human. IOWN's space transmission technology opens up new possibilities for coexistence beyond physical constraints, while the emergence of virtual avatars signals a shift in how we relate to one another.

CASE03: Virtual Yumeshima Venue

A virtual venue was created by reconstructing Yumeshima in a 3D computer-generated online space, enabling VR/AR-based experiences. This inclusive approach allows people who cannot physically attend the Expo to still participate freely.

CASE04: newme

Avatar robot newme has been deployed in a 7-Eleven store at the Expo site. It is connected via IOWN to the NTT Pavilion's back office, allowing remote operators to serve customers daily throughout the Expo, providing seamless, real-time customer service.

CASE05: Live Viewing Experience

The GLION ARENA KOBE's basketball games featuring the Kobe Storks are connected in real-time to the Expo venue via IOWN. In addition to live video streaming, the experience uses F.E.E.L. technology to transmit arena vibrations, creating a new kind of immersive sports viewing.

CASE06: Remotouch

At the NTT Pavilion, a booth was set up where visitors could receive touch therapy remotely. Using IOWN, the precise pressure of touch, tone of voice, and facial expressions of a distant therapist are transmitted in real time, offering a full sensory therapeutic experience.

PART 3: New Computing in Expo 2025

The Potential of IOWN Optical Computing

The experiences offered at the NTT Pavilion were supported by none other than IOWN. Developed as a next generation communication infrastructure, IOWN is characterized by ultra-low power consumption, ultra-high-speed processing, and ultra-large-capacity transmission. The experiences within the pavilion demonstrate how communication itself may be transformed through the social implementation of IOWN.

Among these, the 3D transmission of the Perfume live performance in Zone 2 is a particularly symbolic example of IOWN's technological advantage. The space transmission technology that enables this experience takes a fundamentally different approach from conventional video technologies. Traditional video transmits two-dimensional images captured from fixed camera positions and plays them back at the receiving end. In contrast, space transmission technology reconstructs the entire three-dimensional information of the scene, allowing the generation of visuals in real time from any viewpoint at the receiving end. This requires the integration of several advanced technologies. First, high-precision 3D scanning captures detailed three-dimensional data of the performance space. Then, footage from multiple cameras is combined to record color information at each point in the space. Additionally, three-dimensional audio characteristics are recorded using spatial audio captured through multiple microphones. These enormous volumes of 3D data are transmitted in real time via IOWN's high-capacity communication technology. At the receiving end, the appropriate visual and audio output is generated in real time based on each visitor's position and line of sight. This process enables visitors to freely change their viewpoint and feel as though they are truly present in the space. Notably, the technology extends beyond visual transmission. It also includes the transmission of tactile information. At the exit of Zone 3, the installation titled "Heartfelt Telepresence" allows for the transmission of not only sound and imagery, but also tactile sensations. People located in different physical places can engage in multisensory communication through sight, hearing, and touch.

Another element supporting the pavilion experience is optical computing, an essential component of the IOWN vision. By fusing light-based technology with conventional electronic circuits, this technology enables both faster and more energy-efficient AI processing. A concrete application of optical computing is seen in the control system for the lattice-like sheets surrounding the exterior of the pavilion building. Smiles captured by cameras in Zone 2 are sent via IOWN to NTT West's headquarters near Kyobashi Station in Osaka. There, AI analysis using optical computing detects the smiles and analyzes emotional expressions. The results are then sent back through IOWN to the pavilion, where they are used as control signals to animate the lattice sheets.

This entire process achieves a level of speed and efficiency difficult to realize with conventional electronics-based systems. Optical computing enables the real-time processing of large volumes of image data and the instant delivery of emotion analysis results. Furthermore, this processing is performed with low power consumption, minimizing environmental impact while delivering an advanced experience.

In this way, the realization of a high-speed communication infrastructure such as IOWN makes it possible to connect distant locations in real time. IOWN APN devices have been installed in the optical fiber network of the Expo site, providing a communications environment throughout the venue that combines low power consumption, large capacity, high quality, and low latency. This network links not only the NTT Pavilion but also other areas within the venue, such as the Dynamic Equilibrium of Life pavilion. It even connects remote locations including Hokkaido University and Taipei, extending beyond the confines of the site.

Today, as tools like Zoom allow people to converse effortlessly across the globe, it may seem natural to connect distant places. However, the ability to handle vast amounts of data, such as that required for 3D spatial transmission, with virtually no latency, represents a qualitative shift in communication. Visitors to the NTT Pavilion likely experienced this transformation firsthand. NTT's initiative at the Expo did more than propose a future vision. By putting it into practice, it offered tangible proof of what that future could be.

CASE07: Agricultural Machinery

At the Ministry of Agriculture, Forestry and Fisheries booth during the "Future of Food and Living" theme week, visitors were able to remotely operate agricultural machinery located over 1,900 km away at Hokkaido University's farm. The seamless experience is supported by an IOWN connection.

CASE08: Autonomous Driving

ITS smart poles installed along the route of the Yoshimoto Expo park-and-ride shuttle buses collect sensor data, which is processed via a network server connected through IOWN. This supports safe and smooth autonomous driving operations.

CASE09: Remote Production Environment

During the Expo, the media center at the venue is connected to production facilities at a data center via IOWN. This setup enables multiple broadcasters to share a remote production environment, promoting collaborative usage.

CASE10: Heartfelt Telepresence

At the Japan Pavilion, the Dynamic Equilibrium of Life Pavilion, and Kansai International Airport, installations of a multi-sensory "telepresence" system allow for daily exchanges of sound, vibration, and even tactile feedback. Participants can high-five and share physical sensations with someone in a remote location.

New Connectivity

New Connections Created by IOWN

The domains where IOWN is being implemented continue to expand year by year. From next-generation data centers addressing the surge in power demand accompanying the advancement of generative AI, to remote production enabling seamless content creation by connecting distant locations in real time, and even extending beyond Earth into the vast expanse of space—we explore the ongoing expansion of IOWN implementation while capturing the new connections that IOWN creates.

Next Generation Network for Society

Next-Generation Data Centers Supporting the Society of Tomorrow

In recent years, fueled by the boom in generative AI, data centers have entered a global construction rush. While demand continues to rise, concerns are growing about their environmental impact, including high power consumption and increasing waste heat. This is why attention is now turning to the transformation of data center operations through IOWN. The high-speed networks enabled by IOWN are expected not only to overcome the limitations of conventional data centers and achieve overwhelmingly low power consumption, but also to free operators from long-standing geographic constraints. IOWN is already being introduced into data centers operated by hyperscalers such as Google, and it holds the potential to drive transformation not only within NTT Group facilities but across the broader data center market. What is the current state of the data center industry, and where is it heading next. This section follows the transformation of the data center sector through IOWN.

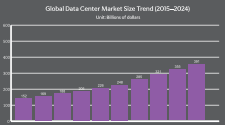
Market Trend of Data Center

Current Status of the Data Center Market

POINT 1

The Global Data Center Market Surpasses 50 Trillion Yen

Driven by the spread of AI and cloud computing, the data center industry is experiencing exceptional growth. The global market is expected to grow from $367 billion in 2024 to $464.6 billion by 2030, with a high compound annual growth rate (CAGR) of approximately 10.3%. One particularly noteworthy factor is the explosive rise in demand for generative AI. By 2030, AI processing is expected to account for more than half of total data center power consumption. In Japan, a construction boom in hyperscale data centers is underway, with major cloud providers accelerating their domestic investments. The Asia-Pacific region is the fastest-growing market. The drive toward digitalization in countries such as China, India, and Southeast Asia is propelling annual growth of more than 15% in this region. Meanwhile, even in mature markets like North America and Europe, the rise of AI is creating new opportunities for expansion.



POINT 2

Generative AI Is Accelerating Demands for Data Centers

60TWh

20TWh

As generative AI and related technologies become more widespread and demand increases, data centers are undergoing rapid transformation. The most significant change is the growing deployment of AI-specific chips. Dedicated processors such as NVIDIA's H100, AMD's MI300X, and Intel's Gaudi3 are being adopted at scale, fundamentally altering data center architecture. These chips deliver over ten times the processing power of conventional CPUs, but they also consume far more energy, necessitating major advances in cooling systems. The introduction of liquid cooling is accelerating as a result. AI is also playing a pivotal role in improving energy efficiency. For example, DeepMind's AI control system has successfully reduced cooling energy usage at Google data centers by 40%. NTT is conducting trials of next-generation data centers that utilize optical technologies as part of its IOWN initiative. In the future, a wide range of technologies, including quantum computing, are expected to contribute to even more efficient data center operations.

POINT 3

Power Supply and Security Concerns Among Mounting Challenges

Power supply constraints are emerging as the most pressing issue for the industry. As AI adoption accelerates, data center electricity consumption is expected to surpass 3% of total demand by 2030, placing immense strain on existing power infrastructure. This is especially acute in areas with concentrated data center development. For instance, in major hubs on the U.S. East Coast, new projects face wait times of over three years for grid connections. A shortage of skilled personnel is another serious concern. The technical vacancy rate in the data center industry has reached 15%. In response, the sector is ramping up training programs and pursuing automation technologies to reduce reliance on human workforce. These challenges also present opportunities. The spread of edge computing is boosting demand for smaller data centers near cities, creating new market openings for a broader range of businesses. The data center ecosystem may continue to evolve in unexpected ways.

POINT 4

Expectations Rise for the Next Generation of Data Centers

The 2030s may usher in a fundamental shift in the data center industry with the integration of quantum computing and photonic technologies. A transition from current electronics-based systems to ultra-efficient Photonics-Electronics Convergence architectures could transform the very concept of the data center. If IOWN enables ultra-high-speed, high-capacity data transfer between centers, it may become possible to manage geographically distributed data centers as a single, unified system. The next decade could see widespread operations powered entirely by renewable energy, the introduction of quantum computing, and full automation through AI. As connected vehicles and smart cities continue to expand, data centers will serve as core infrastructure, integrating and processing information across domains such as transportation, healthcare, and public administration. In this future, data centers will be even more deeply embedded in the fabric of society.

The Impact of New Data Centers

The Dawn of a New Era for Data Centers

In Tochigi City, Tochigi Prefecture, NTT is planning to construct one of Japan's largest data centers, covering 100 hectares—equivalent to ten Tokyo Domes. The project serves as a flagship of the company's ¥1.5 trillion strategic investment planned between fiscal 2023 and 2027. As demand for data centers surges in response to generative AI, NTT is leveraging its domestically developed technologies to pioneer new value creation. At the core of this effort is the development of a next-generation data center underpinned by IOWN's foundational technologies.

One of Japan's Largest Data Center Clusters

The data center landscape has undergone a dramatic transformation over the past decade. What was once primarily the domain of telecommunications carriers and enterprise system operations is now dominated by hyperscalers such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud. These providers have established massive facilities around the world, delivering services at lower cost by leveraging economies of scale.

Since 2023, however, this landscape has begun to shift. The explosive growth of generative AI has brought about an unprecedented demand for computational power and storage capacity. Running and training LLMs requires a continuous operation of vast numbers of GPUs, a demand that many existing data centers are no longer able to meet.

Conventional data centers were originally designed to handle relatively light workloads, such as web services and database operations. In contrast, AI workloads can consume more than ten times the amount of power. This requires a fundamental rethinking of cooling systems, power supply infrastructure, and network bandwidth.

