R&D of Innovative Technologies in Space, Environment, and Energy

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Abstract

It has been two years and seven months since NTT Space Environment and Energy Laboratories was established with the aim of creating innovative technologies for regenerating the global environment and achieving a sustainable and inclusive society. During this time, we have proposed many unconventional research themes heretofore nonexistent at NTT laboratories and have been active in establishing specific themes, setting up systems, and bringing people together. At long last, NTT Space Environment and Energy Laboratories is taking shape. This article takes a new look at Earth from the viewpoint of space and describes the current state of various challenges to be met to change the future of the global environment.

Keywords: space, environment, energy

1. Introduction

NTT Space Environment and Energy Laboratories was established in July 2020 with the aim of taking a new look at Earth and the social environment that we live in from the high vantage point of space and through a wide variety of fields in contrast to the conventional framework of environment and energy. We thus seek to contribute to the regeneration of the global environment and development of innovative technologies.

The NTT Space Environment and Energy Laboratories vision can be summed up as follows.

"NTT Space Environment and Energy Laboratories aims to create next-generation energy technologies and resilient environmental adaptation technologies to help achieve zero environmental impact with a view to regenerating the global environment and creating a sustainable and inclusive society."

The specific image of a society that we wish to create through this vision is called a "resilient society." The idea behind this type of society is not only to make the impact on the global environment of the society that we live in more or less zero but to also enable our society to accommodate the changes in the global environment. To this end, a resilient society aims to achieve zero power outages through the local production and local consumption of green energy and use of a distributed, autonomous, and cooperative energy network. In addition to achieving zero damage by natural disasters through high-accuracy forecasting, it seeks to extract energy from typhoons (disaster green energy).

For these three years since our founding, we have been busy setting up research systems, building up our research team, and forming tie-ups with many research institutions. In particular, we have launched a website called Beyond Our Planet [1] as owned media for boosting recruitment of outside personnel and have been updating the content of this site regularly with the hope of raising the visibility of NTT Space Environment and Energy Laboratories. We have increased our staff 1.5 times since our founding and have begun more than 40 collaborative tie-ups with startup companies, outside institutions, and universities. We are thus taking up the challenge of unconventional research themes in new fields that have so far been nonexistent in NTT laboratories.

As a specific example of a resilient society we are aiming for, we launched the Resilient Society Research Group in collaboration with the National Research Institute for Earth Science and Disaster

