Research and Development on Technologies for Transforming the Global Environment from a Space Perspective

Yuji Maeda

Abstract

NTT Space Environment and Energy Laboratories was established in July 2020 to develop innovative technologies for regenerating the global environment and achieving a sustainable and inclusive society. We are the first NTT laboratories with “space” in our name, but our purpose is not to conduct research on space itself. Rather, we study the Earth from the perspective of the space environment, including the Sun, and take on challenging studies with the aim of transforming the future of the global environment from dynamic viewpoints.

Keywords: space, environment, energy

1. Introduction

NTT embarked on new smart energy business ventures on the basis of NTT Group’s Medium-term Management Strategy “Your Value Partner 2025” announced in November 2018. Next-generation energy technologies, such as nuclear fusion, are beginning to look feasible. There are also growing expectations for the development of technologies, such as the Innovative Optical and Wireless Network (IOWN), that will break through the limitations of current technologies and contribute to the restoration of the global environment. Environmental, social, and governance (ESG) management with efforts to meet the United Nations’ Sustainable Development Goals has a significant impact on the sustainable growth of corporations. It is in this context that the NTT Group announced its Environmental and Energy Vision: Zero Environmental Impact in May 2020, and established NTT Space Environment and Energy Laboratories in July of that year to implement this vision. The purpose of the Laboratories is to develop technologies that will enable innovation in smart energy and transform the future of the global environment.

NTT Space Environment and Energy Laboratories aims to contribute to the regeneration and innovation of the global environment by re-examining the Earth and society from the higher and broader perspective of space without being restricted by conventional technologies.

2. The Laboratories’ vision

NTT Space Environment and Energy Laboratories has the following vision: to regenerate the global environment and achieve a sustainable and inclusive society to develop next-generation energy technologies that adapt to the environment and contribute to the elimination of environmental impact, i.e., zero impact.

The specific type of society that we aim for through this vision is an ultra-resilient smart city, as shown in **Fig. 1**. Our objective is not just to eliminate the impact of our society on the global environment but to bring about a society in which the impact of changes in the global environment becomes acceptable, in

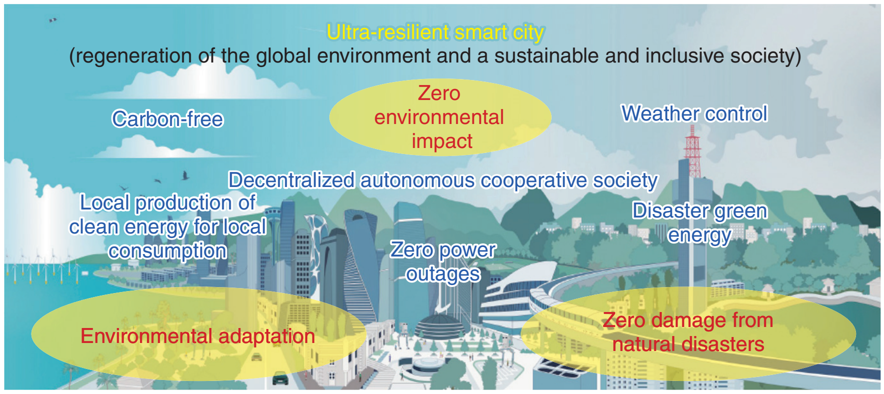

Fig. 1. Image of ultra-resilient society.

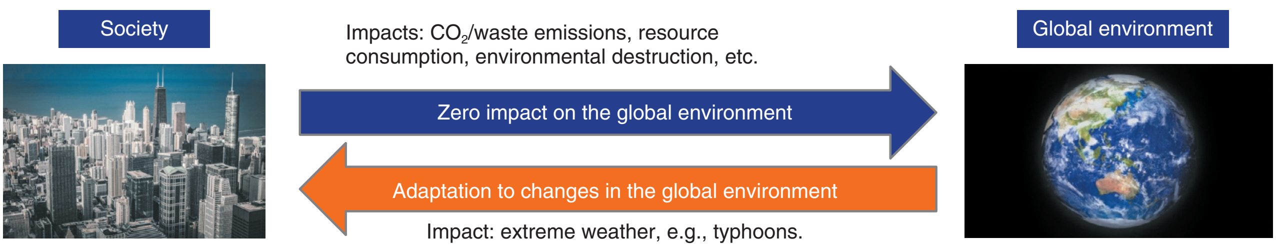

Fig. 2. Future image of the relationship between society and global environment.

which a zero power-outage state is achieved through local production of clean energy for local consumption, use of decentralized autonomous cooperative energy networks, and harnessing the power of severe weather conditions such as typhoons (**Fig. 2**). To achieve such an ultra-resilient smart city, we are conducting research and development of innovative technologies such as for the utilization of overwhelmingly clean next-generation energy, sustainable technologies including carbon dioxide (CO_2) conversion, ESG management, and proactive environmental adaptation.

