Feature Stories

The DREAMS project to bring about innovative solutions to the air traffic management

D-NET2: Integrated Aircraft Operation System for Disaster Relief
The DREAMS project aims to research and develop key technologies for enabling next-generation air traffic management systems, provide a basis for establishing international standards, and promote technology transfers to manufacturers. Over the three years since its inception in May 2012, the DREAMS project has produced a wide variety of output. What sorts of technologies has the DREAMS project been working on? How will the DREAMS project develop into the future? We talked with Project Manager of the DREAMS Project Team, Yasuhiro Koshioka about these questions and more.

Meeting the demands of future air traffic

How did the DREAMS project get started?

Air traffic volume is expected to grow continuously, especially in the Asia/Pacific region, to more than double over the next 20 years. Urban airports are already crowded, and just trying to build new runways and airports will not be enough to handle this kind of increase in air traffic volume. Proportional increase in the number of accidents is also foreseeable. Therefore, technologies that enable higher frequency and safer air traffic management are in global demand. Given these conditions, countries around the world have started to recognize the need for next-generation air traffic management systems. The feature on D-NET2, meanwhile, focuses on how we are working to enable more efficient disaster relief operations through the development of an integral system that uses satellites, unmanned aerial vehicles, and other resources.

What kinds of technologies does the DREAMS project deal with?

Of all the technologies that the DREAMS project is working to establish, four types—weather information technology, noise abatement technology, trajectory control technology, and high-accuracy satellite navigation technology—are designed to help cope with expected increases in air traffic volume. These new technologies cover a diverse range of practical applications, ranging from predicting the wake turbulence and low-level turbulence that get in the way of traffic flow to high-frequency take-offs and landings, generating flight paths that minimize noise exposure range, controlling corresponding frameworks, the “NextGen” in the United States, the “SESAR” in Europe, and the “CARATS” initiative in Japan, which the Ministry of Land, Infrastructure, Transport and Tourism initiated in September 2010. JAXA thus launched the DREAMS (Distributed and Revolutionarily Efficient Air-traffic Management System) Project in 2012 to propel research and development on technologies that CARATS needs and JAXA can provide.

What is D-NET2’s Key Technology?

D-NET2: Integrated Aircraft Operation System for Disaster Relief

In a cockpit from the demonstration experimentation for “trajectory control technology”; information on low-level turbulence transmitted to the cockpit based on “weather information technology”; measurement of sound propagation using a D-NET-compatible terminal mounted on a Kobe City firefighting helicopter (photo courtesy of the Kobe City Fire Aviation Unit).

Creating the basis for new global standards

The DREAMS project to bring about innovative solutions to the air traffic management

The DREAMS project to bring about innovative solutions to the air traffic management; a D-NET-compatible terminal mounted on a Kobe City firefighting helicopter (photo courtesy of the Kobe City Fire Aviation Unit).
flight along optimized routes, and enabling high-accuracy satellite navigation that allows for ideal operations. The other type is small aircraft operation technology for disaster relief, which aims to facilitate information sharing among large numbers of rescue aircraft and relief headquarters during disaster response operations, which will allow users to assign optimal tasks, thereby reducing wasted standby time and the risk of aircraft accidents.

Four technologies that enable safe and efficient air traffic management

Why is “weather information” so crucial to high-efficiency operations?

Weather has a sizable impact on aircraft operations. In our efforts to develop weather information technology, we focused on how to make wake turbulence and low-level turbulence into account might help us boost operational efficiency while securing safety.

Wake turbulence is created by a pair of vortices that form behind an aircraft as it travels over the wings. If an aircraft finds itself following a large aircraft before the wake turbulence behind the leading aircraft has had time to dissipate, the strength of the vortices can cause extremely dangerous and potentially disrupt the attitude of the smaller aircraft. Although wake turbulence fades away naturally with time, weather conditions determine how long it takes to disappear. Therefore, if we could accurately predict how long and where the wake turbulence generated and dissipated based on various conditions, we would be able to use that prediction to ensure that aircraft take off and land more flexibly, cutting down on unnecessary waiting time efficiently and safely.

The other component of our weather information technology serves to predict wind (low-level wind) disturbances (turbulence) on approach routes. JAXA developed a low-level turbulence advisory system that, by providing predictions of low-level turbulence around the airport, assists pilots and airport operators in making decisions on continued approaches, deviations, go-arounds, and cancellations.

Will increased aircraft traffic create more noise?

Technological advances continue to quiet the various noises that aircraft emit, but just reducing the level of individual noises may not be enough. If overall aircraft traffic keeps increasing and creating longer times and more instances of noise exposure, people living around airports might feel that the noise is actually getting worse—which means that just lowering the noise level from aircraft might not be able to offset the growth in aircraft traffic.

Figure that should be considered to mitigate noise around airports is the range of noise exposure, which represents the extent of noise damage perceived on the ground. The noise abatement technology that the DREAMS project has been developing aims to keep noise exposure ranges within the present state even if the overall aircraft traffic increases by 50%. In working toward this goal, we have researched and developed technologies that predict how wind and other weather conditions affect the way noise travels and then map out optimal flight paths to minimize noise exposure ranges.

What sort of technology will it take to enable aircraft to fly low-noise flight paths?

It’ll require technology that allows an aircraft to pinpoint its position more accurately and technology that enables precise curved approaches. The DREAMS project has researched and developed high-accuracy satellite navigation and some methods that enable curved approaches, which will help meet these two needs.

GPS-based satellite navigation technologies have established a major presence in the market, but one of the problems with the GPS approach is that ionospheric disturbances and other issues can limit the availability of GPS. The proportion of time that the position information can be obtained, which requires some sort of compensatory functionality. By supplementing GPS position information with input from the inertial navigation systems (INS), that aircraft are already equipped with, we have successfully improved GPS availability to rates of 99% or higher.

