JAXA Aeronautics Magazine

FLIGHT PATH

Shaping Dreams for Future Skies

JAXA
Institute of Aeronautical Technology

2015

No.7/8

www.aero.jaxa.jp

Feature Stories

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

D-NET2: Integrated Aircraft Operation System for Disaster Relief

FLIGHT PATH

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This issue features the DREAMS project and D-NET2, one of its derivative initiatives. The feature on the DREAMS project wraps up what we have achieved over the past three years since 12 in developing technologies for safe and more efficient 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 .

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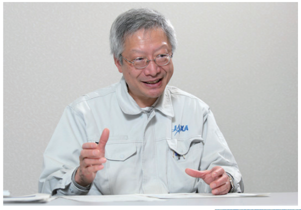

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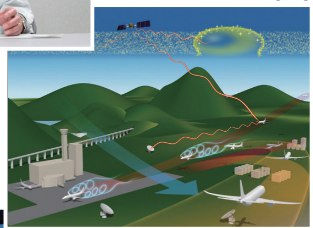

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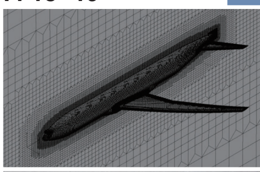

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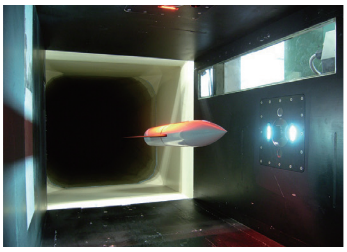

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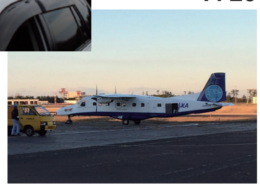


On the cover

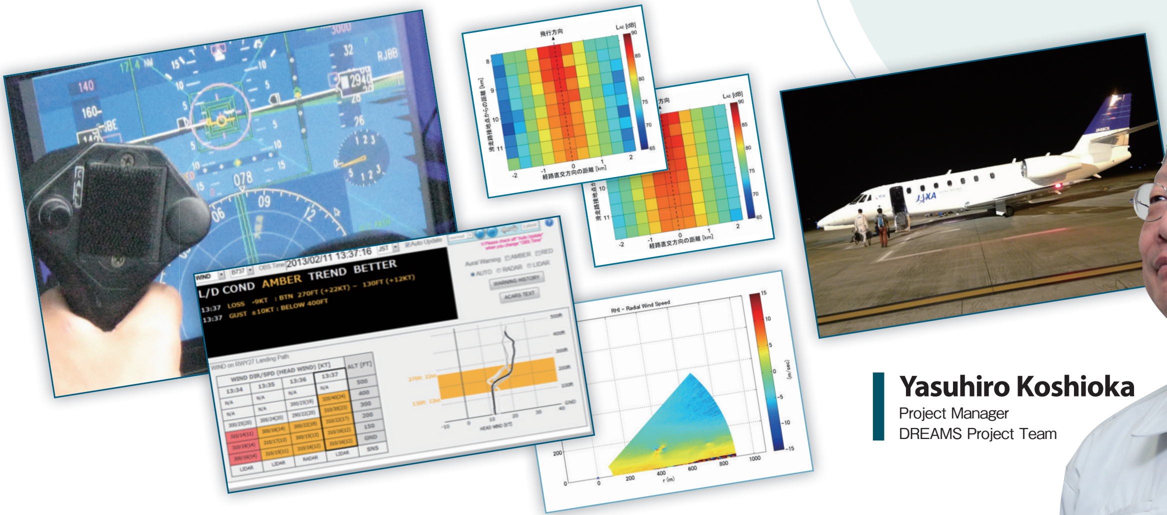
The cover features five images from the DREAMS project: (Background) JAXA's Hisho jet research aircraft performing flight tests for "high-accuracy satellite navigation technology"; (counter-clockwise from left-middle) a flight-path navigation display in a cockpit from the demonstration experimentation for "trajectory control technology"; information on low-level turbulence transmitted to the cockpit based on "weather information technology"; measurement of sound propagation using a tethered balloon that carries noise sources to analyze propagation characteristics for "noise abatement technology"; a D-NET-compatible terminal mounted on a Kobe City firefighting helicopter (photo courtesy of the Kobe City Fire Aviation Unit).

