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Demonstrating 'Future Weather Forecasting' with the Latest Weather Radar and Fugaku

The Osaka-Kansai Expo, scheduled to begin in April 2025, will serve as the backdrop for a demonstration experiment of "future weather forecasting." Specifically, the project aims to predict localized heavy rain — commonly known as "guerrilla downpours" — with high accuracy, and to deliver the results in real time, by using the latest weather radar technology and the supercomputer Fugaku. We spoke with Mr. Daisuke Fujihara, who is in charge of the project at the Ministry of Internal Affairs and Communications (MIC), to learn more about the overall plan and how the results of the experiment will be used in the future.

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A Project That Brings Together Cutting-edge Technology

The concept of the Osaka-Kansai Expo is “People’s Living Lab - A laboratory for a future society.” The Expo aims to serve as a place of challenges, where diverse players — including the government, research institutions, companies, and startups — will collaborate to showcase solutions to social issues. As part of this effort, various ministries have been working since 2021 to develop action plans, and the MIC intends to conduct “future weather forecasting” as one of its plans (officially named “Demonstration of analysis and real-time delivery of high precision remote sensing data”).

“Since around 2008, MIC has been collaborating with the National Institute of Information and Communications Technology (NICT) and other organizations to develop weather radar systems. In recent years, the focus has been on developing the latest system known as the Multi Parameter Phased Array Weather Radar (MP-PAWR). When MIC started designing action plans, two MP-PAWR systems were underway and expected to begin operations in Kobe and Suita just before the Expo（Fig. 1）. So MIC made a plan to make observations in the area, including the Expo venue, with these MP-PAWRs, and use the vast amount of data gathered to carry out high-precision weather forecasting as the demonstration experiment,” Mr. Fujihara explains.

In this demonstration experiment, the plan is to update weather forecasts for the next 30 minutes every 30 seconds, with a particular focus on predicting the occurrence of guerrilla downpours. To quickly complete each step from observations by MP-PAWR to delivering forecast results, various cutting-edge technologies are integrated (Fig. 2). To carry out the weather forecast, the Data Assimilation Research Team at the RIKEN Center for Computational Science (R-CCS) analyzes massive amounts of data in real time using Fugaku.

However, that’s not all. “First, to convert observation data into a format usable for weather forecasting, we use an algorithm developed by the National Research Institute for Earth Science and Disaster Resilience (NIED). Next, to rapidly transmit vast amounts of data via the network, we utilize AI-based data compression and restoration technology developed by Preferred Networks, Inc. under a MIC contract research project. With this technology, the data is compressed before transmission and then restored on the R-CCS’s server, after which it is analyzed by Fugaku. The weather forecast results are then delivered in real time via the RIKEN’s website and

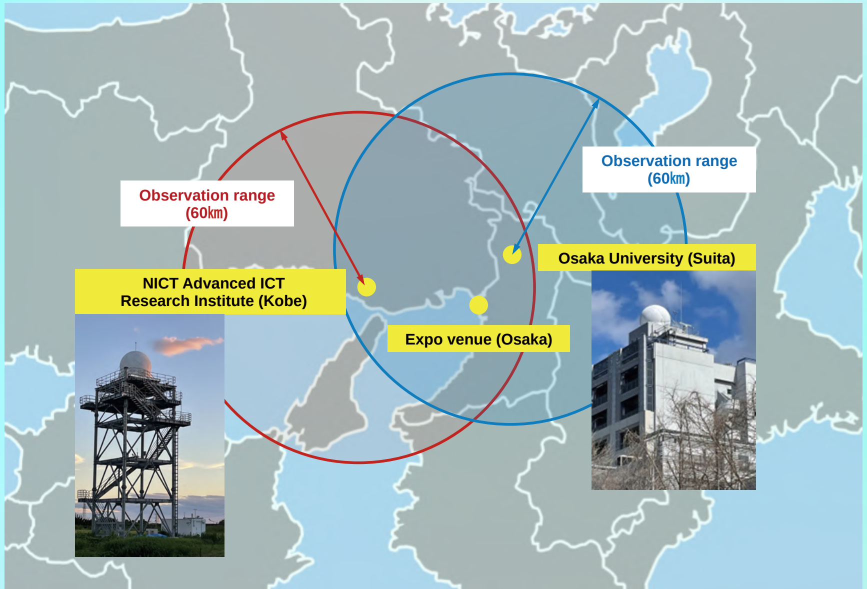

Fig. 1 : The positional relationship between the two MP-PAWRs and the Expo venue

MP-PAWR can perform 3D observations of an area with a radius of 60 km and a height of 14 km in about 30 seconds. The observation range of the two devices, installed at the NICT Future ICT Research Institute (Kobe) and Osaka University (Suita), overlaps at the location of the Expo venue. This figure is adapted from an illustration provided by NICT.