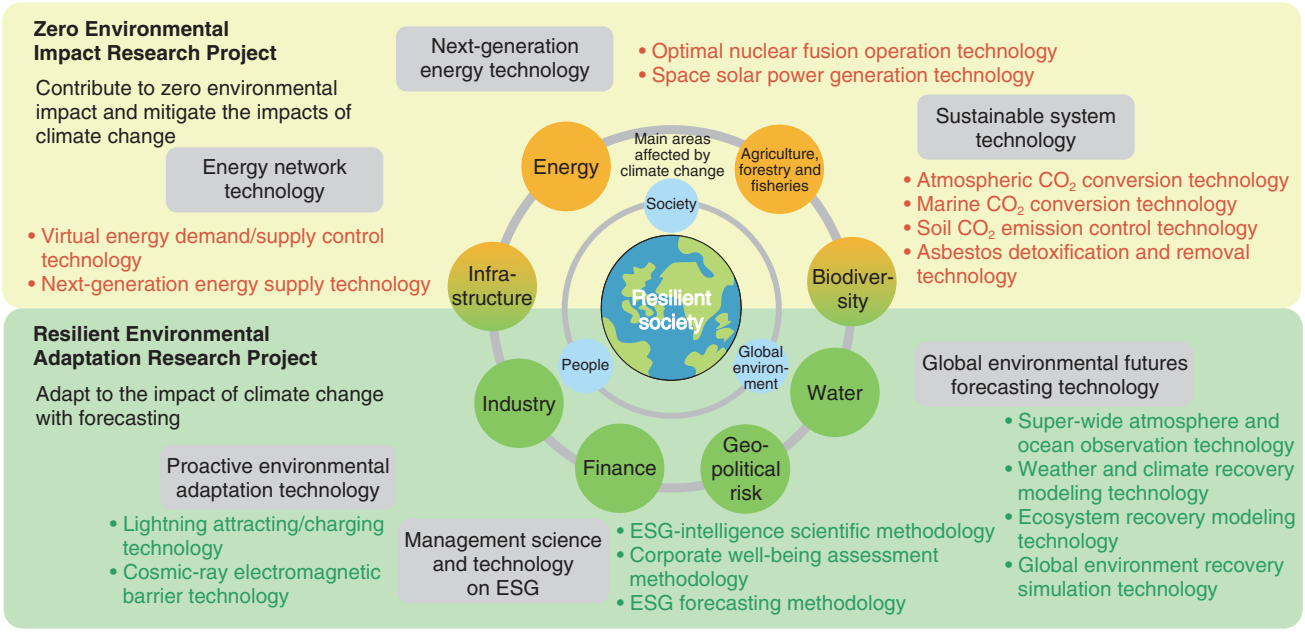

Fig. 1. Total view of research themes.

Resilience (NIED) and compiled the results of studies over a year and several months in a book titled "Realization of Resilient Society" published in April 2022 [2]. To survive a catastrophe such as an earthquake directly under the Nankai Trough or the Tokyo metropolitan area, this book investigates a resilient society that should be achieved and establishes policies for creating such a society by using new technologies based on NIED's science and technology for disaster risk reduction and NTT's Innovative Optical and Wireless Network (IOWN). It then summarizes the above in the form of joint recommendations. Since a resilient society cannot be achieved solely on the basis of technology, the book also examines new social systems and social visions that are deemed necessary together with technical innovation. Specifically, the book examines several social visions that should be adopted including a "distributed, autonomous, and cooperative society" that would eliminate the large-city, centralized type of society that excessively pursues efficiency, "Anthropocene economic society" to achieve economic growth while solving environmental problems, and "carbon-neutral and sustainable society" to coexist with the natural environment. As to how to make things better through a catastrophe, the book makes specific recommendations on "building back better."

The research themes we are now undertaking are shown in **Fig. 1**. These are divided into two main projects at NTT Space Environment and Energy Laboratories, i.e., Zero Environmental Impact Research Project at the top of the figure and Resilient Environmental Adaptation Research Project at the bottom. Each is further divided into three research groups that cooperate with one another in moving research forward. As shown at the center of the figure, our aim is to apply the results of our research to eight areas impacted by climate change and create a resilient society by reducing the impact of climate change while maintaining a balance amongst the global environment, society, and individuals. The following provides an overview of each project.

2. Zero Environmental Impact Research Project

In this project, our research aims to contribute to zero environmental impact as part of the NTT Group's Environment and Energy Vision. We are particularly researching energy network technology to supply renewable energy with good efficiency, next-generation energy technology for creating thoroughly green energy, and sustainable system technology for converting carbon dioxide (CO_2).

Energy network technology will make maximum use of renewable energy. For example, virtual energy demand/supply control technology will absorb the

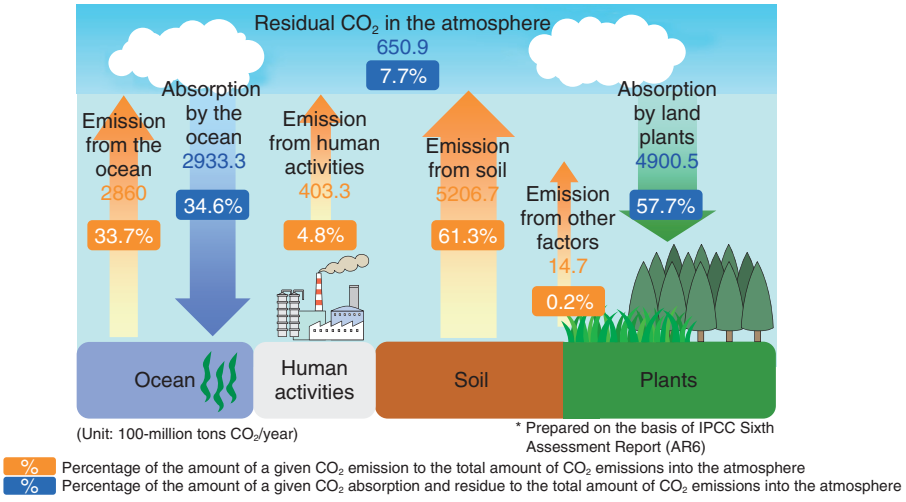

Fig. 2. The overall picture of global CO_2 flux.

output fluctuations in renewable energy by integrating control of the information processing workload of information and communication technology equipment in NTT's datacenters with control of storage batteries and electric vehicles. In addition, next-generation energy supply technology will make safe and reliable use of direct current (DC) power supplies possible and achieve the local production and local consumption of renewable energy and a super-resilient power supply. We have begun technology trials in collaboration with NTT operating companies and have obtained a variety of results such as technical specifications for the safe outdoor use of DC power supplies.