Feature story

The DREAMS Project

Creating the basis for new global standards

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



Yasuhiro Koshioka
Project Manager
DREAMS Project Team

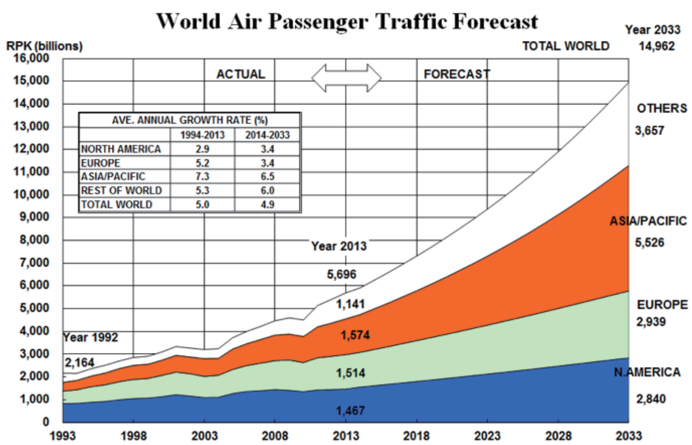
The DREAMS project aims to research and develop key technologies for enabling next-generation air traffic management systems, provide a basis for establishing international standards, and promote technology transfers to manufacturers. Over the three years since its inception in May 2012, the DREAMS project 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 (ATM). In 2003, the International Civil Aviation Organization (ICAO) proposed its "Global ATM Operational Concept" vision—a framework for using new technologies to transform conventional air traffic management systems by 2025. Sharing the ICAO's core vision, some countries and regions have launched 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.



Significant growth is expected in the Asia/Pacific region (the orange band)

(Source: The "FY2013 Commercial Aviation Databook, Chapter 3: Demand Forecasts," published by the Japan Aircraft Development Corporation)

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 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 high-frequency take-offs and landings, generating flight paths that minimize noise exposure range, controlling

Demonstration experiments of the high-accuracy satellite navigation technology using JAXA's "Hisho" jet research aircraft at the New Ishigaki Airport

Measurements of wake turbulence using LIDAR around Narita International Airport

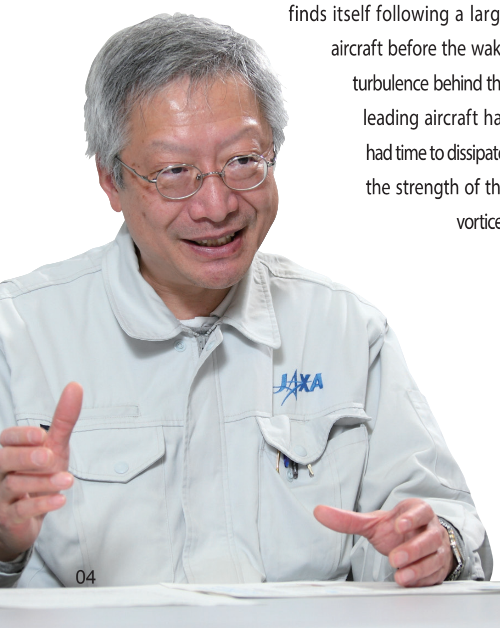
flight along optimized routes, and enabling high-accuracy satellite navigation that allows for ideal operations. The other type is small aircraft operation technology for disaster relief, which aims to facilitate information sharing among large numbers of rescue aircraft and relief headquarters during disaster response operations; this 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 taking 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 air flows 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 place excessive aerodynamic force (force generated by air) on the smaller aircraft—a situation that can be 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 disappeared 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 an 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 like 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. Another factor 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 approach, 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.

Pilots have traditionally used "straight-in approaches" to land at airports, pointing their aircraft directly at the runway and then coming down. At most airports, the guidance systems are designed for straight-in 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 allows for precise curved approaches via autopilot without

Flight tests of the curved approach with the MuPAL-α research aircraft

Noise measurement around Narita International Airport for noise abatement technology

The “fully portable” on-board terminals that came out of D-NET

The “fully preinstalled” on-board device that JAXA developed through D-NET

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?

CARATS 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.

Ever 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 lots 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 share information 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 we 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 agendas to develop international standards and recommendations for civil aviation, we'll be coordinating with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)—the Japanese representative to ICAO and the initiator of CARATS, Japan's Collaborative Actions for Renovation of Air Traffic Systems.