MTI Ltd.'s smartphone application '3D Amagumo Weather'." As Mr. Fujihara emphasizes, this project involves various players working together.

However, the use of Fugaku is limited to only one month during the Expo period. In this demonstration experiment, it is expected that up to 16% (about 26,000) of all Fugaku nodes could be occupied. The period during which Fugaku can be used is limited, as it is also required for other research projects.

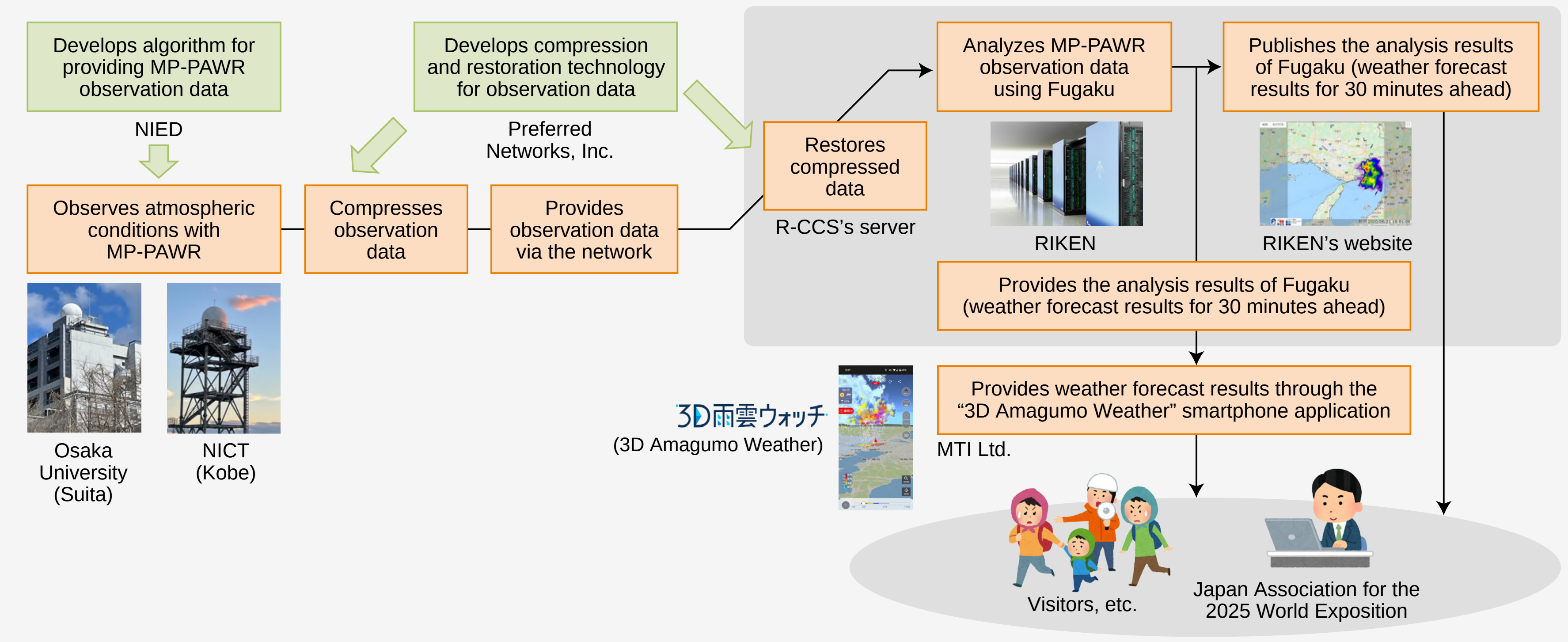

Fig. 2 : Overview of the demonstration experiment

Under the leadership of MIC, the demonstration experiment is being conducted through collaboration between the National Research and Development Agencies (NIED, NICT, and RIKEN), and private companies (Preferred Networks, Inc., and MTI Ltd.). The experiment covers everything from observations by MP-PAWR to the dissemination of weather forecast results. The forecast results will be provided to Expo visitors and, potentially, to the Japan Association for the 2025 World Exposition, which is managing the event. Under the Japanese law, weather forecasting can be performed by private businesses as long as they obtain the approval and review of the Japan Meteorological Agency. This diagram was adapted from one created by the Ministry of Internal Affairs and Communications. The forecast image in the upper right is from RIKEN's website (https://weather.riken.jp/index_en.html). The 3D Amagumo Weather logo, and image screen are provided by MTI Ltd.