Plots have traditionally used “straight-in approaches” to land at airports, painting their aircraft directly at the runway and then coming down. At most airports, the guidance systems are designed for straight approaches. In order to cope with growing capacity needs, however, airports will need to implement technologies that enable curved paths and many other approach types. The DREAMS project has thus researched and developed several methods, which allow for precise curved approaches via autopilot without placing any additional burden on the pilot.

Enabling small aircraft to operate more safely and efficiently during disaster response procedures

What are the challenges of operating aircraft in disaster situations?

JAXA also includes safety measures for small aircraft. To aid in the effort to enhance the safety operations of small aircraft, JAXA has researched and developed technologies that enable safer and more efficient operation of small aircraft—especially in disaster situations that require large numbers of small aircraft.

Even since the Great Hanshin-Awaji Earthquake, helicopters and other small aircraft have become an increasingly central part of disaster relief efforts. However, these types of aircraft have had difficulty in responding quickly and efficiently when large-scale disasters or other serious situations call for large numbers of aircraft to converge on a certain area because operators have tended to use white boards to share information and assign tasks based on the information they get on radio and other resources.

We developed a Disaster Relief Aircraft Information Sharing Network (D-NET). D-NET enables aircraft and Emergency Operations Centers (EOCs) on the ground to have visibility and optimize task assignments to establish a solid framework for safe, efficient operation management. That effort also involved formulating D-NET data specifications, a set of common standards for passing information back and forth among systems at various institutions, and developing terminals that could share information in accordance with the specifications.

The system is already in use at the Fire and Disaster Management Agency, while technology transfers to manufacturers have also spurred sales of various D-NET-compatible terminals for use on board aircraft. As a result, we’ve been starting to see firefighting helicopters and medical services helicopters equipped with D-NET terminals go into service. We’re also teaming up with institutions that don’t normally work with to develop “fully portable” D-NET terminals, which could be valuable resources during disaster-relief operations.

Establishing world-standard technologies

How will JAXA be making proposals to international standards organizations?

To put the results from the DREAMS project on the agenda at ICAO’s committees and working groups, where participating member countries discuss a diverse range of topics, we have been starting to see firefighting helicopters and medical services helicopters equipped with D-NET terminals go into service. We’re also teaming up with institutions that don’t normally work with to develop “fully portable” D-NET terminals, which could be valuable resources during disaster-relief operations.

What will happen after the completion of the DREAMS project?

The DREAMS project is set to finish at the end of FY2019, as originally planned, upon the successful completion of the development of target technologies. In order to share and promote the use of the innovations we’ve made in the broader social context, we are continuously making efforts, accelerating technology transfers to private-sector companies, and continually providing input for international deliberations with the ICAO and other international organizations. As for our small aircraft operation technology for disaster relief, building on D-NET, we’ve started, research and development on an integrated Aircraft Operation System for Disaster Relief (D-NET2) that will integrate information from satellites and unmanned aerial vehicles to enable even more efficient disaster relief activities.

Air traffic technology has always evolved to meet social needs. In the 1700s, for example, international air travel became popular, affordable, and accessible as the development of larger planes brought passenger transport costs down dramatically. To meet the needs of contemporary users of aircraft, I think we’ll be seeing aircraft technology that enables more frequent, flexible, and customized operations together with the shift from larger aircraft to smaller ones. Japanese bullet trains can run five or ten minutes. How can we get aircraft on that kind of schedule? What will we have to do to get airports to provide round-the-clock service? We might soon be talking about the kinds of technologies that would go into answering those questions. We have to keep developing the technologies we have established through DREAMS project, always keeping an eye out for what the needs of the future might be.
The DREAMS Project

How to manage ever-increasing air traffic more safely and efficiently? How will the DREAMS project benefit society? Here introduces four areas of challenges that the DREAMS project has been working on: weather information technology, noise abatement technology, trajectory control technology, and high-accuracy satellite navigation technology.

The challenges of the DREAMS project

Weather information technology: Predicting the wind to ensure safe, efficient take-offs and landings

Wake turbulence interferes with high-density operations

Wake turbulence is a form of "artificial" turbulence that occurs when the vortex created by the wings of an aircraft in flight generates turbulence behind the aircraft. Although wake turbulence disrupts naturally with time, unexpected accidents can occur if another aircraft enters an area of wake turbulence that has yet to fade out. Several countries have reported cases of wake turbulence triggering actual accidents. Not only do the size and strength of wake turbulence vary by aircraft type, but the time it takes for wake turbulence to die out also depends on the weather conditions at the time that the turbulence occurs. Despite this variability, air traffic controllers stipulate prescribed take-off and landing separation intervals to separate the first aircraft (the trailing aircraft) from the following aircraft (the trailing aircraft) based on the sizes of the two aircraft. To ensure safe operations, these intervals are often rather long. These rigid intervals can waste valuable time aircraft sometimes have to wait to take off or land even though the wake turbulence of the leading aircraft has already dissipated. There might also be instances where the intervals should actually be longer to minimize the risk of accidents.

Imagine an airport that permits take-offs and landings at a separation of three minutes, allowing for 20 aircraft to come and go per hour. If the airport were to make its "three-minute" rule more flexible and instead define a separation based on actual period of time that wake turbulence remains active, it might be able to bring the average separation to roughly 90 seconds—a pace that would enable 40 aircraft to take off and land every hour.

Tokyo International Airport's 관한-airport apparently boosted take-off and landing traffic volume by 10 aircraft per hour in 2010 by creating an additional runway. By simply optimizing take-off and landing separations, airports could thus achieve the same increase in take-off and landing volume that a new runway would create.

Measuring wake turbulence data year-round to provide a solid basis for making predictions

Weather conditions, aircraft type, and flight path all affect the ways in which wake turbulence occurs. In hopes of making accurate predictions of wake turbulence effects, the DREAMS project installed an observational system at a location 400 meters away from the take-off and landing path at Narita International Airport, obtained flight data from Japan Airlines Co., Ltd. on specific aircraft, and acquired weather data from the Japan Meteorological Agency. DREAMS researchers then observed the wake turbulence that occurred behind arriving and departing aircraft for at least one month per season (spring, summer, fall, and winter) and gathered data on which aircraft types produced what kinds of wake turbulence.