At the same time, it is also necessary for us to take a bottom-up approach by sharing the findings from the DREAMS project with wider civil aviation community: transfer the technologies that the DREAMS project has established to aircraft equipment manufacturers, get airlines to trial and evaluate the technologies, and then eventually bring the results before the ICAO for international aviation policy discussions. This is because whether the ICAO working groups adopt and/or prioritize the agenda or not depends completely on the situation surrounding the civil aviation community at the time of discussion.

Also, JAXA is assisting MLIT's case studies to increase airport capacity. This is to prepare for the influx of traffic with the coming 2020 Tokyo Olympics, which are going to bring more and more aircraft carrying more and more travelers to Japan. We are assisting the MLIT to investigate how much more air traffic Tokyo International Airport (Haneda Airport) and Narita International Airport will be able to accommodate by using the technologies that the DREAMS project has developed.

—— What will happen after the completion of the DREAMS project?

The DREAMS project is set to finish at the end of FY2014, 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. (For more information on D-NET2, see page 11.)

Aircraft technology has always evolved to meet social needs. In the 1970s, for example, international air travel became popular, accessible, and affordable as the development of larger planes brought per-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 run every five- or ten-minutes. How can we get aircraft on that kind of schedule? What would 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.

Next Contents ▶▶▶

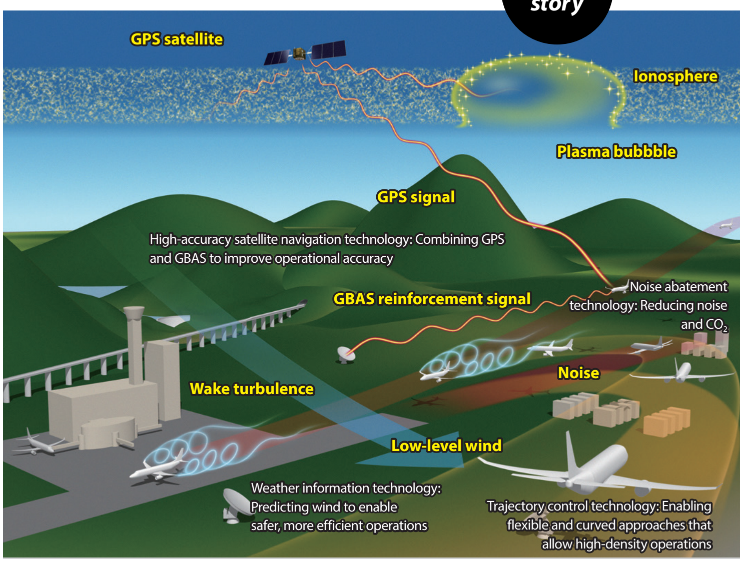
The following pages delve deeper into the DREAMS project's research into weather information technology, high-accuracy satellite navigation technology, noise abatement technology, and trajectory control technology.

How to manage ever-increasing air traffic more safely and efficiently? How will the DREAMS project benefit society? Here introduces four area 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".

For safe and efficient management of ever-increasing air traffic

The challenges of the DREAMS project

The DREAMS Project *Feature story*



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

How 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 dissipates 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 leading 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 cases 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 stiff "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 (Haneda Airport) apparently boosted its take-off and landing traffic volume by around 10 aircraft per hour in 2010 by creating an additional runway. By simply optimizing take-off and landing separation, airports could thus achieve the same increase in take-off and landing volume that a new runway would create.

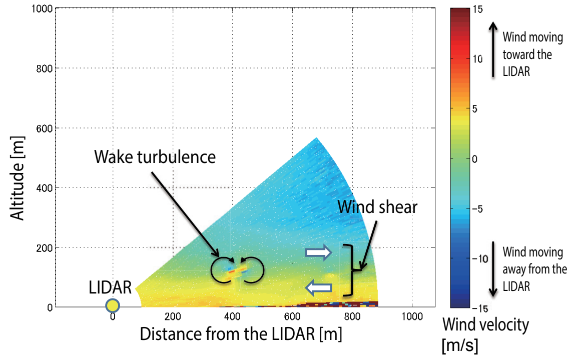
Measuring wake turbulence data year-round to provide a solid basis for making predictions

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 when specific aircraft were flying, 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 air traffic control to work, controllers would need to be able to predict conditions at least 30 to 60minutes out and give instructions accordingly. The DREAMS project function makes it possible to predict what the wake turbulence conditions will be like one hour 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

Naoki Matayoshi
Leader of the Weather Information Technology Section
DREAMS Project Team