Site selection also presents a critical challenge. There are only a limited number of locations capable of reliably supplying the enormous power needed for AI processing. In urban areas, both power shortages and difficulties in securing land have made new construction increasingly impractical. As a result, attention is shifting toward large-scale data centers in regional areas where power infrastructure is more robust, though this transition presents its own challenges.

In May 2023, NTT announced a bold initiative that drew industry-wide attention: an investment of ¥1.5 trillion in its data center business through fiscal 2027. The breakdown of this investment reveals the strategic vision behind it. Approximately 60 percent—around ¥900 billion—will be allocated to the construction of new facilities, while the remaining ¥600 billion will be used to upgrade existing sites and introduce energy-efficient technologies. Of particular note is the concentrated investment in next-generation data centers optimized for AI workloads.

The new data center in Tochigi City, Tochigi Prefecture, serves as a flagship project within this strategy. With a site area of approximately 100 hectares and a total floor space of around 500,000 square meters, it ranks among the largest in Japan. But its significance lies not only in its scale. The facility will integrate NTT's long-cultivated communications technologies with cutting-edge innovations from IOWN.

One of the center's most advanced features is the full-scale implementation of direct liquid cooling. Traditional air cooling systems struggle to dissipate the immense heat generated by AI processing. Direct liquid cooling dramatically improves thermal efficiency

by bringing coolant into direct contact with server CPUs and GPUs. This enables energy savings of approximately 40 percent compared to conventional systems. In traditional data centers, a significant portion of energy consumption is attributed to cooling. By adopting direct liquid cooling, this burden can be significantly reduced. Moreover, the waste heat generated through this process can be reused for heating and hot water, further enhancing overall energy efficiency.

The power supply system also represents a major departure from conventional models. More than 50 percent of electricity will be sourced from renewable energy, with the remainder provided by high-efficiency natural gas generation. A large-scale battery storage system will also be installed to enable flexible response to fluctuations in power demand. In terms of networking, the facility will achieve ultra-low-latency connections using IOWN's All-Photonics Network (APN) technology. It will be directly linked to central Tokyo via optical fiber, keeping round-trip latency below five milliseconds. This allows the facility to deliver response times equivalent to urban data centers, despite its regional location.

A Strategic Approach to Solidifying Its Position as the World's Third-Largest Provider

NTT's data center strategy stands out for its emphasis on creating unique value rather than competing directly with hyperscalers. While major hyperscalers typically construct data centers to support the expansion of their own cloud services, NTT focuses on delivering data center infrastructure that can meet the diverse needs of a broad client base.

This approach is shaped in part by the unique characteristics of the Japanese market. As the value of data increases and awareness of cybersecurity continues to grow, concerns have been mounting over reliance on foreign cloud services. This is especially true among government agencies, financial institutions, and operators of critical infrastructure, where demand for domestic data centers is rising rapidly.

To address these needs, NTT has embraced support for hybrid cloud environments. Rather than migrating all systems to public cloud platforms, many companies are adopting hybrid configurations that retain critical data within privately managed clouds while utilizing public cloud services as needed. NTT's data centers are designed to accommodate such complex requirements flexibly.

Another area of differentiation is the use of edge computing. As IoT devices become more widespread, there is growing demand for processing data closer to its source rather than relying solely on centralized cloud infrastructure. Leveraging its nationwide telecommunications network, NTT is deploying a wide array of small-scale edge data centers to meet this demand.

These efforts also underpin NTT's active collaboration with hyperscalers such as AWS and Microsoft Azure. By integrating with interconnection services and pursuing strategic partnerships, NTT aims to enhance clients' convenience. In January 2025, for example, NTT DATA signed a new strategic collaboration agreement with AWS targeting the Japanese market. The agreement includes offering NTT DATA's LITRON services on AWS, developing integrated solutions that combine its OpenCanvas platform with AWS. Additionally, it provides dedicated connectivity to Microsoft Azure. NTT is also advancing efforts to offer its proprietary LLM, tsuzumi, on Microsoft's Model-as-a-Service platform.

Through these strategic initiatives, NTT has established a distinctive position in the global data center market. With a 1.6 percent share, NTT ranks third worldwide after Equinix (12.4 percent) and Digital Realty (7.1 percent). This position is not the result of competing on scale alone, but rather the outcome of a differentiated value proposition.

Elevating Data Centers as Societal Infrastructure Through Watt–Bit Integration

To further advance its data center business, NTT is pursuing a wide range of technological innovations. One such initiative is the "Data Center Trial Field" in Noda City, Chiba Prefecture. It is a facility for testing liquid-cooling technologies in data centers. Various companies are participating in proof-of-concept trials involving water-cooled servers and immersion cooling systems, with new technologies actively under development.

NTT is also moving forward with the implementation of IOWN APN, con-

Case Study

NTT Group's Data Center Transformation Initiatives

1 Connecting Data Centers to Advance AI-Driven Drug Discovery

NTT and NTT Communications, in collaboration with Mitsubishi Corporation, Morgenrot, and the IPark Institute, are conducting a joint proof-of-concept experiment to provide remote GPU computing power across the Shonan Health Innovation Park and the data centers operated by MC Digital Realty. By linking pharmaceutical R&D hubs with data center–based computational infrastructure via the IOWN APN network, the project delivers the computing resources essential for AI-powered drug discovery.

2 Offshore Data Center Operated on Renewable Energy

NTT Facilities, together with Nippon Yusen, Eurus Energy Holdings, MUFG Bank, and the City of Yokohama, is conducting a proof-of-concept project to establish an offshore data center powered entirely by renewable energy. A container-type data center equipped with solar panels and battery storage systems has been installed on a mini floating platform. The initiative aims to realize the world's first "floating green data center."

3 Next-Generation Data Center Contributing to Carbon Neutrality

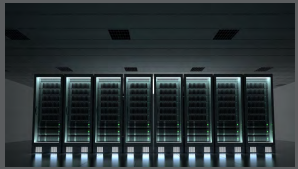
Building on its global experience in developing large-scale data centers, NTT Facilities is envisioning a next-generation data center that fully adopts liquid cooling systems to support carbon neutrality. This approach is expected to reduce energy consumption for cooling by approximately 50 percent. The higher server density enabled by the new cooling system also allows for more flexible land use, presenting a new model of data center that integrates more harmoniously with local communities.

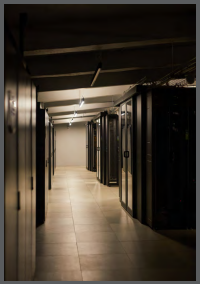
ducting trials aimed at realizing distributed data centers. Whereas conventional AI training required all GPUs to be housed within a single facility, IOWN enables GPUs distributed across multiple data centers to operate seamlessly as a unified system. This contributes to both geographic diversification and improved resiliency in times of disaster, highlighting the key role of IOWN.

The geographic diversification of data centers also has the potential to transform regional economies and urban development. The establishment of a data center can attract a range of associated businesses, such as server maintenance providers, network equipment manufacturers, and security firms, thereby creating local employment opportunities.

NTT's next-generation data center currently under construction in Tochigi City also embodies a vision of integration with the local community. The facility may repurpose waste heat from the data center to support recreational spaces, including heated pools. Looking ahead, it may also incorporate vertical farms to support stable, year-round agricultural production.

Data centers are often referred to as infrastructure for the next-generation society, but their role extends beyond supporting digital services. They are expected to serve as the foundation of future urban life. The Japanese government's GX2040 Vision, adopted by Cabinet decision in February 2025 alongside the Seventh Strategic Energy Plan, highlights "Watt–Bit Integration" as a key strategy for strengthening industrial competitiveness through energy transition and decarbonization. This concept entails the creation of new data center hubs that integrate power and communications infrastructure to optimize computing resources. It also envisions decentral-





ized, high-performance data centers distributed across diverse regions, both to respond to long-term environmental changes and to support regional revitalization, industrial growth, and national resilience. To realize Watt–Bit Integration and advance the local generation and consumption of energy and data, technologies such as IOWN APN will play an essential role. Networking data centers with energy systems and deploying servers equipped with Photonics-Electronics Convergence devices will be key to achieving greater energy efficiency.

NTT's data center strategy forms a core foundation for realizing the IOWN Vision by 2030. In the future society envisioned by IOWN, all devices will be connected through optical networks, and real-time data processing will be the norm. Achieving this vision will require data center infrastructure on an entirely different scale and dimension. Toward 2030, NTT is accelerating construction of data centers across Japan. In June 2025, the company also listed a data center–focused REIT on the Singapore Exchange, accelerating the management of six data center assets located in the United States, Austria, and Singapore. Through these efforts, NTT aims to demonstrate Japan's technological capabilities on the global stage and create new value through data centers as social infrastructure. This bold undertaking is now underway.

Data Centers as Drivers of Urban Planning

Until now, urban planning has typically expanded outward from transportation infrastructure such as railways and roads. In the future, however, cities may take shape around data centers. These facilities will optimize the management of urban operations, seamlessly integrating residential areas, commercial facilities, hospitals, and transportation systems. Networks of autonomous vehicles will enable residents to move freely without relying solely on trains and buses, while transportation and delivery systems will be continuously reconfigured to match the evolving needs of local communities. In times of natural disaster, data centers will play a central role in rapidly coordinating the restoration of essential services, contributing to resilient cities. Whereas urban planning has historically produced uniform cityscapes centered on major roads and stations, data center–oriented design could enable more distinctive, community-specific urban environments.

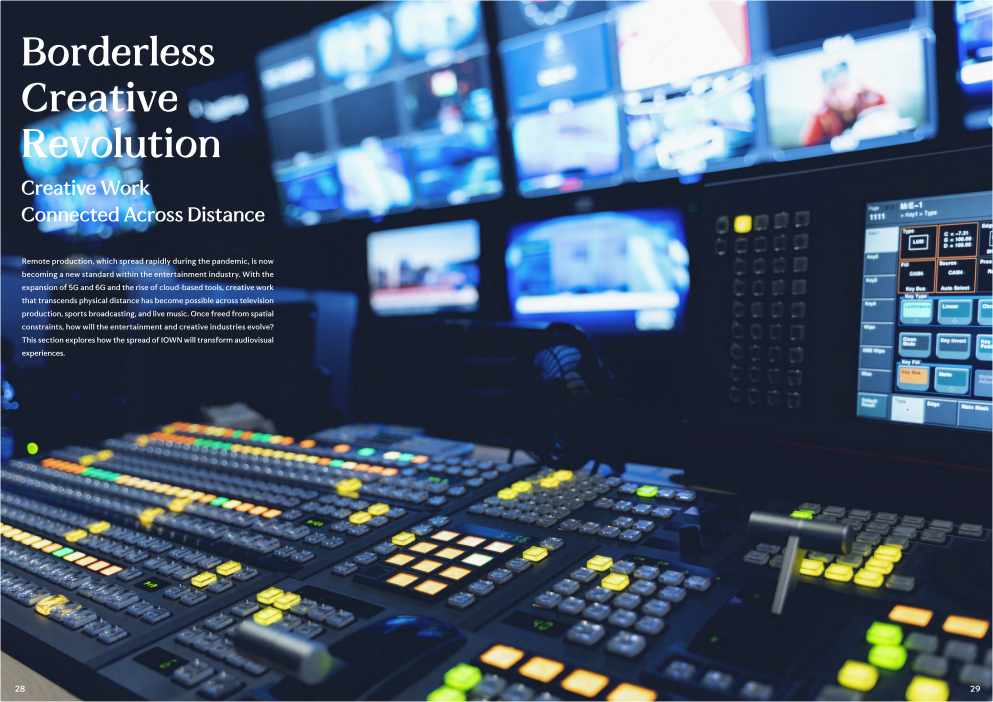
Data Centers Enriched by Nature

Looking beyond conventional efforts to reduce environmental impact, including the adoption of renewable energy, future data centers may serve as anchors for lush, nature-rich environments. Facilities like spas and wellness centers with heated pools, for example, could make use of waste heat from data centers, while the surrounding areas are transformed into green parks open to the public. Large-scale data centers have typically required expansive, centralized sites, but with IOWN enabling the integration of geographically distributed facilities into a single system, their locations can be more decentralized. In this way, data centers may evolve from being viewed as remote or impersonal infrastructure into welcoming spaces where people of all generations gather, connect, and thrive.