Using these findings, the DREAMS project developed a Wake Turbulence Risk Prediction Function capable of calculating safe separation that minimizes the risk of an aircraft encountering wake turbulence based on weather conditions, aircraft type, and flight path. In practice, however, there are some complications: it would be very difficult for an aircraft to reduce its separation at a moment's notice if a controller, noticing that the wake turbulence from the leading aircraft had faded away, told the pilot to come down to the runway immediately. In order for that type of traffic control to work, controllers would need to be able to predict conditions at least 30 to 60 minutes out and give instructions accordingly. The DREAMS project function makes it possible to predict what the wake turbulence conditions will be like one hour or more in advance by combining a pre-modeled wake turbulence database and a weather prediction model.

By optimizing the sequences and separation of take-offs and landings based on predictions of wake turbulence and the amounts of time that various aircraft occupy runways, the DREAMS project successfully reduced take-off and landing separation by an average of 10%.

Noise abatement technology: Taking the effects of ever-changing weather conditions on noise propagation into account to calculate flight paths that minimize noise impact

Experts suggest that increased air traffic will result in both more frequent noise bursts affecting the communities near the airport and more noise problems across larger geographical areas due to smaller aircraft that cover certain areas. In order to cope with sound problems by installing windows with two sashes or using high-noise locations for non-residential purposes, such as parks. In the interest of future traffic growth, efforts will need to focus not only on making aircraft emit less noise at the source but also on operating aircraft in ways that limit noise propagation.

Weather always affects speech propagation—what you hear downwind, for example, is sometimes inaudible upwind. Taking such variable conditions into account, the DREAMS project has developed noise abatement technology that adjusts flight paths based on weather conditions in order to keep aircraft noise levels within the current range even when overall aircraft traffic increases by 10%.

JAXA's noise abatement technology plans low-noise trajectories efficiently. These trajectories can be flown with great precision thanks to new technologies like GRAS (Ground-based Augmentation System) and the DREAMS project's precise-crafted approach. Therefore, future operations will be quieter and perceived noise will not increase.
as part of its noise abatement technology. In the first series of experiments, reference sounds were generated from a tethered balloon equipped with nozzles and, as the effects of weather on sound propagation were measured to verify the accuracy of the sound propagation prediction model. In the second set of experiments, noise from various types of commercial aircraft was measured by incorporating the manually-oversized contributions of weather profiles (data on the vertical distribution of wind direction, wind speed, and temperature) into the DREAMS project successfully built a high-precision prediction model.

Noise disturbance numerical evaluation was done in the following way. First, two traffic patterns were generated: the current Naha (International) Airport traffic and traffic reflecting a 50% traffic increase at the same airport. Next, the airport traffic generated under each traffic pattern were compared. Finally, it was demonstrated that the noise exposure ranges were essentially the same under the traffic patterns. This proved that the original goal—no increase in noise even in the event of a 50% traffic increase—can be achieved in future operations.

In order to enable flight at optimal path approaches that minimize noise propagation, JAXA plans to provide the results of its research for deliberation at meetings of the ICAO working group that evaluates technologies for environmental protection. This working group is also currently discussing and assessing ways of reducing CO2 emissions. Hirokazu Ishii, leader of the Noise Abatement Technology Section for the DREAMS project, sees these two elements as important parts of future efforts. “We will need optimal navigation technologies that can reduce noise levels and CO2 emissions at the same time.”

Trajectory control technology: enabling curved approaches using instrument flight

How high-precision curved approaches help ensure safe navigation in high-density conditions

The DREAMS project’s noise abatement technology maps out optimal flight paths for keeping noise-experiencing areas to a minimum. These flight paths are not always straight, however: in some cases, the optimal flight path might make a curving wrap-around to avoid a residential area. Curved approaches also represent an effective way of averting wake turbulence, which JAXA’s DREAMS Project Team explores methods to augment GPS- and GBAS-based satellite navigation. These improvements reduce the amount of time without access to high-accuracy satellite navigation by half, putting rates of availability (the proportion of time that users can use the technology at over 99%). Conventional satellite navigation equipment can have trouble receiving GPS signals due to the effects of aircraft movement and radio wave environment, but using the aircraft movement information from an INS allows GPS receivers to improve signal tracking performance and reduce the occurrence of radio wave interruptions. An aircraft’s satellite navigation system still has trouble receiving radio waves.

Combining GPS, GBAS, and INS to boost rates of satellite navigation availability

In order to follow a set route exactly, a pilot needs to know exactly where his or her aircraft is. Most aircraft these days feature satellite navigation equipment, similar to car navigation devices, that collects radio waves from GPS satellites to give pilots a clear idea of where they are. However, satellite navigation involves acquiring radio waves from multiple satellites—and if the radio waves from GPS satellites fail to reach the aircraft for some reason, there is no way for the aircraft to make use of the positioning information. Multipath errors, jamming, and problems in the radio wave pathway of the ionosphere can reduce positioning accuracy and limit the amount of time that pilots can use satellite navigation systems.

Some airports have Ground Based Augmentation Systems (GBAS) that augment GPS-derived positioning information to enhance accuracy. By comparing known, accurate locations of ground-based GBAS receivers with positioning information from GPS satellites, a GBAS determines the degree of error in the GPS information and thereby allows the pilot to correct the aircraft’s position automatically. However, GBAS ground receivers are also susceptible to the effects of jamming and ionospheric disturbances; as an aircraft gets farther away from a GBAS installation site, the commodity of the error information suffers. Many aircraft also feature inertial navigation systems (INS), which use built-in accelerometers, gyros, and other devices to determine the position of the aircraft without the need for external information. While this independent approach does eliminate the effects of variability like weather and jamming, INS error grows as the aircraft flies longer distances.