3. Research topics

A list of our research topics is shown in **Fig. 3**. The Laboratories is currently focusing on two research projects: Zero Environmental Impact Research Project and Resilient Environmental Adaptation Research Project. This article presents only an overview of these projects because the details of each are described in separate articles in this issue [1–4].

3.1 Zero Environmental Impact Research Project

As shown in Fig. 3, the Zero Environment Impact Research Project is working on three topics: technology to produce overwhelmingly clean next-generation energy [1], energy network technology to enable efficient distribution of energy [2], and sustainable system technology to reduce CO_2 in the air and water [1].

For next-generation energy, we are focusing on fusion energy and space solar power generation. Fusion energy is power generation using nuclear fusion. In May 2020, NTT concluded a cooperative agreement with the ITER International Fusion Energy Organization (ITER Organization). In November 2020, a collaboration agreement was concluded with the National Institutes for Quantum and Radiological Science and Technology, which is the domestic organization of the ITER Organization. We are seeking to support successful application of the ITER nuclear fusion reactor using IOWN. The ITER Tokamak Fusion Test Reactor is scheduled to begin operation in 2025. This is an attempt to create a “mini-Sun” with the plasma temperature inside the reactor reaching

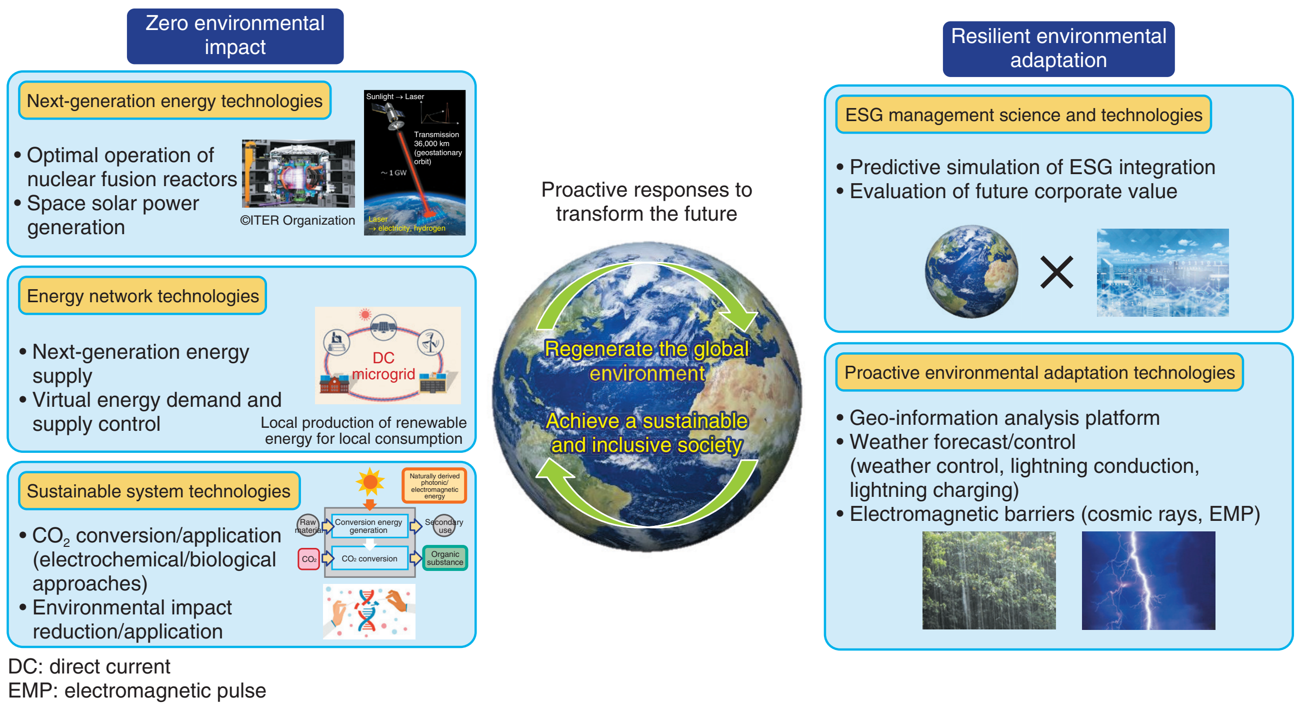

Fig. 3. List of research topics.