The Ideal Weather Radar for Observing Guerrilla Downpours

Why is this demonstration experiment focused on predicting guerrilla downpours? Mr. Fujihara explains the reason: “In recent years, the occurrence of guerrilla downpours has been increasing, causing major social issues such as loss of life due to rapid river swelling, and flooding of subways and underpasses. However, cumulonimbus clouds, which bring about guerrilla downpours, develop quickly, and rainfall begins about 20 minutes after the formation. Therefore, if we don’t detect it around 10 minutes before the rainfall, at the stage, known as the ‘baby cell of heavy rain,’ we won’t be able to take actions such as evacuation. This is why we decided to use MP-PAWR, which enables fast 3D observations, compared to conventional weather radars, to detect ‘baby cells of heavy rain’.”

A weather radar works by rotating an antenna while emitting radio waves into the atmosphere and analyzing the reflected waves to examine rain clouds, rainfall, and other meteorological conditions. Currently, the Japan Meteorological Agency and the Ministry of Land, Infrastructure, Transport, and Tourism operate a parabolic antenna-type Multi Parameter Weather Radar (Fig. 3, left) for precipitation forecasting and wind measurements around airports. Multi Parameter refers to using two types of radio waves: horizontal polarization (where the electric field vibrates in a horizontal direction) and vertical polarization (where the electric field vibrates in a vertical direction). This system allows for high-precision rainfall observation and particle classification. However, because it requires rotating the parabolic antenna many times, each time changing its angle vertically, it takes about 5 minutes for 3D observation.

In contrast, MP-PAWR (Fig. 3, right) uses a phased array antenna with multiple antenna elements arranged in a regular pattern, electronically scanning in the vertical direction. With this system, 3D observations can be made with just one rotation of the antenna, allowing the observation time to be reduced to about 30 seconds, and enabling high-density observations with no gaps in the observation range. “If we can observe in 30 seconds, we can detect the ‘baby cell of heavy rain.’ In fact, with the phased array weather radar, which is a predecessor to MP-PAWR and uses only horizontal polarization, it was possible to capture the formation, growth, and descent of the ‘baby cell of heavy rain’ (Fig. 4),” explains Mr. Fujihara, highlighting the significance of the short observation time.

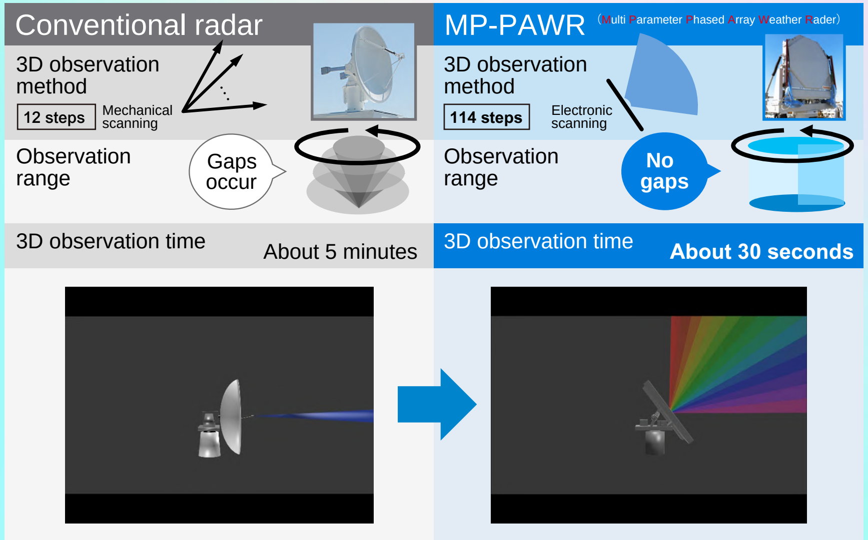

Fig. 3 : Conventional radar vs. MP-PAWR

The conventional radar changes the angle of the parabolic antenna in 12 steps and rotates it each time to perform 3D observations. In contrast, MP-PAWR uses a phased array antenna to electronically scan the vertical direction in 114 steps, allowing 3D observation with just one rotation of the antenna. With MP-PAWR, the observation time is reduced from about 5 minutes to 30 seconds (one-tenth of the time), and the observation density increases from 12 steps to 114 steps, which is almost 10 times greater. As a result, the amount of observation data produced per unit time is about 100 times larger. Illustrations provided by Osaka University.