To help solve these problems, the DREAMS project developed a hybrid navigation technology that uses INS (Inertial Navigation Systems) and GPS navigation equipment. These improvements reduce the amount of time without access to high-accuracy satellite navigation by half, putting rates of availability (the proportion of time that users can use the technology at over 99%). Conventional satellite navigation equipment can have trouble receiving GPS signals due to the effects of aircraft movement and radio wave environment, but using the aircraft movement information from an INS allows GPS receivers to improve signal tracking performance and reduce the occurrence of radio wave interruptions. An aircraft’s satellite navigation system still has trouble receiving radio waves.

High-accuracy satellite navigation technology: Combining GPS, GBAS, and INS to improve operational accuracy

In order to determine whether the hybrid navigation technology could ensure utilization rates of at least 99.5%, JAXA also performed simulations and conducted flight tests with the “Hisho” jet aircraft. One of the ionospheric disturbances that affects GPS signals is a phenomenon called “plasma bubbles”—bubble-shaped instabilities that occur over low-latitude areas (regions close to the equator). In Japan, plasma bubbles can be observed in Okinawa’s land southern Kyushu, an area occupied during the spring and fall. Okinawa’s New Ishigaki Airport features GBAS equipment developed by the Electronic Navigation Research Institute (ENRI), which JAXA worked with to perform demonstrations experiments around Ishigaki Island. DREAMS Project Sub-Manager Toshiaki Tsujii looks back on the tests, saying, “Plasma bubbles occur at night, so we needed to stay up and experiment when most people were sleeping. The local residents were extremely helpful in letting us do our work—which, it turns out, pretty much made us nocturnal.”

JAXA has developed high-accuracy satellite navigation technology in order to allow for landing approaches that were as precise as possible—but the technology is also viable in other applications besides landing procedures. “High-accuracy navigation technology will be a vital piece in lots of situations,” Sub-Manager Tsujii says. “Soon enough, we might be seeing airports use the technology to move aircraft around automatically.”

Section Leader Funabiki. “If we can start talking about the necessary revisions on a global scale, I think we’ll be able to establish a stronger presence for Japan.”

Kohei Funabiki
Leader, DREAMS Project Team
When a major disaster occurs, aircraft from across Japan, especially helicopters,
gather to carry out missions such as reconnaissance, search and rescue, and transportation of cargo
and personnel. Improvements have been made since the Great Hanshin-Awaji Earthquake of 1995, but the Great East Japan Earthquake that struck
in 2011 and created a disaster zone stretching across multiple prefectures showed that operating more than 300 helicopters remained a challenge.
JAXA has been working on the research and development of the Disaster Relief Aircraft Information Sharing Network (D-NET) to enable optimal
assignment of missions to aircraft by sharing information among disaster relief aircraft and ground-based sources like emergency operations
centers (EOCs). Now JAXA is focused on D-NET2, an Integrated Aircraft Operation System for Disaster Relief, an improvement of D-NET, which will
combine information from sources like satellites and unmanned aerial vehicles (UAVs), and enable even more efficient disaster relief operations.

For this feature article we asked Kazutoshi Ishikawa, director of the Operation Systems and Safety Technology Research Group at the Institute
Directorate I, about D-NET2 in terms of aviation and space.

**CHALLENGES SHOWN BY D-NET**

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**Ishikawa**

D-NET generates and suggests optimal flight routes and schedules for efficient and safe helicopter operations, based on the positional information
of the numerous helicopters that gather when a major disaster occurs and on the disaster information they send. A number of dynamic management systems, which employ
D-NET technology installed on firefighting helicopters and medical service helicopters with a physician on board have been commercialized already. In addition, in April 2014
the Fire and Disaster Management Agency (part of the Ministry of Internal Affairs and Communications) adopted D-NET technology for its systems managing firefighting
helicopters nationwide. It is believed that more D-NET-compatible firefighting helicopters will make firefighting operations more efficient.

In the process of D-NET’s research and development, we had actual end-users assess its interface and performance. At that time it was suggested to combine meteorological
information and damage-related information from the ground with information transmitted from helicopters. This guided us into D-NET2 where we incorporate information from diverse sources like satellites and UAVs. It is often said that the first 72 hours after
a disaster are the most critical for rescue and relief operations. We aim at eliminating zero-information zones where the state of damage is unknown within these
critical 72 hours. Our goal is to reduce the number of cases in which

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Feature Story ・・・ D-NET2: Integrated Aircraft Operation System for Disaster Relief

How have satellites been utilized thus far for disaster management?

Toda JAXA operates various Earth observation satellites. For example, DAICHI, the Advanced Land Observing Satellite (ALOS), was in use until May 2011 to monitor the state of the land, and we launched its successor, DAICHI-2 (ALOS-2), in May 2014. We developed a website through which we can provide post-disaster satellite imagery of stricken areas promptly to central government agencies and local governments. To provide better awareness of the damages and changes caused by the disaster, we also provide imagery of the areas taken before the disaster, as well as information such as the location and extent of damage.

When the Great East Japan Earthquake struck in March 2011, we used DAICHI’s observations to provide relevant institutions with images so they could evaluate landslide risk. Recently we received requests from the Japan Meteorological Agency and the Coordinating Committee for Prediction of Volcanic Eruptions to monitor Mt. Ontake. With DAICHI-2, we provide information on the locations of new volcanic orifices and institutions with images so they could evaluate landslide risk. Past satellite imagery provide nominal data, which combined with the imagery obtained after the disaster turns into a powerful tool to evaluate the damage over a wide area efficiently. Furthermore, if we can get UAVs to fly longer at a time, then we should be able to make even more detailed observations of the state of damage. By incorporating such kind of disaster zone information into D-NET2, it will become even easier to generate efficient rescue and relief operation plans. In addition, we can use obstacle information available from terrain and obstacle databases and radars to avoid collision-avoidance as well. We might also use all collected information to predict the weather in local areas more accurately, too.