Borderless Creative Revolution

Creative Work Connected Across Distance

Remote production, which spread rapidly during the pandemic, is now becoming a new standard within the entertainment industry. With the expansion of 5G and 6G and the rise of cloud-based tools, creative work that transcends physical distance has become possible across television production, sports broadcasting, and live music. Once freed from spatial constraints, how will the entertainment and creative industries evolve? This section explores how the spread of IOWN will transform audiovisual experiences.



Market Trend of Remote Production

Remote Production That Overcomes Spatial Barriers

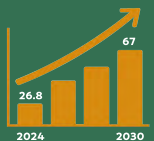
POINT 1

Rapid Market Expansion Driven by the Pandemic

Remote production technology has become a new growth engine in the entertainment industry, propelled by the societal shift toward remote operations during the COVID-19 pandemic and the rapid expansion of the metaverse market. The global remote production market is projected to grow from $2.68 billion in 2024 to $6.7 billion by 2030. A key driver of this growth is the rapid expansion of content platforms. Major platform providers are investing tens of billions of dollars annually in original content production. To enhance production efficiency and reduce costs, demand for remote production is rising accordingly. Another significant post-pandemic shift has been the establishment of hybrid production methods. The advancement of remote collaboration tools now enables creators around the world to work together on a single project. This is not a temporary trend, but a fundamental transformation of the content production ecosystem.

Global Remote Production Market Size

Unit: Hundreds of millions of dollars



POINT 2

Ultra-Low Latency Production Enabled by IOWN

Digital transformation in the remote production industry is accelerating through technological innovation. Generative AI is streamlining the creation of backgrounds, characters, and music, while developments in motion capture now allow human performances to be reflected in digital characters in real time. High-precision capture systems such as OptiTrack and Xsens, when combined with real-time rendering technology, are transforming the production process itself and enabling more interactive forms of creation. These advances are underpinned by next-generation network environments, exemplified by IOWN. With cloud rendering services enabling flexible use of production resources, and with high-capacity formats such as 8K becoming standard, networks like IOWN, which deliver ultra-low latency and high-bandwidth communication, are expected to become essential infrastructure for the creative industries of the future.

POINT 3

Advancing Talent Development and Technical Standardization

A major challenge facing the remote production industry is the shortage of skilled professionals. In addition to traditional video production expertise, remote production demands skills in game engines, 3D modeling, real-time rendering, and network technologies. Yet only about 30 percent of the required talent pool possesses these skills today. Another issue lies in the complexity of integrating multiple types of software and hardware within current production environments. This has created an urgent need for standardized technical specifications. Meanwhile, institutions such as Digital Hollywood University, Tokyo University of the Arts, and Musashino Art University are implementing educational programs tailored to remote production. Efforts toward international standardization are also advancing. Addressing these issues will be essential to unlocking the industry's continued development.

POINT 4

Paradigm Shift in Production through Metaverse Integration

According to projections by Japan's Ministry of Internal Affairs and Communications, the metaverse market is expected to reach 78 trillion yen by 2030, with remote production technologies playing a central role. The most transformative change is the complete virtualization of the production process. Physical studios and sets will become unnecessary, as all production activities shift into virtual environments. Creators, performers, and technical staff will collaborate in real time from anywhere in the world within shared digital environments. Beyond conventional film and television production, new revenue opportunities are expected to emerge in the form of live performances, virtual concerts, and interactive educational content hosted within metaverse spaces. Remote production is not merely a tool for improving efficiency or reducing labor. By removing geographic barriers, reducing costs, and democratizing access to production, remote production may fundamentally reshape our relationship with entertainment.

IOWN for Remote Production

Broadcasting Transformed by Five Milliseconds of Latency

On December 30, 2024, the 66th Japan Record Awards was broadcast live from the stage of the New National Theatre in Tokyo. Behind this event, an innovation was quietly taking place. For the first time in the world, real-time remote audio production was successfully implemented for terrestrial broadcasting, linking the New National Theatre in Shinjuku with the TBS studios in Akasaka. With the support of the IOWN All-Photonics Network, the system achieved a round-trip latency of under five milliseconds. This ultra-low latency connection signals a breakthrough that could help resolve long-standing structural issues facing the broadcast industry.

Structural Challenges in the Broadcast Industry

The broadcast industry is confronting serious structural issues. These include a shortage of video and audio technicians due to a declining and aging population, rising production costs, and the need to adapt to evolving work-style reforms. Each of these challenges is interconnected, collectively threatening the long-term viability of the industry.

The strain is particularly evident in large-scale event broadcasts. Broadcasts of concerts or sports events held in stadiums or theaters typically require extensive resources on-site, including specialized OB vans and large production crews. It is not uncommon for more than 20 staff members to be dispatched, with multiple engineers assigned solely to audio. Factoring in the transport, setup, and removal of equipment, the costs and labor requirements become substantial.

While digital transformation has advanced within the industry, enabling improved efficiency and optimization in program production, these efforts had yet to address the underlying structural constraints. In recent years, remote production technology has increasingly been seen as a potential solution. If production could take place in a studio separate from the stadium or theater, it would not only reduce costs but also allow engineers with specialized skills to work in more stable environments, helping sustain and pass on technical expertise. Yet traditional remote production methods have struggled to meet the rigorous quality standards required for live broadcasting. Latency and jitter in audio and video signals can create a sense of dissonance for viewers and heighten the risk of on-air errors.

IOWN APN's defining ability to eliminate jitter presents a potential breakthrough. In conventional networks, packet routes change dynamically, leading to jitter. By contrast, IOWN APN provides an ultra-high speed, ultra-high capacity, ultra-low latency network that eliminates this variability.

Legacy networks, operating under best-effort principles, have attempted to reduce jitter as much as possible. However, in broadcasting environments, even minimal delay or jitter is unacceptable. APN was seen as a promising candidate to meet these exceptionally demanding requirements.

By leveraging the physical properties of light, APN eliminates delays from electronic circuits and performance instability due to heat. It also enables microsecond-level synchronization between distant locations by transmitting Precision Time Protocol (PTP) signals transparently across the network.

The Significance of 5 Milliseconds of Latency Achieved by APN

Can APN truly function in live broadcasting environments? In recent years, NTT has been conducting a range of demonstration experiments with TBS

Television to address long-standing issues in the broadcasting industry. In 2024, they connected three locations—a studio in Tokyo's Minato Ward, a stadium in Saitama City, and a site in Taiwan—through a production-dedicated private cloud based in Kuramae, Tokyo. These efforts demonstrated the feasibility of large-scale, fully remote production, steadily proving the strength of APN's capabilities.

That strength came into full view on December 30, 2024, during the live broadcast of The Japan Record Awards, an annual program aired by TBS. For the first time, full remote production was realized for a major live television broadcast. The New National Theatre and TBS's Akasaka studio were connected, enabling the transmission of 64 channels of Dante-compliant audio signals with round-trip latency under 5 milliseconds. This level of performance would have been impossible using conventional IP technologies. A delay of 5 milliseconds is almost imperceptible to the human senses, allowing engineers in the studio to work as if on-site.

On the day of the event, TBS's audio team managed the New National Theatre's sound entirely from the Akasaka studio. The live performance audio was transmitted to Akasaka in real time, where skilled engineers optimized the sound quality. The adjusted audio was then sent back to the theatre and broadcast to viewers across the country.

This workflow was made possible by three defining characteristics of APN. Its high capacity enabled the simultaneous transmission of all 64 audio channels. Its low latency allowed real-time audio adjustments. And its jitter-free performance provided the stability essential for live broadcasts.

What stood out most was that even the engineers on-site detected no perceptible delay. In addition to achieving strong technical metrics, the system delivered communication quality that felt entirely natural to the people using it. This represents a major step toward practical implementation. In the past, it was often difficult to achieve optimal sound production on-site due to the acoustic characteristics of venues and equipment limitations. Now, by enabling engineers to work from familiar studio environments, it becomes possible to deliver higher-quality audio to viewers.

The reduction in labor costs is also significant. Previously, around five sound engineers had to be sent on location. In this case, more than half were able to work from the studio. This not only reduced staffing costs but also made it possible to allocate limited expert personnel more efficiently.

The success of this remote production could have far-reaching effects throughout the broadcasting industry. For regional stations in particular, the implications are substantial. They have traditionally needed to send large teams to major urban events. With remote production, these costs can be sharply reduced. Some estimates suggest that remote production could reduce costs across the industry by up to 70 percent. Such a shift could lead to a fundamental transformation in both the structure and business models of broadcasting.

Producing from stable, familiar studios

Case Study

NTT Group Expands the Possibility of Remote Production

1 Remote Production for the World Athletics Championships

NTT and TBS Television have continued joint proof-of-concept trials for remote production. In 2024, they connected three locations, the TBS studio in Tokyo, a stadium in Saitama, and Taipei, approximately 3,000 kilometers away, via APN, achieving Japan's first large-scale, full remote production. Building on this success, full-scale implementation is planned for the 2025 World Athletics Championships.

2 Starlink-Based Video Transmission

NTT Communications and TBS Television conducted a proof-of-concept trial using network slicing, a technology designed to stabilize communication. The trial simulated congested environments during live broadcasts and emergency scenarios where transmission equipment may not be fully available. By combining mobile base station vehicles with Starlink and network slicing, the team established a stable communications environment. This marked Japan's first use of Starlink video transmission in conjunction with slicing, opening the door to more flexible broadcast capabilities.

3 Multi-Stream 8K VR Transmission in the J.League

At the Meiji Yasuda J.League World Challenge 2023, NTT and NTT East conducted a trial of remote production using APN, combined with simultaneous multi-stream transmission of 8K VR video. The setup enabled immersive viewing experiences with flexible perspectives, even from remote locations. By connecting the Japan National Stadium with eXeField Akiba, they transmitted high-bitrate video in real time and allowed users to switch among multiple VR camera angles, creating the sensation of dynamically moving across the pitch.

rather than unpredictable event venues can also raise program quality. Working consistently in studio environments enables experienced engineers to train younger staff more effectively and help address the shortage of skilled successors. In terms of work-style reform, remote production reduces the burden of long travel and overnight stays. This may open the door for talented individuals to contribute regardless of gender, age, or family circumstances. Connecting Tokyo studios to regional facilities could also allow local specialists to contribute, helping to decentralize talent from Tokyo and enabling more diverse work arrangements.

IOWN as the Foundation
for a New Media Experience

The implementation of APN and realization of a full remote production environment for the Japan Record Awards marked a world first. Although interest in remote production is growing globally, few cases have yet reached a quality suitable for live broadcasting. NTT has conducted numerous proof-of-concept demonstrations connecting Taiwan and Japan via APN, paving the way for future cross-border program production.