150 million degrees Celsius. IOWN's ultra-low-latency, high-speed, high-capacity network will be used to transmit the huge volume of sensor data coming from the test reactor to the operation center. We will also contribute to achieving optimal operation by using our Digital Twin Computing (DTC) to predict future outcomes from the collected data.

Space solar power generation is an ambitious research project in which a satellite in geostationary orbit at an altitude of 36,000 km above the ground wirelessly transmits energy from sunlight to the Earth 24 hours a day, 7 days a week. Several mechanisms have been conceived for wireless power transmission. We are focusing on using laser light. We will build on our photonics and photoelectric conversion technologies developed for telecommunications to achieve high-efficiency, ultra-long-distance wireless power transmission in the very near future.

Regarding energy network technology, we will apply the indoor direct-current (DC) power supply technology, in which we have considerable expertise, to the outdoors. We are aiming to build highly resilient, decentralized, autonomous cooperative energy networks by setting up DC transmission links between NTT buildings (central offices) and electric-power consumers' premises in their surrounding regions. The network will enable the participating companies to give and take power flexibly and efficiently. It will also enable power to be supplied stably in the event of a disaster. We are studying technology for simulating energy demand, generation, and storage in an integrated manner in cyberspace and reflecting the resultant optimal solution in the actual field to balance power supply and demand. We are also working on technology for flexibly reallocating information-processing loads for communications traffic and computation among multiple sites to efficiently use renewable energy, the generation of which is affected by weather conditions.

Sustainable systems technology is aimed at reducing CO_2 in the air and water. We intend to take two approaches. One (electrochemical) is to produce artificial photosynthesis using semiconductor and catalyst technologies. The other (biological) is to fully exploit the abilities of plants and algae. With the former, we use materials informatics[*1] to identify

*1 Material informatics: A method for achieving efficient material development. It uses information-processing technology, including artificial intelligence, to identify candidates for compounds that have desirable characteristics, on the basis of a huge volume of chemical compound data, experiment results, and simulation results.

combinations of materials that cannot be discovered with conventional approaches on the basis of experimental rules and existing concepts. With the latter, we will use DTC to reproduce a wide range of plant-growing environments in cyberspace and reflect the results in real space after verifying the effects of genome editing and environmental control.

3.2 Resilient Environmental Adaptation Research Project

The Resilient Environmental Adaptation Research Project is working on two research topics: ESG management science [3] and proactive environmental adaptation [4].

ESG management has recently become one of the important criteria for investment decisions, prompting many corporations to adopt it. However, most corporations have difficulty in effectively linking the three ESG elements. To solve this problem, we are working on ESG management science and technology with a focus on minimizing risk in ESG management by using future prediction and future transformation. Specifically, we draw on DTC to analyze data about the environment and society and predict the future of both on the basis of scientific evidence. We aim to transform the future of the global environment and human society by taking proactive actions on the basis of those predictions. For example, the corporate value and well-being of a company can be evaluated on the basis of its future prediction results. We are studying methods of predicting what actions will enhance corporate value and presenting a future scenario.

In proactive environmental adaptation, we are working on four research topics to enable aggressive and physical adaptation to weather patterns and environmental conditions, which are becoming increasingly extreme. Enhancing prediction of weather conditions and disaster damage is most critical for environmental adaptation. NTT currently predicts potential damage to telecommunications equipment from forecasts provided by the Japan Meteorological Agency.

The first of the four topics is studying geo-information-analysis platform technology for enhancing such prediction. The key to this technology is an entirely new sensing technology whereby a satellite orbiting at about 500 km collects data from Internet-of-Things sensors (920-MHz band), bundles the data, and transmits them back to Earth [5]. We are using this sensing technology to collect and analyze data from sensors on and beneath the sea and in mountainous areas, none of which are currently well monitored. We are seeking to enhance the degree of accuracy of weather forecasts and disaster-damage prediction using the analysis results.