How far has D-NET2’s R&D progressed thus far?

Toda Until now we have provided central government agencies and local governments involved in disasters with image data to see the big picture of the damage. That is still important, but there is also another critical aspect to take into account—how to deliver satellite imagery information to people operating directly in the disaster zone. For example, firefighters and Self-Defense Force personnel on rescue missions and medical staff can benefit greatly from such information. I expect that with D-NET2, people on the disaster scene will be able to use satellite data to determine their search and rescue plans. You can’t collect all the information only with satellites or only with aircraft. You need both. For example, a satellite is good for monitoring the situation in places that are hard to reach on the ground or where aircraft cannot get a complete view. Besides, DAICHI-2’s PALSAR-2 synthetic aperture radar can see the Earth’s surface even when there are clouds or volcanic smoke on the way. It can even take images at night. Satellite imagery becomes a powerful tool then. However, there are some limitations, too. If on the other hand, you want to specify a location to see its condition in detail, then that can be difficult with today’s satellite capabilities. Furthermore, you can only take images during the time that the satellite orbits over the disaster area.

I think that with D-NET2’s integral systems combining JAXA’s satellites and aviation technology we may be able to provide the people involved in direct search and rescue with new solutions they hadn’t before. D-NET2 is a good example on how to make use of satellite information, and we do very much welcome such satellite application.

FIVE-YEAR-GOAL FOR A USABLE ON-SITE SYSTEM

Toda For the August 30 drill we created a satellite data simulation to determine which areas will be partially flooded, converted that data according to D-NET data specifications, and fed it into D-NET2. The drill was a good opportunity to demonstrate the usefulness of satellite data. In the future, I would like to create a two-way interface so we can use information collected with D-NET2 to consider candidates for the next observation area, then have that reflected in satellite observation plans accordingly.

Toda Ground-based communications networks incurred heavy damage in the Great East Japan Earthquake. Immediately after the quake struck, JAXA used KIZUNA, the Wideband InterNetworking engineering test and Demonstration Satellite, and KIKU-II, the Engineering Test Satellite VIII, to provide satellite communications lines in the disaster area. Since the earthquake, JAXA has formed partnerships with local governments and has proceeded with demonstration tests to provide communication lines during disasters by using KIZUNA. We are also considering using JAXA aircraft to transport antennas needed to communicate with satellites in the event of a big disaster.

What is your ultimate goal with D-NET2?

Toda I want to form integral partnerships between aeronautics and space that enable us to combine information for efficient real-time operations in disaster relief, mitigate damage and save more lives.

Toda I want to deepen the collaboration between aviation and space, develop D-NET2 into an even better system, and make JAXA’s aerial information more accessible to those involved in disaster response and rescue operations on the ground.
What is D-NET2's Key Technology?

Through the use of aerospace equipment such as satellites and unmanned aerial vehicles (UAVs) instead of only manned aircraft, and the integrated management of voluminous disaster-related information, JAXA’s Integrated Aircraft Operation System for Disaster Relief (D-NET) is a system that assists with optimal allocation of available resources in order to speed up and make more efficient relief operations in the immediate aftermath of a disaster.

Unlike other existing systems, D-NET relies not only on manned aircraft, but also incorporates information from other aerospace equipment such as satellites and unmanned aerial vehicles (UAVs). Here, we will explore the key technologies behind D-NET to find out how everything comes together to aid disaster relief.

Shift from “passive” to “active”

JAXA has been working on the research and development of the Disaster Relief Aircraft Information Sharing Network (D-NET). D-NET’s expected contribution is twofold: first, it will allow for real-time information sharing between local emergency operations centers (EOCs) and fire department helicopters and other aircraft participating in the direct search and rescue right after a major disaster; and second, it will support optimal aircraft operation planning. D-NET will shorten the “wasted time,” i.e., the time when an aircraft is not involved in a mission. Wasted time includes the time when aircraft wait to refuel, wait for missions to be assigned to them or wait to pick up evacuees as landing is obstructed by other aircraft performing a rescue mission. By minimizing wasted time, the number of completed missions can be increased. Furthermore, by optimizing the planning, possible collisions can be avoided by planning the trajectories and pick-up points in advance, thus enabling safer and more efficient disaster relief operations.

In conventional disaster response, aircraft and EOCs rely on voice communication. On the ground, the information is made available to all people at a certain EOC through white boards. In the event of a major disaster, however, EOCs must handle an enormous amount of information, so rescue operations become inefficient.

One of D-NET’s goals is to make smooth information sharing possible regardless of the type of equipment used by each aircraft and on the ground by standardizing the data all participants should share in accordance with D-NET Data Specifications. Recently, the number of medical service helicopters (also known as ambulances), fire department helicopters and other disaster relief aircraft which are using D-NET has been constantly increasing, which shows that D-NET is on the right path. However, issues still remain. One of these issues is responding to a large-scale disaster over a large territory, such as the Great East Japan Earthquake which hit on March 11, 2011. The scope of the disaster caused a slowdown in information gathering and situation awareness which in turn resulted in rescue operation delays.

Adriana Andrei-Nori, a researcher on the D-NET R&D project and in charge of the Optimal Operation Control Subsystem, explains the difference between D-NET and D-NET2. “D-NET is a ‘passive’ system, i.e., you can conduct relief operations only once you have information about the people in need of rescue. D-NET, on the other hand, is being developed as an ‘active’ system, because it involves not only information already obtained in the search process in the immediate aftermath, but also predictions of rescue needs. In other words, rescue aircraft can be assigned to locations from which no information has been collected yet. To make the best ‘active’ judgment, all information must be collected, managed and integrated properly. With D-NET, JAXA has already managed to reduce the non-operational time of disaster relief aircraft and minimize near collisions. D-NET2 goes a step further and includes information from UAVs and satellites as well. The ability for reconnaissance over a broad area, as well as dangerous areas where human pilot presence is impossible, D-NET2 will be able to efficiently integrate all of the above diverse information.