Next-generation energy technology includes optimal nuclear fusion operation technology to achieve stable and high-output operation of fusion reactors and space solar power generation technology to wirelessly transmit energy obtained in outer space to the ground in a large-capacity and efficient manner. Nuclear fusion power is a safe energy source that reproduces on Earth a phenomenon that occurs on the sun. Research in this field is now underway in countries worldwide aiming for commercialization in the 2050s. We are working with the National Institutes for Quantum Science and Technology in Japan and the ITER International Fusion Energy Organization on research related to the stable control of plasma in fusion reactors using IOWN. Next-generation energy technology also includes space solar power generation, which is an ambitious undertaking to use lasers or microwaves to wirelessly transmit energy obtained from sunlight by using geostationary satellites at an altitude of 36,000 km to the ground on a continuous 24/365 basis. To begin with, we are researching long-distance wireless power transmission on the ground and studying applying technology to supply power to drones, transmit power wirelessly to areas hit by a power outage, and use power in outer space, on the surface of the moon, etc.

The CO_2 flux throughout Earth is shown in **Fig. 2**. The numerical values in the figure are the results of calculations based on the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) published in August 2021. It may be surprising to some people that the amount of CO_2 emitted by human activities, which is associated mostly with energy use, is no more than 4.8% throughout Earth. Soil actually emits the most CO_2 at 61.3%, and even the ocean emits 33.7%. As for the amount of CO_2 absorbed, land plants absorb 57.7% while the ocean absorbs 34.6%. In short, while it is certainly important to decrease the amount of CO_2 emitted by human activities and to essentially make it zero, it is just as important when considering balance and circulation throughout Earth to consider and deal with the absorption/emission of CO_2 from the soil and ocean simultaneously with human activities. On land, where emissions are greater than the amount absorbed, decreasing emissions from the soil and increasing absorption by plants to achieve a better balance is a matter of urgency. It is likewise necessary to enhance its absorbing power of the ocean and decrease its emission of CO_2. In summary, there is a

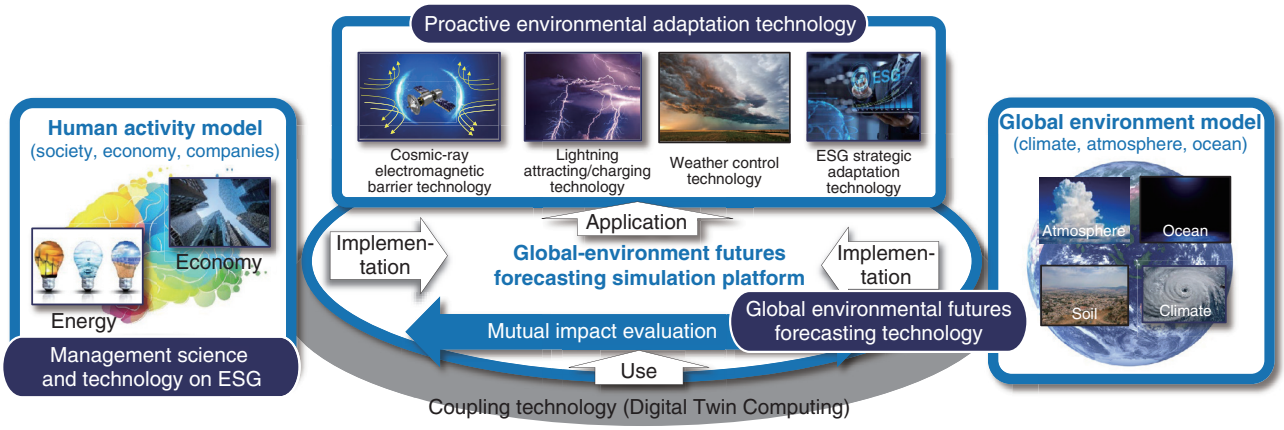

Fig. 3. Resilient Environmental Adaptation Research Project.

need to halt or reduce deforestation, soil contamination, and marine destruction/pollution while reducing CO_2 emission caused by human activities.