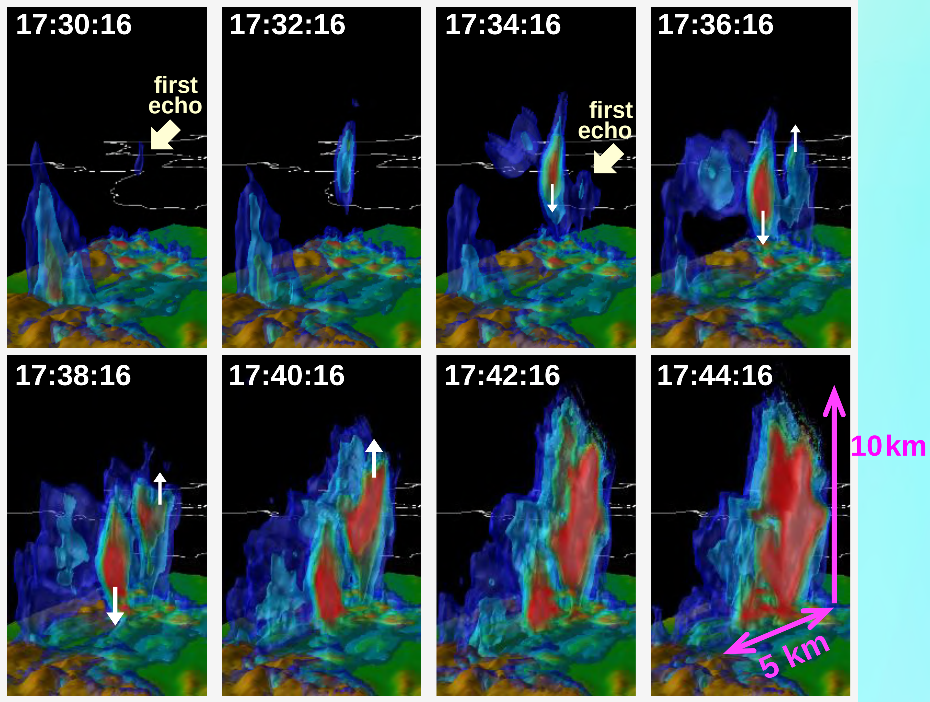

Fig. 4 : Time-series observation of cumulonimbus clouds using a phased array weather radar

This is a visualization of the radar observation results. The red color indicates a high volume of raindrops. It captures in detail the formation, growth, and descent of the "baby cell of heavy rain" (precipitation at high altitudes). This figure shows observations taken every 2 minutes, but in reality, observations are possible every 30 seconds. Illustration provided by NICT.

Quick Weather Forecasting from Massive Observation Data Using Fugaku

However, having observation data from MP-PAWR doesn't automatically mean we can immediately predict guerrilla downpours with high precision.

In general, a method called "numerical forecasting" is used to connect observation data to weather forecasting and current weather forecasts are based on the results of numerical forecasting. In numerical forecasting, much like predicting the trajectory of a thrown ball by solving physical equations, the state of the atmosphere is simulated by solving physical equations with the current atmospheric conditions as initial values, thus predicting how the state of the atmosphere will change.

Numerical forecasting is not as simple as predicting the trajectory of a ball. There are always errors in the observation data of the atmosphere, and the data available is limited to specific locations and times. Therefore, missing data has to be estimated in the simulation. Additionally, the models used for forecasting (sets of equations) are not perfect. Therefore, as the simulation continues, the calculated result (forecast) will deviate further from the true state of the atmosphere. To prevent this, numerical forecasting compares the forecast with observation data during the simulation and makes "trajectory corrections" to bring the forecast closer to the true atmospheric state (Fig. 5). This method is called "data assimilation." Moreover, to estimate errors in the numerical forecast, a method called "ensemble forecasting" is used, where simulations are run from multiple initial values. Numerical forecasting uses these various methods, which is why supercomputers are necessary.