Another difference between D-NET and D-NET2 is the expected user scope. D-NET is developed to be used in the direct proximity of the disaster site, while D-NET2 will enable optimal disaster relief planning and management at EOCs in control of multiple disaster areas. D-NET2 is not a replacement for D-NET, but a system in which all is under one roof. D-NET2 is composed of three subsystems. The Information Integration Subsystem integrates and manages information on disaster prediction such as hazard maps issued by local authorities, as well as information collected by aerospace vehicles such as aircraft and satellites after the disaster has hit. Based on the information gathered, the Optimal Operation Control Subsystem proposes efficient aircraft mission assignments for search, rescue and relief, goods supply, etc. Finally, the Mission Support Subsystem assists in the work of disaster relief aircraft to which missions have been assigned.

For example, D-NET2 obtains aerial data on disaster areas by the Advanced Land Observing Satellite-2 “Daichi-2” (ALOS-2). In particular, landslides and flooded areas can be indicated well through satellite imagery. When this aerial data is combined with information from the Emergency Medical Information System (EMIS), which includes information on hospital statuses, for example, D-NET2 can instantly provide a valuable overview of the damage incurred. This overview can include flooded hospitals and those in need of rescue, as well as hospitals which can receive patients.

Data from the sky, space and ground gathered for rescue operations

D-NET2 is composed of three subsystems. The Information Integration Subsystem integrates and manages information on disaster prediction such as hazard maps issued by local authorities, as well as information collected by aerospace vehicles such as aircraft and satellites after the disaster has hit. Based on the information gathered, the Optimal Operation Control Subsystem proposes efficient aircraft mission assignments for search, rescue and relief, goods supply, etc. Finally, the Mission Support Subsystem assists in the work of disaster relief aircraft to which missions have been assigned.

Considering the first 72 hours after a disaster as being critical, JAXA has defined D-NET2’s performance goal as a 66% reduction in disaster affected areas by the Advanced Land Observing Satellite-2 “Daichi-2” (ALOS-2). In particular, landslides and flooded areas can be indicated well through satellite imagery, which in turn results in rescue and relief operations.

In other words, implementing aerospace resources in direct search and rescue will reduce by 66% the areas where people’s life is still endangered even 72 hours after the disaster.

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Feature Story  What is D-NET2’s Key Technology?

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Determining priorities with QOL

The first 72 hours in the immediate aftermath of the disaster are said to be critical. Therefore, appropriate allocation of the limited resources to search and rescue is vital to save more lives. JAXA has applied the QOL concept to D-NET2 to determine mission priorities. Operators can grasp the situation in each area easily by referring to the color-coded QOL for each grid on the D-NET2 display. High priority is assigned to highly dangerous places with low QOL. D-NET2 will suggest EOC operators to send rescue missions to such locations. For example, the system will assign QOL 1 to the areas from which no information is available yet. It is also observed that the D-NET2 system assigns QOL 2 to the areas that are urgently requiring data collection, and recommend the use of disaster relief aircraft to execute a reconnaissance mission.

Thus, the QOL is a key factor in deciding on priorities in D-NET2. Explaining the QOL issue, Dr. Adrianea-Mori says, “Since factors like population density and terrain are also considered when assigning QOL, saving a single stranded person, for example, will not necessarily raise QOL. Fair and proper QOL assignment is still a big research issue.”

It should be noted that D-NET2 is a decision support tool: it provides a plan for rescue and relief operations based on a vast amount of information, but the final judgment is made by EOC operators.

Using JAXA’s aerospace technology at disaster sites

During the Cabinet Office’s wide-area medical transport drill conducted on August 30, 2014, D-NET2 terminals were installed for demonstration testing at the prefectural EOC set up in Miyakita Prefecture’s capital building and the Disaster Medical Assistance Team (DMAT) office in Tachikawa, Tokyo. DMAT members and local crisis management officers provided valuable comments on D-NET2’s features. Participation in such disaster drills is needed in the future as well to fine-tune D-NET2 into a truly usable system at the disaster scene. Therefore, JAXA is currently collecting more feedback from various sources in order to improve D-NET2 even further.

For example, most people will find it natural to specify a given location by its corresponding latitude and longitude expressed in degrees and minutes, but using a UTM coordinate grid at the site of a disaster to number each area site can be more efficient, so JAXA has added this feature to the D-NET2 map display. This is just one example of how JAXA actively incorporates users’ needs into D-NET2.

An advantage of massive amounts of data, or so-called “big data,” is that the growing volume of information allows us to make more accurate decisions. However, it requires the development of a system with advanced processing capabilities, and the ability to deal accurately and appropriately with inaccurate data (noise). A badly constructed system might confuse operators instead of aiding them in the decision process. To ensure that each user receives the exact information they need to avoid confusion, D-NET2 has opted for layered data, i.e., one can select to display only the information required. Furthermore, to help the execution of search-and-rescue missions by all pilots regardless of their knowledge of the terrain they fly over, research is also underway on the Mission Support Subsystems. Such subsystems will introduce technology which shares information on obstacles (transmission towers and power lines that pose a risk of collision, buildings knocked down by the disaster, etc.), as well as technology which enables pilots to fly in low visibility and at night.

Seeing the future and striving to make it reality as soon as possible

Fire department and medical service helicopters, along with police and Self-Defense Force helicopters are just some of the aircraft which are deployed in disaster relief missions. Sharing information among a greater number of institutions makes disaster relief operations more efficient. Section Leader Dr. Keiji Kobayashi, who has played a central role in D-NET’s research and development since its start, says, “I visit many different institutions and give presentations on D-NET and D-NET2. Lately I feel that expectations are growing for these systems to serve as technologies to keep disaster damage to a minimum.”