At Osaka-Kansai Expo 2025 for example, the performance ‹CHO-KABUKI› powered by IOWN: Konjaku Kyoen Senbonzakura, Expo 2025 ver. connected performers in Taiwan to the venue, enabling them to participate naturally in the show. At the Expo, NTT West connected the venue and a data center in Osaka City using IOWN APN, and multiple broadcasters jointly tested a shared remote production environment. These efforts illustrate the wide range of possible applications for remote production.

In particular, the shared-use model demonstrated at the Expo holds significant potential to accelerate structural reform in the broadcasting industry. Rather than having each station maintain its own production facilities, broadcasters can achieve greater efficiency and cost savings by sharing a high-quality remote production environment across the industry.

Remote production is more than just a new means of content creation. It has the potential to transform the broadcasting ecosystem as a whole. From production and distribution to viewing itself, the entire landscape of audiovisual content could become fully integrated.

Beyond conventional television programming, the definition of audiovisual content may expand as it becomes possible to connect distant locations without delay or jitter. Viewer participation formats may evolve as well. While audience surveys have long been common, more advanced real-time participation in programs could become a reality, giving rise to entirely new forms of interactive media that goes beyond traditional one-way broadcasting.

In this sense, remote production could serve as a platform for creating entirely new forms of content. If remote production becomes the norm, it may

shift how programs are developed, encouraging bold new ideas and experimental concepts. By transcending the limits of time and distance, IOWN makes it possible to unleash human creativity and expertise on an unprecedented scale.

On the night of December 30th, 2024, within the imperceptible span of just five milliseconds, an infinite horizon of possibilities emerged for the broadcasting industry and society itself. By 2030, in the world envisioned by IOWN, remote production may no longer be seen as a cutting-edge innovation but rather as an ordinary part of our infrastructure. By then, the media experiences we know today will likely be completely transformed. A society where people connect across distance, across time, and beyond all constraints took a decisive step forward that night at the New National Theatre.

Virtual Broadcast Studio Connected to the World

IOWN networks will soon make it possible to link theaters, concert halls, outdoor stages, and production studios around the globe in real time, creating a virtual broadcast studio on a planetary scale. Artists active in cities such as Tokyo, New York, London, Paris, and Seoul will be able to perform together as if sharing a single stage. Temporal and spatial limitations will gradually disappear, enabling people in both rural areas and major cities to access entertainment on equal footing. Sound engineers and other professionals involved in content production will connect with ease, driving unprecedented levels of collaboration. The entire Earth will become a new stage.

Collaboration Beyond the Limits of Time and Space

Until now, live performances have generally involved audiences gathering at physical venues to watch in person, with its footage distributed via broadcast. With IOWN networks, both artists and audiences will be able to connect freely, enjoying performances interactively from any location. Audio and visual data will be transmitted in real time, along with sensory inputs such as touch and smell, enabling people worldwide to experience the same performance simultaneously. Audience members will also be able to communicate across time and space, making it possible to share sensations and experiences from anywhere on Earth, and potentially even from space, transcending all differences to enjoy performances.

Beyond Earth's Boundaries

IOWN's Network Extends Beyond Earth into Space

In recent years, the space industry has seen remarkable development. Led by the private sector, the expansion of the space economy is poised to build even more momentum as AI is leveraged for satellite data utilization. IOWN will also spread into space. The NTT Group has established new ventures to develop wireless power transmission for the lunar surface and space-based power generation as we consider the future awaiting the burgeoning space industry.

Market Trend of Space Industry

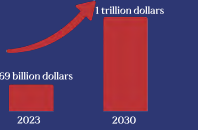
The Expanding Space Business Sector

POINT 1

Expansion of the Space Economy Driven by the Private Sector

The space industry is shifting from a government-led to a commercially driven model, propelled by active participation from private companies. The global space market, valued at $469 billion in 2023, is projected to exceed $1 trillion by 2030. In Japan, the Ministry of Economy, Trade and Industry has outlined a goal in its Space Industry Vision 2030 to double the market size from the current 4 trillion yen to 8 trillion yen by the 2030s. To achieve this, the government has launched a 1-trillion-yen Space Strategy Fund over ten years to support private-sector technology development and commercialization. In addition, the market for space data utilization is growing rapidly. New business models are emerging in areas such as agricultural optimization, disaster monitoring, urban planning, and climate change response through the use of data from Earth observation satellites. The scope of the space industry is expanding beyond outer space into a wide range of applications.

Global Space Industry Market Size Trend



POINT 2

Integration of Satellite Data and AI Technologies

Digital transformation in the space sector is advancing through the integration of satellite data and AI technologies, generating new service domains that transcend conventional space applications. In particular, the commercial use of Earth observation data is accelerating across fields such as agriculture, finance, insurance, urban planning, and environmental monitoring. A key development is the practical use of AI in satellite data analysis services. Companies like Planet Labs and Maxar Technologies are deploying machine learning algorithms to automatically extract information from satellite imagery and deliver it to clients in real time. Advancements are underway in space-based manufacturing technologies. On the International Space Station, demonstration experiments are underway involving new material development, pharmaceutical production, and 3D printing in microgravity. Once commercialized, these technologies could enable the manufacture of high-value-added products in space that are difficult to produce on Earth. Technologies in the space industry are evolving through reciprocal advances between space and Earth.

POINT 3

Talent Development and Enhancement of International Competitiveness

The shortage of specialized personnel is one of the most pressing challenges in the space business. According to Professor Shinichi Nakasuka of the University of Tokyo, expanded government investment will require the production of dozens of satellites over the next five to six years, but there is an overwhelming lack of qualified personnel. This talent shortage stems in part from the low proportion of the workforce employed in the space sector, which currently is about one person per 10,000 workers, far behind other advanced technology fields. Beyond workforce development, space business also demands long lead times in both technology development and commercialization, with many projects requiring over a decade from conception to implementation. In addition, launch failures pose additional risks, making investment recovery highly uncertain for private enterprises. Furthermore, competition with countries such as the United States, China, and India is intensifying, and Japan is falling behind in both technological and cost competitiveness. While startup activity is gradually increasing, Japan's space industry must pursue further growth.

POINT 4

Realizing Lunar Economy and Space Resource Development

Over the long term, the establishment of a lunar economy and the full-scale development of space resources are expected to expand the space business from an Earth-orbit-centric industry to one that spans the solar system—scale economic activity. Under the Artemis program led by NASA, ESA, and JAXA, operations of a crewed lunar base are slated to begin in the early 2030s, enabling continuous economic activity on the Moon. Major telecommunications providers have announced plans to offer lunar communication services by 2030, bringing continuous connectivity between lunar bases and Earth within reach. Infrastructure will also be developed for a variety of space-based businesses, including resource extraction, manufacturing, and transportation. The expansion of satellite constellations is laying the groundwork for ultra-high-speed global communications, and space-based solar power systems are nearing practical deployment. These advances will have significant implications for life on Earth. The space domain is evolving from one centered on exploration and observation to a site of integrated economic activity encompassing manufacturing, habitation, and resource development.

New Constellation from NTT 89

The 89th Constellation Dancing in the Stratosphere

In February 2025, at an altitude of approximately 20 kilometers above Kenya, an HAPS developed by the NTT Group streaked across the blue sky of the stratosphere. This marked the world's first successful direct communication between the stratosphere and a ground-based smartphone. With its new brand, "NTT C89," the NTT Group is making a bold move into the rapidly expanding space business.

Achieving the World's First Direct Communication with HAPS

NTT launched the brand "NTT C89" in June 2024 with the message "Creating the 89th constellation," aiming to build a new communications infrastructure in space and realize a networked society integrating Earth and space.

At the core of this initiative is a stratospheric communication platform known as HAPS (High Altitude Platform Station). Positioned between conventional ground base stations and satellites, HAPS holds the potential to transform the telecommunications industry. Flying at an altitude of around 20 kilometers in the stratosphere, a single HAPS unit can cover a radius of several hundred kilometers. It is expected to be a breakthrough technology for securing communications during disasters and providing services to mountainous regions and remote islands, a longstanding challenge for existing technologies.

Communications infrastructure is as essential to modern society as electricity and water. However, as depopulation and aging accelerate, maintaining infrastructure in mountainous and remote regions is becoming increasingly unprofitable. Moreover, in the face of frequent natural disasters in recent years, ground base stations are often damaged, leading to widespread communication outages. For instance, the Noto Peninsula earthquake on January 1, 2024, severely damaged many base stations, making connectivity a major challenge in affected areas.

Traditionally, the only options for communication infrastructure have been ground base stations and satellites. While ground stations provide high-quality service, they are vulnerable to disasters and constrained by terrain. Satellites can cover broader areas, but geostationary satellites at 36,000 kilometers have high latency, and low Earth orbit satellites require large numbers, leading to immense costs. HAPS is drawing attention as a third option to bridge these two extremes.

The stratosphere at 20 kilometers, where HAPS operates, is far above commercial aircraft altitudes and is less affected by weather. Operating HAPS in this environment offers the potential to combine the quality of ground base stations with the broad coverage of satellites. However, making this technology viable requires overcoming highly complex technical challenges.

In February 2025, a demonstration conducted in Laikipia County, Kenya, marked a historic moment in the development of HAPS. The test used the Zephyr, a small fixed-wing HAPS aircraft developed and operated by AALTO HAPS Limited. This aircraft had already made history in 2022 with the world's longest continuous unmanned flight at 64 days, making it a proven platform in stratospheric aviation.

Despite using the Zephyr, the demonstration posed extreme challenges. At 20 kilometers, the stratosphere is a frigid world with temperatures below minus 50 degrees Celsius and atmospheric density only about one percent

of that at sea level. This makes it impossible for ordinary aircraft to operate. In this harsh environment, the HAPS needs to maintain stable flight while establishing LTE connectivity with smartphones on the ground.

While it may sound simple, establishing a direct communication with ground-based smartphones from the stratosphere required years of technical development by engineers at NTT DOCOMO and Space Compass. The key to success was balancing the HAPS's mobility with communication quality. In the stratosphere, wind speeds can exceed 200 kilometers per hour. Stabilizing the aircraft under such conditions while maintaining precise communications with the ground was considered impossible with previous technology. However, Zephyr's advanced flight control and NTT's stratosphere-optimized communication system helped overcome the challenge.

In this demonstration, the HAPS successfully relayed LTE signals from the ground station to smartphones. This technology now offers a clear path toward delivering high-quality communication services to mountainous areas, islands, offshore zones, and disaster-stricken regions where ground base stations have limited reach.

Toward a Resilient Communication Infrastructure

HAPS (High Altitude Platform Stations) offer several technological advantages. One of the most significant is the ability to communicate directly with ground terminals. Unlike conventional satellite communications, which require multiple relay points from the terminal to the satellite and then to a ground station, HAPS can connect directly from the stratosphere to the ground terminal. This drastically shortens the communication path, dramatically reducing latency and enabling practical performance for applications that demand real-time responsiveness.

HAPS also support high-speed, high-capacity communication. Because they operate at a distance that is just one eighteen-hundredth that of geostationary satellites, signal attenuation is minimal, allowing more efficient use of higher frequency bands. As a result, a single HAPS can cover a wide area with a radius of several hundred kilometers while achieving communication speeds comparable to ground base stations. While geostationary satellites typically experience latency of about 500 milliseconds, HAPS can reduce this to just a few milliseconds. This low-latency communication is especially critical for delay-sensitive applications such as autonomous driving, remote surgery, and industrial IoT.