The technology behind numerical forecasting has improved with advancements in supercomputers, but predicting guerrilla downpours has not yet been achieved because it requires analyzing highly detailed observation data with high-resolution numerical forecasting models in a short amount of time, which is more complex than standard weather forecasting. This is why Fugaku is being used in this demonstration experiment.

This needs to be explained in more detail. First, MP-PAWR generates 100

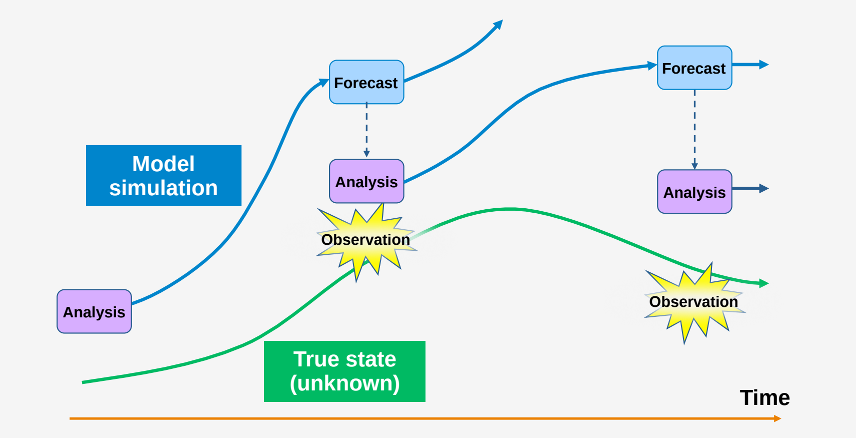

Fig. 5 : Data assimilation

As the simulation progresses, the forecast moves further away from the true state, so the trajectory is corrected by comparing it with the observation data at certain points. In the figure, the two "forecasts" are adjusted to the position of "analysis," and the simulation continues from there. It should be noted that the observation data also does not necessarily match the true state due to errors and other influences. The diagram is adapted from one provided by Dr. Takemasa Miyoshi.

times more observation data than conventional radars. The plan is to perform calculations while incorporating this massive amount of data every 30 seconds through data assimilation. Moreover, the accuracy of the forecast increases with the number of ensemble simulations, so the number of ensembles for this experiment will be set to 1,000, making the calculation volume 1,000 times larger. Furthermore, to predict such a localized event as guerrilla downpours, simulations will be carried out by dividing the ground into grids with 500-square-meter sections.

"When all of these factors are combined, the calculation volume becomes enormous, but the goal is to complete all the calculations in 3 minutes. For this reason, we have decided to use Fugaku, which has overwhelming computing power, for government-initiated projects that will be proposed to the Ministry of Education, Culture, Sports, Science and Technology by related organizations regarding policy-important issues," Mr. Fujihara says.

In the past, during the 2021 Tokyo Olympic and Paralympic Games, observation data by MP-PAWR, installed at Saitama University, was analyzed using Fugaku in a real-time demonstration experiment to predict the weather for the Tokyo metropolitan area 30 minutes ahead and update the forecast every 30 seconds. The results of this experiment were highly regarded and selected as a finalist for the 2023 ACM Gordon Bell Prize for Climate Modelling*[1].

This time, two MP-PAWRs will be used. "MP-PAWR is an excellent radar, but when heavy rain is falling, a phenomenon called 'rain attenuation' occurs, where the reflection of radio waves from behind the rain becomes weaker. By using two MP-PAWRs for observation, the impact of rain attenuation is minimized, and observation accuracy improves, which is expected to enable more accurate weather forecasting. However, since the data volume will be double that of using just one, the analysis on Fugaku will be a significant challenge," Mr. Fujihara explains, reflecting on the difficulty of this demonstration experiment.

Toward the Social Implementation of "Future Weather Forecasting"

In preparation for the real deployment, data assimilation and ensemble computation tests were conducted using offline data in July 2024, followed by connection tests transmitting and analyzing real-time data in September. Research and development for improving forecast accuracy and accelerating computation continued, and in January 2025 a rehearsal was held for the process from MP-PAWR observation to weather forecast delivery. Finally, the final checks will take place between April and June 2025, with full-scale operation expected to run around July-August 2025.