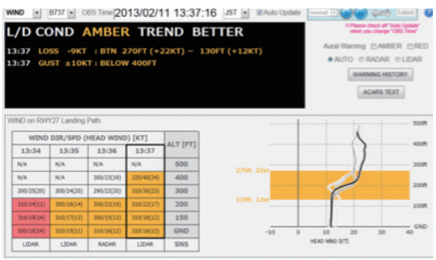
Wind velocity distribution on a LIDAR observation plane (a cross-section in the direction perpendicular to the runway); the image shows an observation of B777 wake turbulence

the amounts of time that various aircraft occupy runways, the DREAMS project successfully reduced take-off and landing separation by an average of 10%. JAXA plans to provide its findings for deliberation at the ICAO Wake Turbulence Study Group (WTSG) to help the ICAO develop international standards that will allow for flexible take-off and landing separation.

Helping pilots make take-off and landing decisions by providing information on wind conditions

When an aircraft is making its landing approach, the pilot sometimes has to redo the landing (make a "go-around") due to turbulence in the flight path ("low-level turbulence"). Low-level turbulence, when severe enough, can also lead to flight cancellations. Of the roughly 100 go-arounds that occur every year at Narita International Airport, around 90% are caused by the effects of low-level turbulence—a "natural" phenomenon triggered by topographical features, not an "artificial" phenomenon like wake turbulence.

If it were possible to predict flight path wind conditions when initiating a landing approach, pilots would have better control over their aircraft: they could stand by in the air until the wind settled down or, if they were already bringing their aircraft down for landing, they could at least be prepared for the wind as they made their descent. The DREAMS project has developed the Low-level Turbulence Advisory System (LOTAS), which installs relatively small, low-cost weather radar and lidar systems near an airport to measure wind around the airport in any type of weather and predict atmospheric conditions 10 minutes in advance. Using this information, the system advises aircraft dispatchers on when to give landing instructions and provides pilots with predictions of wind patterns on the approach route. Dispatchers can get a visual picture of wind conditions on the system's web screen, while pilots can use ACARS—a text-based information transmission feature commonly installed on commercial aircraft—to output data from the system on their cockpit printers or monitors.



A screen shot of LOTAS that graphically visualizes wind information by assigning colors based on severity to aircraft operations.

At airports that do not get much aircraft traffic, using LOTAS is relatively easy: a pilot can radio a dispatcher on the ground and ask for wind-related information, and the dispatcher can then check the LOTAS screen and send instructions or information via radio or ACARS. At busy urban airports, however, it would be impossible for dispatchers to follow that kind of approach in relaying LOTAS information to every arriving aircraft. The DREAMS project thus teamed up with the Japan Meteorological Agency to develop the "Airport Low-level Wind InformatioN" (ALWIN) system, a LOTAS enhancement that enables pilots to retrieve wind-related information automatically by simply issuing a command from the cockpit.

The Japan Meteorological Agency is currently combining the ALWIN technology with the weather data that it collects from airport weather Doppler LIDAR and Doppler radar units at Narita International Airport and other locations to develop a pilot information provision system for implementation in FY2016. Japan Airlines Co., Ltd., meanwhile, has already upgraded its aircraft so that pilots can obtain information via ACARS, with All Nippon Airways Co., Ltd. planning to follow suit. Other airlines from around the world will have access to information online, where they will be able to see just how convenient and useful the system is—and hopefully elect to incorporate the ALWIN and LOTAS technologies into their operations.

Alleviating wind-related problems to improve operating rates

"LOTAS and ALWIN are accessible, user-friendly systems—qualities that helped the technologies get good reviews and establish a solid foundation for practical use," says Naoki Matayoshi, Leader of the DREAMS Project Team's Weather Information Technology Section. "We're excited about working on a system for providing advice on optimal take-off and landing sequences and separation for wake turbulence conditions, too."

"About one out of every three airports in Japan struggles with wind-related issues. I hope they try LOTAS and ALWIN out—I think our technologies can really make a difference," says Section Leader Matayoshi.

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

How will increased air traffic affect noise ranges?

Experts suggest that increased air traffic will result in both more frequent noise bouts affecting the communities near the airport and more noise problems across larger geographical areas. Areas that endure certain levels of noise have to cope with sound problems by installing windows with two sashes or using high-noise locations for non-residential purposes, such as parks. In light 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 sound propagation—what you can 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 50%.

JAXA's noise abatement technology plans low-noise trajectories efficiently. These trajectories can be flown with great precision thanks to new technologies like GBAS (Ground-Based Augmentation System)*1 and the DREAMS project's precision curved approach.