Globally, systems like SpaceX's Starlink hold a significant share of the market. However, low Earth orbit satellite constellations like Starlink require an enormous number of satellites, leading to extremely high operational costs. HAPS, on the other hand, can cover wide areas with a small number of units, offering a clear advantage in cost efficiency. Moreover, they can adjust their position as needed and be deployed quickly over disaster-affected areas. This mobility is a major advantage that satellites, which follow fixed orbits, cannot offer. Another strength is that HAPS can be retrieved and maintained, allowing for continuous technological upgrades and improvements.

NTT DOCOMO has launched the "Noto HAPS Partner Program" in Ishikawa Prefecture, with which it had previously signed a comprehensive partnership agreement for disaster recovery and regional revitalization. The program aims to develop use cases and recruit partners to promote the utilization of HAPS.

The Noto Peninsula Earthquake, with a seismic intensity of 7, caused extensive damage to communication infrastructure. Base stations collapsed, fiber-optic cables were severed, and power outages disabled communication facilities. These combined factors led to widespread network outages, obstructing safety checks and rescue operations. The importance of resilient communications infrastructure was once again brought to light. In such scenarios, HAPS have clear advantages. Even when ground base stations are damaged, HAPS flying in the stratosphere remain unaffected. By deploying them quickly over disaster areas, it becomes possible to restore wide-area communications within a few hours. While conventional emergency recovery methods, such as setting up temporary base stations or laying new lines, typically take days or even weeks, HAPS can significantly reduce recovery time.

Case Study

NTT Group Pioneers a New Frontier in Space

1 A New Company Providing Earth Observation Satellite Services

NTT DATA has launched a new company, Marble Visions, to develop an advanced Earth observation satellite system capable of higher-frequency and higher-precision imaging. The company aims to provide a seamless, end-to-end service from satellite imagery delivery to user decision-making support. By vertically integrating a wide range of operations including satellite manufacturing and operation, ground station management, data analysis, and application development, it is also expected to contribute to the advancement of digital twin environments that leverage diverse data from the ground.

2 Wireless Power Transmission on the Lunar Surface

NTT Space Environment and Energy Laboratories is applying its longstanding expertise in optical communication technologies to explore wireless power transmission from space using laser and microwave systems. By incorporating electric field resonance technology, the goal is to build a cable-free power transmission system, enabling the development of sustainable infrastructure on the lunar surface.

3 Space-Based Solar Power Generation Systems

NTT Space Environment and Energy Laboratories is also researching space-based solar power technology, which involves harvesting solar energy via geostationary satellites at an altitude of 36,000 kilometers and transmitting it to Earth for conversion into electricity or hydrogen. Capable of generating power nearly year-round, day and night, space-based solar power is estimated to receive approximately ten times more solar energy than ground-based systems. This virtually inexhaustible energy source holds great potential as a clean and sustainable power supply.

Demonstration tests in the Noto region are targeting a service launch in fiscal year 2028. These trials are intended not only to verify the technology, but also to emphasize collaboration with local communities. In partnership with Ishikawa Prefecture and local companies, the program will explore how HAPS can be utilized in major regional industries such as agriculture, fisheries, and tourism. For example, in agriculture, HAPS-enabled IoT sensor networks could enable large-scale monitoring of farmland environments. Real-time data on soil moisture, temperature, and humidity could support the realization of precision farming. In the fisheries sector, securing offshore communications would improve the safety of fishing vessels and facilitate the sharing of catch data.

IOWN's Potential Extends into Space

What is important is that for NTT C89, HAPS are not merely a standalone solution, but part of a broader vision of an integrated space-based computing and communication network. NTT C89 aims to connect Earth and space through an optical wireless communication network that integrates HAPS, geostationary satellites (GEO), and low Earth observation satellites (LEO).

At the core of this vision is the coordination of communication platforms across three different altitudes. HAPS, operating at an altitude of 20 kilometers, provide high-speed, low-latency communication by linking directly with the ground. Geostationary satellites at 36,000 kilometers relay optical data and perform in-orbit computing to process and transmit the massive volumes of data collected in space. Mean-

while, low Earth orbit observation satellites, located below 2,000 kilometers, are responsible for collecting Earth observation data and providing detailed, high-frequency imaging of the planet.

Of particular note is the use of optical wireless communication technology. By applying optical communication technologies that NTT has cultivated over many years to outer space, the system enables high-capacity, high-speed communication that was previously difficult to achieve using conventional radio waves. The optical data relay service developed by Space Compass reaches transmission speeds exceeding 5 Gbit/s, far surpassing the performance of existing ground station services.

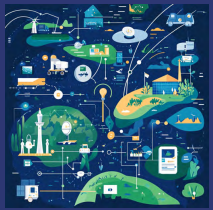
This vision of an integrated space network also represents an expansion of IOWN. By linking the terrestrial IOWN network with its space-based counterpart, it will become possible to deliver the same high-quality communication services not only throughout every corner of the Earth, but also into outer space. This integration is expected to support the expansion of human activity and the realization of a new digital society.

The faint beam of light that shone high above Kenya may one day become the 89th constellation, illuminating skies around the world. The future envisioned by NTT C89 is one in which the communication technologies developed by NTT are extended into space, unlocking limitless possibilities for humanity. The challenge that began in the stratosphere now reaches into space, and toward a new future for humankind. The first chapter of this grand story is just beginning.

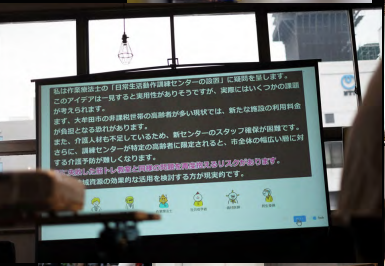
An Operating System That Watches Over Earth 24/7 from Space

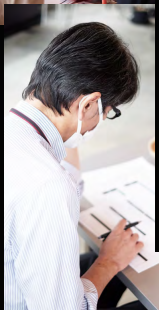
A new operating system that integrates all networks from HAPS to satellites and space stations will emerge to cover the entire planet. Constant monitoring of changes on Earth from space, 24 hours a day, 365 days a year, will enable the automatic prevention and mitigation of natural disasters and environmental changes. Early detection of threats such as typhoons, tsunamis, and wildfires will help minimize damage. While disaster response has traditionally varied across national and local governments, the ability to address global-scale environmental issues such as marine and air pollution or deforestation through a unified approach, could position IOWN as a foundational infrastructure supporting the entire planet.

A Space-Based Power Grid That Supports the Earth



As NTT continues to advance its research and development of space-based power generation technologies, a future may emerge in which solar energy collected by geostationary satellites powers Earth's electricity consumption. NTT is developing technologies to efficiently convert solar energy into laser beams, transmit beams to Earth while minimizing diffraction and atmospheric disturbances, and convert high-intensity beams into electricity and other forms of power with high efficiency. These efforts also consider supplying power to mobile platforms such as drones and vehicles. In the past, delivering electricity to remote islands or disaster-stricken areas was often difficult, but if power can be supplied anywhere, free from terrestrial constraints, the very concept of energy infrastructure will evolve. Satellites orbiting in space will become a stable infrastructure supporting our daily lives.





AI Constellation Shapes New Collaborations

The New Form of Collaboration, Made Possible by AI Constellation

A New Vision of AI for an Increasingly Complex Society

Today's business environment is marked by an unprecedented degree of complexity and volatility. The accelerating pace of globalization and the digital revolution have brought companies face to face with multi-dimensional challenges that no longer fit within conventional management frameworks. Market trends are increasingly difficult to forecast, customer needs have become more fragmented and diverse, and the competitive landscape continues to shift at an ever-quickening pace.

Traditional AI technologies have been developed as stand-alone systems, each delivering specialized capabilities within a specific domain. However, the challenges businesses face today are cross-disciplinary in nature. Effective decision-making now requires the integration of insights across areas such as finance, marketing, technology, human resources, and legal affairs, along with a holistic understanding of how these elements interact. No single AI system can adequately address such multifaceted and complex problems.

To transcend this limitation, attention is turning to the concept of multi-agent AI systems, in which multiple AIs work in collaboration to solve problems. NTT has proposed a unique approach to this emerging field: the AI Constellation. As its name suggests, the system envisions each AI agent as a distinct star, maintaining its own specialized function while working together to generate integrated value across the whole.

The Evolution from Single AI to Multi-AI Collaboration

AI technologies have traditionally evolved under a single-agent model, in which an individual AI system is assigned to a specific task. Examples include chatbots dedicated to customer service, image recognition systems focused on quality control, and data analysis tools tailored for sales forecasting. By concentrating on a narrowly defined function, these systems have achieved high levels of accuracy.

Reality, however, is more complex. Take, for instance, the challenge of developing a go-to-market strategy for a new product. This process demands the integration of multiple forms of expertise, including market analysis, competitive research, technical feasibility studies, financial impact forecasting, risk evaluation, and marketing planning. The conventional single-AI approach struggles to organically connect and coordinate these diverse elements.

To address this limitation, NTT's AI Constellation employs two distinct models of collaboration based on the nature of the problem at hand. The first, the Task-Oriented AI Constellation, is designed for the efficient execution of clearly defined operations. In this model, multiple AI agents work together with clearly assigned roles, proceeding along predefined workflows. It proves especially effective in automating and optimizing standardized business processes.

The second model, the Autonomous Discussion-Based AI Constellation, is better suited to creative and exploratory problem-solving. In this framework, AI agents with different areas of expertise and perspectives engage in active dialogue, resembling a human meeting. Each agent presents its views based on its own knowledge base and responds to others through rebuttals, additions, or questions. This process brings to

light issues and opportunities that a single viewpoint might overlook, enabling the emergence of more comprehensive and innovative solutions.

The Five Core Technologies
Underpinning the AI Constellation

NTT's AI Constellation is supported by five interrelated technological components. The first is the Generation and Retrieval of Diverse AI Agents. This technology enables the dynamic generation and discovery of optimal AI agents tailored to the nature of a given problem. Unlike conventional fixed AI models, it flexibly generates new agents by taking into account the complexity of the task and the required expertise.

The second is Dynamic Workflow Generation. This function automatically constructs the most suitable task flow based on changing problems or situational contexts. By holistically assessing the capabilities of each AI agent and the characteristics of the task, it determines and dynamically updates the ideal sequence of operations. By adjusting the workflow depending on the conditions, the problem-solving process can remain optimal. The third is Consensus Building through Autonomous Discussion, which enables constructive dialogue among AI agents with different areas of expertise. Each agent presents logical arguments based on its own knowledge domain, and critically examines the viewpoints of others. Through this iterative process, the system reaches more precise and rational conclusions.

The fourth is the Agent Pool, which efficiently manages a diverse collection of AI agents capable of handling a wide range of tasks. The expertise, capabilities, and past performance of each agent are systematically recorded, allowing the system to swiftly identify and assemble the most effective configuration of agents according to the nature of the issue at hand. Lastly, the External Knowledge Referencing and Autonomous Learning technology enables both knowledge transfer among agents and continuous learning. By leveraging knowledge graphs and hierarchical knowledge structures, it facilitates efficient knowledge sharing and mutual learning between agents. This, in turn, supports the sustained accumulation of knowledge and the ongoing enhancement of the system's overall capabilities.

Real-World Proof of Concept Through Workshops

To realize the concept of the AI Constellation, NTT is advancing a cross-organizational initiative led by the NTT Computer & Data Science Laboratories and the NTT Human Informatics Laboratories. This effort integrates basic and applied research with Proof of Concept (PoC) experiments, enabling both theoretical and practical approaches to proceed in parallel. Collaborative trials are also being actively pursued with various NTT Group companies across business domains such as telecommunications, information systems, data centers, and consulting, with each trial tailored to the specific characteristics of the respective field. These diverse demonstrations are gradually verifying the versatility and practical applicability of the AI Constellation.