The second topic is studying technology for proactively controlling the weather on the basis of accurate weather forecasts. For example, water mass replacement*2 can be used to lower the temperature of the Japanese coastal waters that supply energy for extreme weather events such as typhoons and trainings (line-shaped rainfall systems), thereby weakening their power. We are investigating disaster green energy. For example, typhoon power can be harnessed to generate electricity. However, it is also necessary to study the potential impact of such weather control. Therefore, we plan to simulate and evaluate such impact by exploiting DTC to reproduce the global environment in cyberspace. This will include socio-economic systems, as referred to in the explanation of ESG management science and technology. We will also predict the future in cyberspace to derive optimal solutions and implement them in the real world.

The third topic is studying lightning as one of the targets of weather control. We already have advanced measures to protect telecommunications equipment from lightning strikes. We will build upon this to study lightning control and lightning charging. Specifically, we are investigating lightning-control technology that will predict the lightning-strike area with a high degree of accuracy and induce lightning to strike a drone and lightning-charging technology for storing lightning-generated energy. We are aiming to develop an airborne lightning-energy-absorption system that will operate autonomously using lightning energy and absorb energy before a lightning strike occurs.

The fourth topic is studying measures against cosmic rays, which can be considered a “weather problem in space.” Malfunctions of semiconductors caused by cosmic rays emanating from the Sun and other stars in the galaxy are called *soft errors*. We are expanding our conventional technology for evaluating soft errors, not only to prevent soft errors on Earth but also to predict the impact of cosmic rays and electromagnetic pulses on devices and human bodies, which are directly exposed to them in outer space, and to develop electromagnetic-barrier technology, which

*2 Water mass replacement: Technology to replace warm seawater in the surface layer with cold seawater in the deep sea for cooling and power generation. There is a temperature difference of more than 30 degrees in some sea areas.

will proactively protect devices and human bodies against those phenomena. Since there are overheating risks and cosmic rays in space, it is difficult to use sophisticated electronic devices in that environment and difficult for humans to remain in space over an extended period. Once further progress is made on technology and IOWN, such facilities as space-based datacenters will become feasible.

4. Conclusion

The research projects introduced in this article are still in the embryonic stage. They have only just been initiated with modest resources, but our dreams are far more ambitious. We will strengthen our resources to take on challenges in new fields that we currently cannot undertake and work to contribute to the regeneration of the global environment and transformation of our future.

The resumption of economic activities after COVID-19 should move toward achieving a resilient society that solves problems such as climate change and marine pollution. This movement is accelerating in governments and industries around the world. Therefore, we will accelerate our research while reinforcing our resources and collaborating with partners in various industries. Stay tuned to follow the growth of our Laboratories as it works to develop innovative technologies in the environment and energy fields from a space perspective.

References

[1] K. Akiyama and K. Takaya, "Next-generation Energy-utilization and CO_2-conversion Technologies Contributing to Zero Environmental Impact," NTT Technical Review, Vol. 19, No. 6, pp. 17–21, June 2021. https://ntt-review.jp/archive/ntttechnical.php?contents=ntr202106fa2.html

[2] T. Tanaka, H. Minami, T. Tanaka, N. Nakamura, T. Hayashi, M. Kozai, Y. Higuchi, N. Hanaoka, and M. Iwamoto, "Energy-distribution Platform Technologies toward Zero Environmental Impact," NTT Technical Review, Vol. 19, No. 6, pp. 22–29, June 2021. https://ntt-review.jp/archive/ntttechnical.php?contents=ntr202106fa3.html

[3] Y. Tanaka, X. Zhang, and M. Shinozuka, "ESG Management Science and Technology for a Sustainable and Inclusive Society," NTT Technical Review, Vol. 19, No. 6, pp. 30–36, June 2021. https://ntt-review.jp/archive/ntttechnical.php?contents=ntr202106fa4.html

[4] J. Kato, "Proactive Environment Adaptation Technology for Living Safely and Securely," NTT Technical Review, Vol. 19, No. 6, pp. 37–41, June 2021. https://ntt-review.jp/archive/ntttechnical.php?contents=ntr202106fa5.html

[5] NTT press release issued on May 29, 2020 (in Japanese), https://www.ntt.co.jp/news2020/2005/200529a.html

Yuji Maeda

Vice President of NTT Space Environment and Energy Laboratories.

He received a Ph.D. in systems information science from Future University Hakodate, Hokkaido, in 2013. He joined NTT Telecommunication Networks Laboratories in 1991. He has been engaged in managing projects related to general emergency management such as those concerning natural disaster response and cybersecurity. He received the Scholarship Encouragement Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 1998. He is a senior member of IEICE and a member of the Institute of Electrical and Electronics Engineers (IEEE).