Therefore, future operations will be quieter and perceived noise will not increase.

Predicting sound propagation based on weather conditions

JAXA's noise abatement technology comprises a noise prediction model and a flight path optimization program. The noise prediction model considers meteorological data and simulates noise exposure caused by aircraft flying along a given trajectory. This prediction is then used in the path optimization program to generate the optimal flight path for noise abatement. These optimal flight paths will, of course, need to be feasible for each actual aircraft.

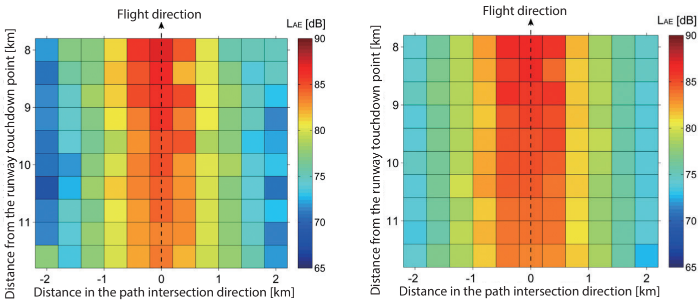
JAXA developed a sound propagation prediction model

Feature Story ▸▸▸ The DREAMS Project

Hirokazu Ishii
Leader of the Noise Abatement Technology Section
DREAMS Project Team

as part of its noise abatement technology. In the first series of experiments, reference sounds were generated from a tethered balloon-hung loudspeaker, and 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 largely overlooked contributions of weather profiles (data on the vertical distributions of wind direction, wind speed, and temperature), 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 Narita International Airport traffic and traffic reflecting a 50% traffic increase at the same airport. Next, the optimal flight paths 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 noise increase even in the event of a 50% traffic increase—can be achieved via efficient operations.



The measured aircraft noise (left) nearly matches the predicted value (right), proving high prediction accuracy. Deeper red colors correspond to higher noise levels.

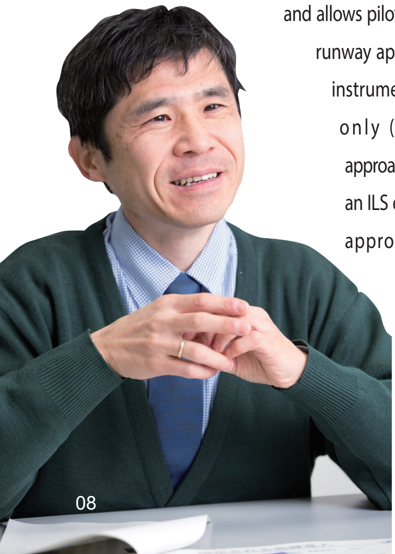
In order to enable flight at optimal approach paths that minimize noise propagation, JAXA plans to provide the results of its research for deliberation at meetings of the ICAO working group that evaluates technologies for environmental protection. This working group is also currently discussing and assessing ways of reducing CO_2 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 CO_2 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 weather information technology can predict.

Most existing airports have ILS,[*2] which sends highly directional wave beams from the ground to oncoming aircraft and allows pilots to make their runway approaches using instrument information only ("instrument approaches"). Although an ILS enables landing approaches in poor visibility conditions, it also requires a straight path of at least 3 miles (4.8 kilometers) in length and places limitations on landing approach paths that involve flying over buildings and other structures of certain heights. These requirements and restrictions mean that ILS-based instrument approaches are only possible with certain runways and approach paths.



Kohei Funabiki
Leader of the Trajectory Control Technology Section
DREAMS Project Team

Researchers have thus combined a GPS-based GLS (satellite navigation system approach method) and an FMS (a navigation airborne computer)-based method to create a curved approach method (tentatively called the "GLS-FMS method"), which will likely enter practical use within the next few years. The DREAMS project explores methods for ensuring that the GLS-FMS system demonstrates safety and precision levels that meet or exceed those of conventional straight-in approach methods.

Pilots and airlines need to have special qualifications and undergo special training to use the GLS-FMS method. To reduce the burden on pilots, JAXA is currently researching and developing a unique autoflight algorithm that uses a GBAS extension called TAP[*3] to enable curved approaches via autopilot. "The goal," explains Kohei Funabiki, Leader of the DREAMS project Trajectory Control Technology Section, "was to allow any pilot with an instrument pilot license to make curved approaches."