Furthermore, JAXA is making it easier for various institutions to share information with D-NET and D-NET2. For example, R&D is underway on an interface which allows users to obtain data from an institution which has an information sharing system already. JAXA is working with hardware manufacturers to jointly develop tablet-like mobile terminals that would only be carried onto an airplane during a time of disaster, while flying an airplane during a time of disaster.

Research Group

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JAXA examined the feasibility of a fully portable D-NET terminal for medical service helicopters.

A review of D-NET2 at an EOC set up at Miyakati Prefecture’s capital building during a wide-area medical transport drill.

The Growing Lineup of D-NET-Compatible Airborne Terminals

TheGrowingLineupofD-NET-CompatibleAirborneTerminals

Aircraft need to be equipped with D-NET-compatible terminals in order to share information on D-NET and D-NET2. Compatible equipment comprises communication equipment, including an antenna and an input/display device, and although the purpose is always to share information, the aircraft’s capabilities, mission role, special needs and installation cost can vary widely. JAXA is working with manufacturers to develop onboard terminals to add to the number of D-NET-capable aircraft. D-NET-compatible terminals presently come in three variations.

Fully Preinstalled

With this type of terminal, a fully portable D-NET terminal is installed inside the aircraft. Upgrades and modifications are costly, and after the upgrade a modification and alteration review for guarantee post-upgrade airworthiness as prescribed by the Civil Aeronautics Act is required, but this type allows pilots and other crew to send and receive a large amount of information. This type is mainly used in the disaster helicopters.

Partially Preinstalled

With this type of terminal, the communication and information display device is carried on board and connected only when needed. It is designed for transport crew members to operate and is considered appropriate for aircraft that have already undergone a modification and alteration review for onboard satellite communication equipment.

Fully Portable (no preinstallation necessary)

This solution features a portable D-NET terminal, which can be connected to onboard satellite communication equipment to bring on board as needed. The type of equipment and information implemented is limited, but it does keep the cost of introducing the technology low. This version is for institutions which cannot afford to share information with other institutions.

Collecting and aggregating as much information as possible is a must for disaster response, but so is the flexibility to assemble systems that address the needs of institutions responding to disasters, as well as organizing the collected information and showing it in an easily understandable manner. D-NET2 terminals will continue to evolve to suit the needs of their users.
Deriving accurate explanations of how air and other fluids make programs commonly available. “We eventually decided individual studies—there was never much of an effort to computational hurdles to reach a workable, practical speed. extensive, time-consuming calculations. As increasing surfaces of and spaces around the aircraft body, the wing, air around aircraft and spacecraft for many years, beginning aviation sphere involves generating a grid by splitting the 1960s, use computers to solve these elaborate equations for the partial differential equations that come into play. flow around an object. Although the CFD approach has meticulous nature of the job, it normally takes even the most lack easy access to supercomputers, JAXA has also developed our software.” Aiming to reach educational environments that opportunities to use the technology in a hands-on format, JAXA was working on FaSTAR, Nagoya University contacted the researchers about using the software in class settings. Up to that point, CFD had rarely ever been more than a topic of one-sided classroom lectures—opportunities to use the technology in a hands-on format that had been few and far between. “We worked with the Japan Society for Aeronautical and Space Sciences to set up the Forum of Aeronautical Education Support, which introduced lists of audiences to possible uses of the technology in different educational settings,” says Section Leader Kichi Murakami. “Schools have been showing interest in what we do. Currently (as of March 2015), there are fifteen universities and two technical colleges using our software.” At JAXA, helping researchers solve problems in a wide range of different projects. The tools are also proving useful for the Digital/Analog Hybrid Wind Tunnel (DIAMHT), which actually played a role in accelerating the development of the two software tools. While the current version of FaSTAR can produce high-quality data if the target air is flowing smoothly, the software still has trouble performing calculations on the types of unsteady air that occur as air separates when an aircraft loses speed. JAXA is planning to continue improving FaSTAR so that it can perform analyses for diverse sets of conditions at a feasible, practical speed. Researchers are also looking into augmenting HexaGrid, too, with custom features that will give users the option to manually generate grids for areas that they want to recreate with a higher degree of precision.
Magnetic Suspension
Wind Tunnel

First-Ever Practical Magnetic Suspension Wind Tunnel

The idea of supporting a model in a wind tunnel with magnets to get close to actual flight conditions inside the tunnel has been around for a long time, and countries around the world have conducted related research. JAXA commenced basic research in 1986, succeeding in creating the first-ever suspension wind tunnel with a measurement section 0.6 meters each electromagnet creates a magnetic field. Meanwhile, a wind tunnel in 2000, and has been operating it as a magnetic suspension wind tunnel with a measurement section 0.6 meters tall and 0.6 meters wide.

The mechanism for the magnetic suspension wind tunnel supports a model on a coil placed in the center of the tunnel. The magnetic suspension wind tunnel is easy to move to any position as long as you wish—even while air is flowing through—by controlling the force of the electromagnets.

Hiroki Sugiyama, associate senior researcher at the Aerodynamics Research Group, explains: “We can take readings of wind tunnel test models that are being oscillated vertically or horizontally at any rate, or of a revolution of an aircraft’s turning motion by altering the position and angle.”

Precision Readings of Challenging Objects: Potted Arches and Reentry Capsule Airflow

The magnetic suspension wind tunnel has also been equipped with a camera at the bottom of the tunnel to take pictures at various angles as the model moves. This enables more accurate readings of rear airflow’s effect on the measured data. JAXA is conducting R&D on the “Digital/Analog-Hybrid Wind tunnel” (DAHWIN), which uses X-ray CT scans to measure the model during measurement. The system already includes CFD analysis results.