That said, the realization of the AI Constellation is not something that can be achieved overnight. Tsukasa Yoshida, a researcher at the NTT Computer & Data Science Laboratories, notes, "Even when we speak of linking AIs, there are a great many factors that must be considered. Determining which AIs to combine is crucial, and there are multiple possible approaches to how they might be linked, including the methods of communication. The form in which the outputs of that collaboration are delivered also depends on the specific issues and intended uses. And before any of that, we must also consider how to design multiple specialized models in the first place."

In response to Yoshida's remarks, Takashi Takeuchi, the principal researcher and group leader overseeing the AI Constellation at the same laboratory, adds, "Connecting AI models is only a means." Indeed, the AI Constellation can take various forms depending on the issue at hand. For this reason, NTT is currently pursuing PoC experiments to explore how such AI linkages should be realized.

A representative example is the participatory workshop held in Omuta City, Fukuoka Prefecture, in October 2024, titled "Meeting Singularity: Envisioning the Future of Omuta with AI." This workshop addressed social challenges emerging in many regional cities due to population decline. By bringing together local stakeholders and experts to engage in dialogue with AI systems, the initiative examined whether deeper discussions could be achieved. With topics including support for small and medium-sized enterprises and preventive care for the elderly, citizens from diverse professions came together to explore these issues in conversation with AI.

"Through the actual workshop, we were able to confirm the usefulness of the AI Constellation in fostering consensus and expanding perspectives," says Yoshida. "The AI sometimes offered critical viewpoints that human participants might hesitate to express, which in turn stimulated discussion. We also found that by preloading local knowledge into the system, trust and familiarity toward the AI improved."

As Yoshida's reflections suggest, the use of AI in meetings, strategy planning, and ideation, whether in corporations or local governments, can have significant positive effects. Similar workshops are now being conducted in other regions, and through these repeated trials, efforts are underway to explore further use cases and fine-tuning of AI systems.

At the same time, Yoshida notes that these PoC initiatives have brought certain challenges to light. "To generate more effective discussions, a great deal of fine-tuning must be conducted beforehand. This increases the number of required settings and may raise concerns about development costs. Moreover, unless the participants already share some level of communication, it is difficult to foster constructive dialogue. In that sense, there are issues that must be addressed even prior to introducing the AI Constellation."

Innovative Approaches
to Complex Business Challenges

NTT's initiatives resonate with the current trajectory of AI development. Around the world, the evolution from large language models (LLMs) to the deployment of "AI agents" is progressing rapidly. The approach of assigning specific tasks to various AI agents to drive operational efficiency and automation is closely linked to the AI Constellation concept, in which multiple AI systems collaborate seamlessly.

While it is possible to scale a single model to address a wide range of tasks, and even to simulate diverse viewpoints, entrusting all decision-making to an AI shaped by the values of a single company or cultural context carries certain risks. Just as human collaboration thrives on the diversity of individual values, AI models should also be developed based on a variety of value systems. This view aligns with the concept of "organic alignment" that has gained attention in

the field of artificial life research. Just as the norms and rules of human society form organically, the importance of diverse AI models is expected to become increasingly recognized.

This is precisely why NTT is not focused solely on achieving efficiency and automation through massive LLMs. Instead, the company is exploring ways to generate new value through diverse AI models. The AI Constellation approach provides a fundamentally different way of addressing complex business challenges. Multiple AI agents, each with its own area of expertise, conduct analyses in parallel, sharing information in real time and engaging in ongoing dialogue. This process allows for the early identification of cross-domain interactions and latent risks that are often overlooked in traditional methods, leading to more comprehensive and accurate analysis.

Consider the example of marketing strategy formulation. A constellation of agents, specializing in market analysis, competitive analysis, customer behavior analysis, brand strategy, and financial modeling, can begin analysis simultaneously. As they share information in real time, they collaboratively develop an integrated strategy. Market opportunities and hidden risks that might be missed from a single perspective are revealed through the interaction among agents.

In the field of urban planning, agents responsible for analyzing traffic flow, environmental impact, economic effects, resident needs, and disaster preparedness work in close collaboration. Each agent dynamically updates its analysis using real-time data while continuously adjusting its proposals based on the findings of other agents. This mutual interaction enables the creation of holistic and sustainable urban plans that would be difficult to achieve through conventional siloed approaches.

When formulating corporate strategies, organizations can simultaneously evaluate the business environment, competitive landscape, internal strengths and weaknesses, technology trends, and financial feasibility. Considering multiple scenarios in parallel helps ensure the robustness of strategies in the face of environmental change. Moreover, dialogue among agents with expertise in different domains makes it possible to uncover previously unnoticed strategic opportunities and hidden risks.

By adopting the AI Constellation model, organizations can enhance decision-making quality, streamline processes, and strengthen organizational learning capabilities. These advances lead directly to improved return on investment. Greater analytical precision reduces the risk of strategic failure, while accelerated decision-making increases the likelihood of capturing market opportunities.

Perhaps most importantly, active dialogue among agents from different fields can lead to creative ideas and breakthrough solutions that would not emerge otherwise. The integration of knowledge across domains paves the way for innovation that transcends conventional boundaries.

The Dawn of a New Intelligent Society

The AI Constellation represents more than just a technological innovation. It holds the potential to fundamentally reshape how people work, how businesses operate, and how society functions. In this new paradigm, where humans and AI collaborate as equal partners in solving complex problems, individuals will be able to focus on more creative and strategic pursuits. AI will act as a powerful intellectual partner, amplifying human judgment and complementing the limits of our cognitive capacity.

At the enterprise level, it will significantly enhance the quality and speed of decision-making, while strengthening adaptability in the face of rapid market change. It will deepen and broaden strategic thinking, providing a foundation for sustained competitive advantage. Organizational learning will also improve, enabling the systematic accumulation and application of knowledge and experience. On a broader societal level, AI Constellation can be applied to areas such as urban planning, healthcare, education, and environmental issues, domains where conventional approaches have struggled to deliver solutions. By integrating expertise across disciplines, it enables more sophisticated policymaking and strengthens society's capacity to address complex challenges.

NTT's vision for AI Constellation marks the beginning of a new era in intelligent society, where human insight and technology are organically intertwined. As we enter an age of collaboration with AI, AI Constellation will reveal its true value, by transforming the problem-solving abilities of businesses and societies and greatly enhancing potential in human intellectual activity.

The Rise of Quantum Computing

The Quantum Computing Revolution Begins

Why Do Quantum Computers Matter?

Six Questions About Quantum Computing

Quantum computers are garnering greater attention in recent years. Based on entirely different principles from the computers we have grown familiar with, what exactly are quantum computers, and why do they have the potential to solve problems previously considered computationally impossible? We pose six questions to explore the current state of research and development being pursued by companies and research institutions worldwide.

Question 1 Why Are Quantum Computers Important?

Question 2 How Much Attention Are Quantum Computers Receiving?

Question 3 What Types of Quantum Computers Exist?

Question 4 Will Quantum Computers Truly Become a Reality?

Question 5 What Will Quantum Computers Be Used For?

Question 6 How Do Quantum Computers Relate to IOWN?

Introduction
What Are Quantum Computers?

Quantum computers are advanced computers that perform information processing by leveraging the principles of quantum mechanics. Whereas conventional computers process information using bits that are encoded as zeros or ones, quantum computers assign information to physical states called qubits and perform calculations by controlling their quantum behavior. Using qubits enables "superposition," where quantum states corresponding to both 0 and 1 exist simultaneously. Additionally, quantum computers can utilize "quantum entanglement," a state in which the logical relationships between multiple quantum states are manifest as quantum phenomena. These traits are expected to enable computational capabilities fundamentally different from conventional systems.

Question 1

Why Are Quantum Computers Important?

Quantum computers use "superposition" and "quantum entanglement" to enable calculations beyond the capabilities of conventional computers, achieving exceptional processing speeds for specific tasks involving complex combinations and scenarios. Problems previously deemed unsolvable, such as factoring large numbers or simulating complex molecular structures, can be tackled with orders-of-magnitude greater efficiency, potentially heralding a new industrial revolution. At extremely small scales, the physical world operates according to quantum mechanics, where superposition and entanglement are inherent natural phenomena. This means the universe itself rests on a foundation of vast, complex combinations that conventional computers cannot adequately model, from material properties to the mechanisms of life. We have barely begun to tap into this rich potential. Whereas conventional approaches have relied on experience, approximation, and limited computational resources to understand nature, quantum computers promise to enable access to nature's quantum depths, opening up new avenues to achieve more abundant co-existence with nature, through advances in drug discovery, materials development, chemical reaction design, control of biological phenomena, and other fields.

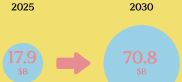
Classical Computer

Quantum Computer

Question 2

How Much Attention Are Quantum Computers Receiving?

Investment in quantum computing is growing rapidly. The global market, valued at approximately $1.79 billion in 2025, is projected to expand to $7.08 billion by 2030. Governments worldwide have identified quantum computing as a strategic priority: China leads with over $15 billion in public investment, followed by Europe with over $7 billion and the United States with nearly $4 billion. In the U.S., major tech companies like IBM and Google are at the forefront of R&D efforts, while Europe pursues consortium-based industry-academia partnerships. Japanese companies are also developing the technology in collaboration with public institutions. Recent trends have shifted as venture capital investment settles down, and investment in China moves from tech giants to government agencies, but governments, corporations, and venture capitalists continue to view quantum technology as a critical component of future competitiveness and make long-term investments.



Annual Growth Rate: Approximately 30%

Question 3

What Types of Quantum Computers Exist?

Quantum computers fall into three main categories based on their technical approach. First, superconducting systems use superconducting circuits to realize qubits. Most research today focuses on this approach, which offers the advantage of enabling qubit integration using existing semiconductor processes. However, it requires large-scale refrigeration systems to cool the computer to approximately 1 degree Kelvin—just above absolute zero. Second, "neutral atom" systems use neutral atomic states as qubits. This approach has risen in prominence with the achievement of error-correctable quantum states and small-scale quantum computation in 2024. Third, "optical" systems perform quantum information processing using photons and the phase and amplitude of light waves. These can operate at room temperature and are largely implementable with optical components. Optical approaches have demonstrated potential for large-scale, high-speed computation, but issues such as signal loss have so far prevented the creation of working quantum computers that can perform complex operations. Each approach has strengths and weaknesses, which companies worldwide, including NTT, are working to address and overcome.

Superconducting	○	Enables stable control. Most advanced in development with early practical implementation expected.
	×	Requires large-scale cooling systems consuming significant power, presenting scalability challenges.
Neutral Atom	○	Recently gaining attention due to rapid performance improvements; relatively easier to scale than superconducting systems.
	×	Faces challenges in qubit coupling and computational speed.
Optical	○	Operates at room temperature and pressure, allowing compact devices and easier scaling.
	×	Quantum states are unstable, requiring generation of squeezed light with quantum properties.

Question 4

Will Quantum Computers Truly Become a Reality?