"During the Expo, the smartphone application will allow users to view the movement of rain clouds up to 30 minutes ahead in 3D. Additionally, users will receive push notifications when it is predicted that more than 30mm of heavy rain will fall. We hope that visitors to the Expo and people in the Kansai region will participate in this demonstration experiment via the smartphone application and the RIKEN's website. We believe they will experience firsthand how weather forecasting has leveled up with the combination of two MP-PAWRs and Fugaku," Mr. Fujihara says, looking forward to the full deployment.

In the social implementation following the demonstration experiment, AI is expected to play a key role. Mr. Fujihara says: "It's not feasible to use Fugaku regularly for weather forecasting, but based on the weather forecasting model developed using Fugaku in this demonstration experiment, we expect to develop AI-based forecasting models. Furthermore, AI will likely be crucial in selecting useful data from the vast amounts of observation data generated by MP-PAWR."

"While the target of this demonstration experiment is guerrilla downpours, the observation capabilities of MP-PAWR are also expected to improve the forecasting accuracy for other phenomena like lightning. It may take some time before existing weather radars are replaced by MP-PAWR, but we want to continue advancing research and demonstrations with relevant parties toward realizing 'future weather forecasting' that contributes to disaster prevention and mitigation," Mr. Fujihara says passionately. The Expo seems to be a significant opportunity to bring the future closer.

*1 The ACM Gordon Bell Prize is awarded by the Association for Computing Machinery (ACM) to the research group that achieves the most outstanding result in scientific and technological research using supercomputers during that year. It was established in 1987 by Gordon Bell, a researcher in massively parallel computing, and became an ACM award in 2006. In addition to the main prize, a special award for climate modeling was established in 2023 for a 10-year period. The recipient group of this award is decided each year based on the significance of the impact on climate modeling and broader society.

About the
Person in Charge

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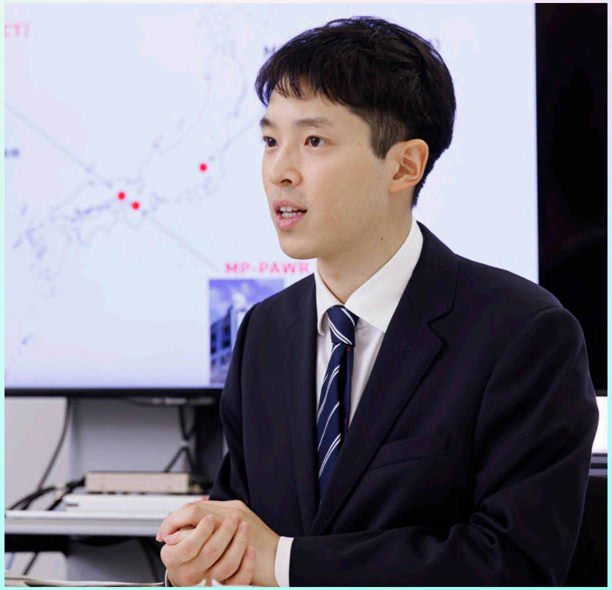

Having grown up near Osaka Itami Airport and developed a love for airplanes, Mr. Fujihara studied eVTOL in university. After graduating, he worked for an airline, where he was involved in aircraft maintenance. However, he eventually decided to switch to the Ministry of Land, Infrastructure, Transport and Tourism, as he wanted to contribute to improving safety and advancing the aviation industry as a whole. In July 2024, he was seconded to the Ministry of Internal Affairs and Communications (MIC), where he now leads the project of "future weather forecasting." Interestingly, since weather plays a crucial role in aviation operations, Mr. Fujihara had obtained a weather forecaster qualification in 2023 before his secondment to the MIC. This knowledge is now proving invaluable in his current work. Additionally, due to the involvement of many players in this project, he says that managing coordination requires a lot of attention. One of his many hobbies includes playing the bassoon in an orchestra. On weekends, he dedicates time to studying for various certification exams relevant to the aviation industry.

Interview date: December 12, 2024

Associated Research Projects:

Demonstration of analysis techniques and real-time delivery of high precision remote sensing data using Fugaku (hp240374)

Project Representative:

Shinji Ide, Office of Research Promotion, Technology Policy Division, Global Strategy Bureau, Ministry of Internal Affairs and Communications

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