Tests in Magnetic Suspension Wind Tunnel

The magnetic suspension wind tunnel, which has no support apparatus, is also good for measuring the aerodynamics of simple shapes such as spheres and cylinders. Measuring the flow over a simple shape facilitates our understanding of aerodynamics’ basic mechanisms and aids the validation of CFD analysis results.

Another feature of the magnetic suspension wind tunnel is that it can freely change the orientation of the model during measurement. One can also move a model on a support apparatus in a regular wind tunnel but with the magnetic suspension wind tunnel it is easy to move the model all you wish—even while air is flowing through—by controlling the force of the electromagnets.

- The magnetic suspension wind tunnel requires a powerful magnetic field to support the model and move the model, so care is needed so that the model does not fall down. Furthermore, when wind tunnel tests using large models representing real aircraft and the like take place, a large amount of power is used. The powerful magnets will float into the air. This will require special safety considerations, so there are currently limits to the size of a practical wind tunnel capable of testing.

The mechanism for the magnetic suspension wind tunnel supports a model on a coil mounted to the sides, above, below, and in front of the model, so the airflow to its rear is closer to real flight. In combination with non-invasive measuring, this enables more accurate readings of rear airflow’s effect on the measured data. JAXA is conducting R&D on the “Digital/Analog-Hybrid Wind tunnel” (DAHWIN), which uses X-ray CT scans to measure the model during measurement. The system already includes CFD analysis results.

In order to fly an aircraft, each vehicle must receive a Certificate of Airworthiness from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by the Japan Transport Safety Board (JTSB). In order to fly an aircraft, each vehicle must receive a Certificate of Airworthiness from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by the Japan Transport Safety Board (JTSB). JAXA researchers assist the JTSB in various forms, such as by providing technical advice and analyzing relevant materials from the scene, along with performing flight analysis, structural analysis and so on. On October 1, 2008, the JTSB and JAXA concluded a comprehensive cooperation agreement.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is the authority in charge of civil aviation administration in Japan. JAXA has served as Japan’s leading research institute in the field of aeronautical science and technology since the time of its predecessor, the National Aerospace Laboratory (NAL), and has continuously contributed to civil aviation administration by providing the MLIT with its research findings, expertise and more. Here we present how JAXA is working with the MLIT today.

Utilizing JAXA’s Expertise to Develop International Standards

The Civil Aviation Bureau of the MLIT represents Japan as a member of the International Civil Aviation Organization (ICAO), a specialized UN agency, and has been participating in the ICAO’s activities in developing international standards for civil aviation. JAXA, along with research institutes and private aviation companies, plays advisory roles for the MLIT and provides expert knowledge on each topic of discussion required by the ICAO’s committees, panels, working groups and so on.

For example, JAXA has been involved in the ICAO’s Committee on Aviation Environmental Protection (CAEP) as an advisor to the MLIT since 2001. The CAEP is a technical committee where members discuss such environmental issues as aircraft emissions and noise, and conduct examinations of technology and assessment criteria. One of its working groups considers the formulation of sonic boom standards and proposed regulations on aircraft engine emissions (NOx, PM, CO, CO2), and data collected by JAXA researchers are utilized by the ICAO’s working groups.

Also, at the request of the Civil Aviation Bureau of the MLIT, JAXA researchers have been participating at the ICAO’s Remotely Piloted Aircraft Systems Panel (RPASP), which considers matters like rules for the operation of remotely piloted aircraft systems (RPAS), since 2012. The panel’s predecessor body, the Unmanned Aircraft Systems Study Group (UASSSG). Several suggestions and proposals made by JAXA researchers have been adopted in the ICAO’s Manual on Remotely Piloted Aircraft Systems, which is about to be published.

For Safe Aircraft Operations

In order to fly an aircraft, each vehicle must receive a Certificate of Airworthiness from the MLIT proving that the aircraft fulfills standards of safety and environmental compatibility. Additionally, when a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes. However, as a new aircraft is developed, there is a Type Certification System that allows for the issuance of relevant designs in the Certification of Airworthiness for inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. This allows for safer and more efficient design and development processes.

This is how the MLIT and JAXA are closely partnering and collaborating in many areas for the sake of the development of the aviation industry and safe operations in Japan and around the world, and that relationship is continuing on into the future.
Flight experiments using MuPAL-a to enable precise curved approaches performed

From December 5th to 19th, 2014, JAXA conducted flight experiments with the MuPAL-a research aircraft at Sendai Airport to verify how GEMS could enable precise curved approaches. In addition to measuring the need for shorter intervals between takeoffs and landings, escalating airport traffic break up on any landing, leading to increased turbulence around airports and noise problems in local residents. Tailoring operations to support curved approaches mitigating the need for sharp, 90°-angled turns, will enhance technology that enables curved paths and other types of flexible approaches. For its next experiments, JAXA teamed up with the Electro Navigation Research, International Civil Aviation Organization (ICAO) and NPO "Cosmo" to conduct curved and multiple approaches between Sendai International Airport and the MuPAL-a in order to receive the path information on received, MuPAL-a was then used by flight-management to make the largest, in-en-route approach via Headed automatic system. The results of the experiments will be used in the flight certification of the automatic control system and the DEMS Project has developed and fully tested. In point of fact, the success of the study opens a great deal to the wide-ranging support and cooperation of ICAO, the Tokyo Regional Civil Aviation Bureau, the Sendai Airport office, the Civil Aviation College, and other organizations.

Main wing deformation measured during Hisho flight

During flight, the shape of a aircraft's wing is affected by the force of the air. This is a change in shape caused by aerodynamic forces. The shape change may be due to aerodynamic forces, and may be expressed as by applying the Maneuvering margin equations. Viscous flow may be the flow when a vehicle changes its flight path and encountered wind flow. These methods signifies lift quantity (obtaining lift quantity) using a small, fast-moving wing with the shape of the airfoil of the main wing and then applying the results of the obtained lift quantity. A set equipped with a equipped in the aircraft for the specific purpose of evaluation.