While researchers have had partial success in building quantum computers, no methods have yet approached the estimated one million qubits considered necessary for useful general-purpose computation. Continued progress depends on error correction technology to detect and fix quantum state errors caused by noise, which is essential for large-scale computation. Additionally, scaling up by a factor of 100 to 1,000 from current levels presents challenges in miniaturizing and integrating cooling systems and control mechanisms while reducing power consumption. Time-domain multiplexed optical systems offer advantages for scaling using the time domain, but this requires further advances in optical component performance. Despite these challenges, the active research efforts underway worldwide could result in general-purpose quantum computers arriving sooner than earlier estimates of around 2050. Among various quantum computing development efforts, some systems useful for practical applications are expected to emerge around 2030, although they may not be fully mature.

Question 5

What Will Quantum Computers Be Used For?

Quantum computer applications will develop in stages. We are currently in the NISQ (Noisy Intermediate-Scale Quantum) era, where some practical applications are beginning to emerge despite error rates. Optimization problems like traffic congestion mitigation and delivery route planning can be approached, albeit with limited scope. Research institutions are therefore accelerating development of FTQC (Fault-Tolerant Quantum Computers) capable of error correction. As these systems tackle more complex problems, they could potentially break modern cryptographic systems like RSA encryption. However, fields like the development of new drugs and materials are likely the most impactful near-term applications. In the future, quantum computers may enable individual genetic information to be utilized for personalized medicine.

Question 6

How Do Quantum Computers Relate to IOWN?

Within the IOWN vision, computing technology is crucial for realizing Digital Twin and Cognitive Foundation. Quantum computers will play a vital role as computational infrastructure enabling real-time control of vast amounts of information, a necessary prerequisite for Digital Twin applications. Quantum-state Digital Twins and quantum computing technology will be a natural and necessary tool for building advanced Digital Twins, particularly for drug discovery and chemical reaction control. Additionally, NTT's photonic technology developed for optical communications can also be applied to optical quantum computers, and pursuit of this ultimate technology will contribute to further refinement of optical capabilities. NTT's extensive expertise in optical communication could be leveraged to implement long-distance quantum information transmission via optical fiber and enable distributed quantum computing. Collaboration with the photonics industry, where Japanese companies are technological leaders, should accelerate the implementation of optical quantum computers in society.

The Future of Optical Quantum Computing

Epochal Shift in Computational Methods

On November 8, 2024, an announcement made computing history. A joint research team from RIKEN, the University of Tokyo, and NTT announced the world's first general-purpose optical quantum computing platform. What is so revolutionary about an optical quantum computer? We explore the journey of NTT's optical quantum computer development.

The World's First Optical Quantum Computer

NTT has been engaged in fundamental quantum information research since the mid-1980s, well before quantum computing became a major area of study. While various implementations exist, including superconducting and ion-trap methods, optical quantum computing uniquely leverages NTT's accumulated expertise.

The greatest advantage of the optical approach lies in its ability to operate at room temperature. While superconducting systems must be cooled to near absolute zero, optical quantum computers do not require special cooling equipment. This reduces restrictions on installation environments and offers the possibility of significantly lowering operational costs. However, the realization of optical quantum computers has long been regarded as technically demanding. Photons, the quantum units of light, interact only weakly and are difficult to control.

The method that addresses these challenges is known as "continuous-variable optical quantum computing". Rather than relying on conventional digital processing based on zeros and ones, this approach employs continuous variables that draw on the wave nature of light. Built upon existing optical technologies, it enables light wave control. As a result, it opens new pathways for overcoming long-standing challenges and for realizing quantum computers that operate at room temperatures.

NTT's quantum research operates through comprehensive multi-institution collaboration. The NTT Basic Research Laboratories conducts fundamental research in functional materials science, quantum electronics, and quantum optics. Meanwhile, the NTT Theoretical Quantum Information Research Center, established in 2023, advances cutting-edge theoretical work on quantum cryptography, computing algorithms, computer architecture, and repeater technology.

NTT possesses world-leading optical technology. Precise control techniques, device technology, and fiber expertise from optical communications enabled this breakthrough. The Coherent Ising Machine "LASOLV®" solves certain 100,000-node combinatorial optimization problems approximately 1,000 times faster than digital machines, demonstrating NTT's optical advantage.

NTT also achieved the world's first quantum entanglement control between superconducting qubits and single photons. In October 2024, NTT announced a new superconducting flux qubit requiring no external magnetic field, continuing technological breakthroughs toward practical implementation.

Through this multifaceted research and development structure, NTT Research Laboratories continues producing world-leading results. The optical quantum computer represents the culmination of this accumulated research.

Collaboration across Industry, Academia, and Government

A key factor in the realization of the optical quantum computer was the collaboration with Professor Akira Furusawa of the University of Tokyo. Widely recognized as a world-leading authority in optical quantum technologies, Furusawa achieved the world's first complete quantum teleportation experiment in 1998.

The partnership between Furusawa and NTT began in the 2010s. Although the realization of optical quantum computers was theoretically possi-

ble at the time, the technical barriers made practical implementation seem far off. The turning point came from combining NTT's high-performance optical devices with Furusawa's continuous-variable quantum information processing. Conventional research in optical quantum computing had relied largely on a discrete-variable approach that controlled individual photons. Furusawa, however, proposed a continuous-variable approach that draws on the wave properties, and NTT's optical device technologies made this concept feasible.

In particular, the development of quantum light sources capable of generating highly stable quantum states, along with techniques for detecting these optical waves with high precision, enabled the generation and measurement of quantum states, the operations essential to quantum computing, to be carried out at room temperature.

In 2019, RIKEN joined the initiative, and construction of an optical quantum computer began at its Wako campus. This brought together RIKEN's knowledge of computing systems, the University of Tokyo's advanced capabilities in optical quantum experimentation, and NTT's optical technologies. This ideal collaboration enabled consistent development from basic research to practical implementation.

The core of the unveiled optical quantum computer is a device known as the Optical Parametric Amplifier (OPA), which serves as the quantum light source and was developed by NTT. Adapted from ultra-high-speed communication devices, the OPA can achieve optical quantum entanglement generation and real-time measurement at world-leading speeds.

Asuka Inoue of NTT explains: "This achievement was only possible through NTT's involvement, founded on vast knowledge from our optical communications research. Quantum light source technology exemplifies this. Conversely, insights from optical quantum computer R&D feed back into optical communications. For NTT, this R&D offers synergistic potential."

Optical Technology Bridges Quantum and Reality

The announcement in November 2024 marked a major turning point in optical quantum computer research. The system now operates as a measurement-induced analog quantum computer capable of handling one hundred quantum states, a scale far beyond previous optical platforms and a significant milestone toward practical use. This advance was enabled by NTT's long-developed technologies, particularly high-speed quantum state measurement and an ultra-broadband quantum light source. The system is also designed for broad applications such as optimization and machine learning, giving it clear potential for industrial use rather than specialization in narrow tasks.

These achievements signal that the universal optical quantum computer, once viewed as purely theoretical, is beginning to take shape as real technology.

As global efforts to develop quantum computers accelerate, Japan's optical quantum computer stands out. Its significance within NTT's IOWN initiative is expected to grow, as integrating optical quantum computing with IOWN could support network-based access to advanced computational resources.

Quantum information processing also advances communications, with quantum cryptography enabling ultimately secure key distribution based on physical laws rather than computational complexity. Using quantum entanglement or single photons, it provides protection essential for sectors such as finance, healthcare, and government, as well as domains where real-time performance and safety must coexist, including autonomous vehicles and smart city infrastructure.

NTT is also developing quantum repeater technology, working toward a "quantum internet" distributing quantum entanglement and utilizing quantum teleportation. This new network would share and transmit quantum states remotely, enabling distributed quantum computing and secure quantum cloud services.

Within the IOWN initiative, the optical quantum computer functions not only as a computational engine but as a technology that elevates the network itself.

For NTT, optical quantum computers are part of a larger quantum technology ecosystem. Researchers with diverse backgrounds are developing various technologies spanning quantum communications, sensing, and beyond.

As the culmination of forty years of research, the optical quantum computer represents a decisive step toward the practical application of quantum technologies. These technologies help construct new social systems that seamlessly integrate communication, computation, and sensing. Yet significant challenges remain, including improving error correction, reducing costs, and scaling systems, as well as establishing legal frameworks, developing a skilled workforce, and defining international standards.

This is why NTT continues to collaborate with institutions such as the University of Tokyo and RIKEN. The social implementation of quantum computers will require cooperation across traditional boundaries. Connecting quantum possibilities to reality through optical technologies will be one of NTT's crucial roles in the next-generation society.

How Quantum Computers Will Transform Society

Envisioning the Next-Generation Society through the Lens of Optical Quantum Computing

NTT's optical quantum computer is on the verge of becoming a reality. What kind of transformation might it bring to society? To go beyond concrete use cases and explore the potential for a shift at the level of civilization, science fiction author Yusuke Miyauchi joined NTT researchers Toshikazu Hashimoto and Asuka Inoue for a roundtable discussion. Their conversation offered a glimpse of the emerging relationship between humanity and quantum computing.

Quantum Computers as an Environmentally Friendly Computing Infrastructure

—Until recently, quantum computers and quantum computing were portrayed as cutting-edge elements of science fiction. Today, however, with the advent of technologies like NTT's optical quantum computer, they are becoming a reality. What kind of image have you had of quantum computers up to now?

Yusuke Miyauchi: In the world of science fiction, quantum motifs such as the measurement problem in quantum mechanics or interpretations of multiverseal worlds appear frequently, and works by authors such as Greg Egan are of particular interest in this regard. For example, in his early novel Permutation City, the story depicts a world in which people's brains are augmented and able to choose their future in a quantum manner. That said, in science fiction, quantum computers are often treated like a magic box that can do anything. They connect different universes or enable something akin to time travel.

Asuka Inoue: They are often portrayed as super machines capable of solving any problem in an instant, but in reality, quantum computers are suited to solving specific types of problems. I once read a sci-fi novel where quantum phenomena allowed all the information on Earth to be transmitted in an instant, and as a researcher in quantum computing, I certainly had some thoughts about that (laughs).

Toshikazu Hashimoto: Concrete use cases often mentioned include drug discovery, materials design, logistics and transportation, and financial portfolios. There are cases where they are used in areas such as cosmetics development as well. Problems that have been regarded as complex are represented using quantum superposition and then manipulated quantum mechanically, which allows them to be solved in fewer steps. Problems in logistics and finance, for instance, can be approached by leveraging the quantum complexity inherent in nature.

Miyauchi: That is fascinating. There are problems, like the boardgame Go or protein structures, that were once thought solvable only by quantum computers but are now being tackled by pouring massive computational resources into current AI technologies. I hope quantum computing will offer more elegant solutions to these challenges.

Hashimoto: Of course, improving efficiency through AI is extremely important. However, AI raises concerns about energy consumption and often requires large data centers. In contrast, I believe that NTT's optical quantum computers could deliver ultra-low-power, ultra-high-speed computing while keeping cooling costs low.

Inoue: Optical quantum computers may significantly reduce the power consumption of data centers and are likely to become a computing infrastructure that is friendly to the planet. Rather than continually expanding the number of power plants and data centers to meet computing demands, we may be able to build a more sustainable computing foundation.

Miyauchi: To be honest, I have long felt resistance to the idea of vast computational resources being spent on things that have little social significance, so this is encouraging to hear. Although, I suppose there is also the paradox that reducing power consumption may in turn create new demand.

Hashimoto: Much like how web conferencing improved efficiency yet increased the total number of meetings because people could now join from anywhere, anytime. As for us, we need to provide computing resources that meet a variety of needs, while thinking carefully about how they can be used to create genuine value.