Sustainable system technology thus involves the research of CO_2 conversion technology for reducing CO_2 in the atmosphere, water, and soil. Specifically, we are researching the application of genome editing to plants and algae to increase CO_2 absorption and reduce CO_2 in the atmosphere in relation to the food chain and food circulation while increasing long-term fixation of carbon in the ground, in living organisms, and organic matter. We are also actively forming tie-ups with startup companies such as Regional Fish Institute, Ltd. and Euglena Co., Ltd. and expanding such activities. We are also researching the use of laser light to detoxify asbestos in construction materials.

3. Resilient Environmental Adaptation Research Project

The Resilient Environmental Adaptation Research Project has been undertaking two key research themes: management science and technology on environmental, social, and governance (ESG) and proactive environmental adaptation technology for making ultrahigh-accuracy forecasts of the global environment and society and avoiding/reducing risk. As part of this project, the Global Environmental Futures Forecasting Technology Group was established in October 2021 to boost research and development on forecasting the global environment and society on the basis of the analysis of measurement data obtained from outer space and the overall global environment (**Fig. 3**). Management science and technology on ESG seeks to construct a forecast model of human society and the economy and global environmental futures forecasting technology seeks to construct a forecast model of the climate, weather, and oceans. Coupling these two models to achieve high-accuracy forecasts on the global environment will contribute to the creation of a resilient society that can proactively and preemptively adapt to changes in the global environment.

In management science and technology on ESG, we are researching ways of forecasting in terms of human society and environmental impact. Our aim is to formulate ESG-related management strategies so that the NTT Group can resiliently adapt to even unpredictable risks to society and the economy. Since this is a new academic field, we have been conducting a variety of surveys and analyses, automating the sorting and collection/analysis of information sources, and holding discussions with outside institutions. Going forward, we plan to launch seminars and workshops at academic societies and test future predictions in actual business.

With global environmental futures forecasting technology, we aim to clarify the path to regenerating the global environment and achieve a resilient society that can adapt to changes in the environment. We will make wide-area observations of the atmosphere and oceans to create high-accuracy weather and climate models that are based on physical processes on Earth and ecosystem models that are based on biological and chemical processes on Earth. We will then use these models to forecast global regenerative processes. In this regard, there are currently few real-time observations of ocean water vapor or undersea

characteristics that act as energy sources of extreme weather such as typhoons and linear rainbands, so this is an unexplored area. We are therefore researching this area in collaboration with Okinawa Institute of Science and Technology Graduate University, Japan Agency for Marine-Earth Science and Technology, and Typhoon Science and Technology Research Center in the Institute of Advanced Sciences, Yokohama National University to measure and analyze these characteristics using satellite Internet of Things [3] and create advanced weather and climate models.

Finally, with proactive environmental adaptation technology, we are researching means of proactively adapting to lightning and cosmic rays that can now be predicted to some extent. We are researching technology for preventing damage by lightning strikes to critical facilities by using drones to attract and guide lightning to a desired location and technology for storing and using the electrical energy of lightning. After completing testing of lightning-resistant drones using artificial lightning, we conducted tests using natural lightning up to March 2022 in Uchinada Town, Ishikawa Prefecture, the area in Japan with the most lightning in winter. We will continue this testing this winter to firmly establish this technology.

The National Institute of Information and Communications Technology reports on the impact of cosmic rays, which are caused by solar activity, in the form of space weather forecasts. Cosmic rays can cause software errors and erroneous operation in semiconductors mounted on communications equipment, and technology for evaluating these errors has been advancing for some time. To further this development, we are evaluating the impact of cosmic rays on space equipment and the human body and researching cosmic-ray electromagnetic barrier technology for reducing the impact of powerful electromagnetic fields. Looking to the future, we plan to develop proactive cosmic-ray protection technology for use in outer space at locations such as space datacenters and the surface of the moon that are impacted directly by cosmic rays.

4. Conclusion

The research introduced in this article is still in its infancy, but the Feature Articles in this issue will take up several themes in which real results are starting to appear [4–7]. Readers can look forward to continued growth at NTT Space Environment and Energy Laboratories as we take up the challenge of creating innovative technologies in the fields of environment and energy from the viewpoint of space.

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