Embracing Diversity through the IOWN Initiative

—Once quantum computers are put into use, how do you envision society changing?

Inoue: Once the hardware is in place, the race to discover new algorithms will begin. It will ultimately be up to humans to decide how to use these tools. As more algorithms are developed, some types of work may decrease. Looking beyond drug discovery and energy innovation, I believe we'll even see possibilities like simulating life itself.

Miyauchi: I have elderly family members, so I naturally pay close attention

Yusuke Miyauchi
Author. Born in Tokyo in 1979. Graduate of Waseda University. Winner of the Japan SF Grand Prize in 2013 for Night on the Board. In 2017, received the Mishima Yukio Prize for Garden of Kabul. Other notable works include When She Was a Psychic, Searching for Lauri Kuusk, and Child of the Cipher.

Asuka Inoue
NTT Device Technology Laboratories
Principal Research Scientist

Toshikazu Hashimoto
NTT Device Technology Laboratories
Senior Distinguished Researcher

to medical applications such as diagnostic support and drug discovery. On a broader scale, since Japan is a country prone to natural disasters, I also hope to see progress in areas such as analyzing extreme weather events, post-disaster recovery, and logistics optimization. In preparing for this discussion, I also looked into the IOWN initiative and was surprised to learn that it aims to advance understanding of diversity. Having witnessed communication divides created by technology since the Web 1.0 era, I am very interested and excited in seeing how NTT plans to implement IOWN in society.

Hashimoto: More broadly, the realization of digital twins within NTT's IOWN initiative will involve handling private information of individuals as well as urban and natural environments. Ethical considerations will become more important as systems handle personal information, with more cases where such concerns are addressed within increasingly complex computations such as life simulations. This requires enormous computational power, and quantum computers will likely serve as part of the infrastructure. At the same time, we recognize that such an infrastructure cannot be achieved by NTT alone. Once our quantum computer has been completed, we hope to expand its use through initiatives such as the IOWN Global Forum, where we collaborate with a wide range of companies, and promote its adoption as a shared computational foundation.

Miyauchi: Ordinary people, myself included, tend to immediately wonder how these technologies will be applied, and we end up asking questions in that direction. But for those engaged in fundamental research, being asked about practical applications at this stage must be difficult. Science fiction writers like myself often offer up ideas, but there's an inherent irresponsibility in that, and I always feel a sense of dilemma.

Hashimoto: NTT has established the IOWN Global Forum and is collaborating with a wide range of companies. Once quantum computers are ready for practical use, we hope to offer them as a resource to these communities as soon as possible, and accelerate their adoption as computational infrastructure.

Miyauchi: For researchers like you who are engaged in fundamental research, I imagine it's difficult to come up with immediate applications or implementations. Writers like myself often offer up ideas, but there's an inherent irresponsibility in that, and I always feel a sense of dilemma.

Inoue: As engineers and researchers, we often conduct thought experiments through the imagination of science fiction writers like yourself. Some of the technologies depicted by the writer Shinichi Hoshi fifty years ago have become reality, and more recently, we've had discussions among researchers after reading Andy Weir's Project Hail Mary. While these may not directly influence our own research, they provide valuable opportunities to gain a broader perspective on science.

"Quantum Natives" and the Formation of a New Society

— As quantum computers become more widespread, how will our society change?

Miyauchi: G. K. Chesterton, a British writer, wrote a critique of science fiction in 1904 in which he argued that even after a hundred years, the world would remain largely unchanged. There is truth in that, and such a perspective is important, but if we compare 1904 with today, we can clearly see changes such as the advent of antibiotics and the decline in infant mortality. In the same way, quantum computers may optimize supply chains and reduce various forms of waste. If we imagine further, they may even be able to simulate interactions among complex financial instruments and help prevent financial crises. These are not changes that ordinary people may tangibly perceive in their daily lives. Even so, I believe that such incremental advances constitute invaluable contributions toward the future.

Hashimoto: Life may not transform overnight, but as information technologies advance, the way we perceive value, including currency, may change. Until now, value has been exchanged using currency, but we may move toward representing value as information and exchanging it through communication.

Miyauchi: If currency emerged as a convenient tool because the world grew complex, then if quantum computers allow us to engage with complexity directly, the nature of currency may also change. Over a longer span, the concept of money itself might even disappear.

—If quantum technologies become so pervasive that society is described as a quantum civilization or a quantum society, then perhaps people's ways of thinking will change dramatically, such as money eventually vanishing.

Hashimoto: As more people grow up in a society where quantum computers have been widely deployed, a generation of so-called quantum natives may emerge, and such a shift in values could occur. Just as today's youth have a different relationship with smartphones because they have been immersed in them since birth, I think that as the number of quantum natives increases, ways of thinking will evolve and society will change accordingly.

Inoue: From the perspective of those who have long been involved in quantum research, I might be considered a kind of quantum native myself. When I recently spoke with Professor Akira Furusawa at the University of Tokyo, he was surprised that I used a laser viewer in my experiments, a card coated with fluorescent material that glows when exposed to strong light. For me, it was perfectly ordinary, but in earlier times, it was not possible to view quantum light so easily. As the next generation emerges, say ten or twenty years younger, I think their perception of quantum technologies will be quite different.

Miyauchi: In that sense, we might say that the AI-native generation might already be emerging. Today, there are people who were born in the era of rotary phones who now actively use social media platforms like X, so perhaps these changes depend greatly on the individual.

Inoue: While I wouldn't want to return to a pre-computer world, it's hard to say that the form of human happiness has changed with its advent.

Hashimoto: Just as people today take running water for granted, I think society will continue to evolve as new technologies become woven into daily life. For example, while quantum algorithms are still complex for us, it may

become second nature for quantum-native youth.

Is True AI Hidden
Within the Quantum Realm?

— When considering quantum computing on a larger scale, Mr. Miyauchi, what kinds of societal transformations do you hope to see?

Miyauchi: As simulations of life and natural phenomena become more widespread, I believe our ethics, views on life and death, and understanding of humanity may begin to shift. At the same time, when it comes to AI, we tend to operate on the premise of emulating human beings. Science fiction often depicts AI in that way, and current LLMs are also developing along that trajectory. Personally, though, I hope for something beyond imitation. Rather than reproducing human cognition through brute-force computation, I would like to see quantum computers give rise to a more elegant approach that is entirely different from what we have now.

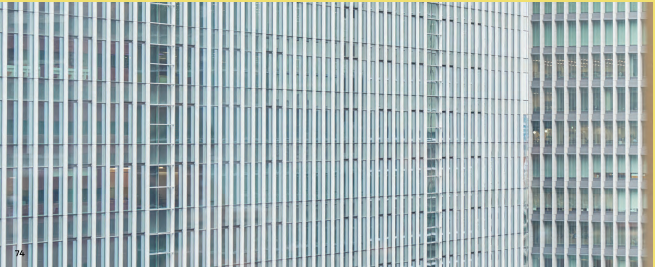
Hashimoto: Perhaps true AI lies hidden within the quantum realm. Today, we use classical computers to simulate natural phenomena or to gain insight into human thought. But it's possible that entirely different modes of thinking will emerge, modes still beyond our understanding.

Inoue: My personal view is that quantum intelligence, seen from the perspective of efficient computation, will develop together with systems of analog computation similar to the human brain. The human brain can be thought of as an extremely efficient living computer, capable of flexible and parallel processing of vast amounts of information with a small amount of energy. That computation results in strong recognition with a tolerance for noise and ambiguity, which gives it different characteristics from digital computation. On the other hand, quantum computing also enables flexible and efficient computation by making use of superposition and probabilistic behavior. It is possible that the fusion of these characteristics with analog computing methods will give rise to more advanced forms of information processing.

Miyauchi: In any case, as someone who lives on this planet, I sincerely hope that Earth can become a more sustainable place. Having lived through the evolution from rotary phones to computers, I can't help but feel that building power plants just to support data centers is not quite the future we once envisioned. That's why I place great hope in the IOWN Initiative, even if for personal perspective.

Inoue: In that sense, the optical quantum computer we are developing offers a significant advantage by dramatically lowering cooling costs, which in turn reduce the power consumption. It could prove to be a powerful solution to our energy challenges. Half-jokingly, when people ask me about my work, I say I'm a kind of "planetary defense force". Although that's an exaggeration, I do believe that quantum computers are deeply connected to the goal of planetary sustainability.

Hashimoto: At NTT, the IOWN initiative is also focusing on the concept of "paraconsistency"—rather than seeking a single definitive answer, the goal is to embrace contradictions and generate diverse solutions by incorporating multiple perspectives. Quantum computers are not only about offering sustainable computational resources. They hold the potential to fundamentally reshape the ways of thinking and modes of understanding that have been built atop classical computing. Through the development of optical quantum computers, I hope to contribute to this kind of future.



Three works of science fiction that continue to inspire quantum computing researchers

Yusuke Miyauchi
Night on the Board
The piece "A Thousand Years of Void" features a match between a shogi player and a quantum computer that claims to have solved the game in its entirety.

Greg Egan
Quarantine
Published in 1992, this early novel by world-renowned science fiction author Greg Egan explores themes such as brain augmentation through software and the quantum mechanical many-worlds interpretation. A work of hard science fiction that follows the protagonist through an epic entanglement with reality itself.

Andy Weir
Project Hail Mary
The story follows a protagonist stranded alone in space, racing to save humanity from extinction. Although quantum mechanics is not a direct motif, this widely acclaimed novel continues to inspire researchers. It is being adapted into a film set for release in the United States in 2026.

Afterword

Toward a Sustainable Future Society

In 1950, Goro Yoshida, the first director of the then-Electrical Communication Laboratory, stated: "Let us do research by drawing from the fountain of knowledge and, through practical application, deliver tangible benefits to the world." More than 70 years later, these words continue to embody the spirit of NTT's research institutes.

As this message suggests, NTT has long aspired to become a Center of Excellence (CoE) that not only advances research and development but also assumes responsibility for social implementation. In research, NTT currently ranks ninth globally and first in Japan (as of the 2019–2023 period) in the number of published papers, demonstrating world-class capabilities in areas such as optical communications, information security, and quantum computing. In development, practical implementation is rapidly progressing for foundational technologies such as IOWN and NTT's proprietary AI, tsuzumi. In social implementation, NTT pursues both market-driven and product-driven approaches. Through spin-offs from its laboratories and technical collaboration with alliance partners, a diverse array of products and services has emerged. These three interlocking cycles—research, development, and social implementation—will continue to accelerate the application of advanced technologies.

The wide-ranging efforts introduced in this year's NTT IOWN Technology Report exemplify this philosophy in practice. Social implementation is already underway in domains such as data centers, remote production, and AI Constellation. The technologies and solutions showcased at Osaka-Kansai Expo 2025 are expected to extend far beyond the event itself, enriching people's everyday lives. Expectations are also rising for the practical application of quantum computing, which has been under development for many years, in fields such as drug discovery.

Technologies such as IOWN hold intrinsic value, but it is through social implementation that their true potential is realized. NTT's aim is not simply to develop advanced technologies, but to help realize a sustainable future society. Conceived as a foundational pillar of the next-generation society, the IOWN initiative is now accelerating collaboration across diverse domains and steadily permeating every corner of our society.

Cover Visual

The exterior of the NTT Pavilion at Expo 2025 Osaka, Kansai, held from April to October this year. Designed around the keyword "natural," the pavilion was enveloped in plant-based fabric whose appearance shifts in response to wind and human movement. Its organic transformation, as if sheathed in emotions, drew significant attention..

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