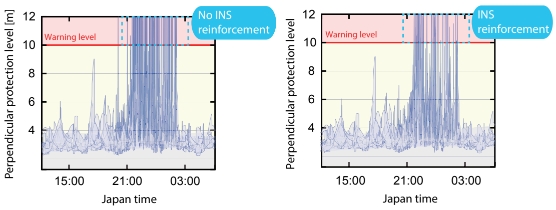
A Tunnel-in-the-Sky display in the cockpit; the display shows a GBAS-based curved approach

Evaluating an autoflight algorithm with the "MuPAL-α" research aircraft

In order to verify the new autoflight algorithm, JAXA worked with the Electronic Navigation Research Institute (ENRI) to conduct flight tests at Kansai International Airport and Sendai Airport using the fly-by-wire feature of the MuPAL-α research aircraft and experimental GBAS ground-based stations operated by ENRI at those airports. Although the aircraft initially experienced periods of unexpected deviation from the nominal path in the wind due to flaws in the algorithm, subsequent improvements made it possible for the aircraft to perform precise curved approaches within the assumed weather parameters of actual operations.

International discussions in the field will likely focus for the foreseeable future on the GLS-FMS (in operational wording, "RNP to XLS") method, which is getting closer to practical application. Given these conditions, JAXA is thus looking to propose its autoflight algorithm for implementation after the GLS-FMS method goes into use. "The GLS-TAP method is a brand-new proposal with plenty of specifications-related defects left to iron out, and the flight tests gave us a good idea of what we need to concentrate on," says 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."

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



The results of a simulation using the hybrid technology; the amount of time without access to satellite navigation that exceeds the warning level (the red line) is 1.92% with the conventional approach (left) but just 0.8% (half the amount under the conventional approach) with the hybrid technology (right).

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 technology. Multipath errors,[*4] 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 GPS 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 GPS information accordingly. 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 commonality of the error information suffers.

Many aircraft also feature inertial navigation systems (INS), which use built-in accelerometers, gyroscopes, 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 variables 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 technology 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 rate 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. If an aircraft's satellite navigation equipment still has trouble receiving radio waves in this augmented setup, the pilot can use INS-based inertial navigation to supplement the aircraft's positional information.

Toshiaki Tsujii
Leader of the
Satellite Navigation Technology Section
Sub-Manager, DREAMS Project Team

Flying "Hisho" over Ishigaki Island to evaluate rates of availability

In order to determine whether the hybrid navigation technology could ensure utilization rates of at least 99%, JAXA also performed simulations and conducted flight tests with the "Hisho" jet research 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 (and southern Kyushu, on rare occasions) 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 demonstration 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."

*1: Ground Based Augmentation System: A system that uses satellite information to aid aircraft landing; the system uses computers to process positioning signals from multiple ground-based stations and then sends correction information, ground-based station location information, runway information, flight path information, GPS satellite information, and other data to aircraft via VHF to enable extremely high-accuracy guidance.

*2: Instrument Landing System: A radio-based landing support device that emits highly directional wave beams to give course instructions to aircraft preparing for runway landings

*3: Terminal Area Path: A data format currently being researched and developed as a GBAS extension; the technology makes it possible to send multiple- and curved approach segment to aircraft

*4: A type of error that occurs when a GPS signal reaches a receiver from two or more paths, one directly from the satellite and others reflected or diffracted by other objects


JAXA's research helicopter BK117C-2


Advanced Land Observing Satellite-2 "DAICHI-2" (ALOS-2)

Feature story

Towards more efficient disaster relief through aviation and space partnerships

D-NET2: Integrated Aircraft Operation System for Disaster Relief

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 of Aeronautical Technology, and Kenichi Toda, head of the Disaster Management Support Systems Office at the Satellite Applications Mission Directorate I, about D-NET2 in terms of aviation and space.

CHALLENGES SHOWN BY D-NET

—— What changed between D-NET and D-NET2?

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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Head, Disaster Management Support Systems Office
Satellite Applications and Promotion Center
Satellite Applications Mission Directorate I

Kazutoshi Ishikawa
Director, Operation Systems and Safety Technology Research Group
Institute of Aeronautical Technology

highly urgent relief operations cannot be executed due to a lack of information with current means and systems to one-third of the present level.

——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 area 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 damage and tsunami flooding. 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 orifice and the range of the volcanic ash's spread, which is being used to monitor and assess eruptions.

System configuration of the Integrated Aircraft Operation System for Disaster Relief (D-NET2)

PROVIDE NEW SOLUTIONS WITH SPACE-&-AVIATION COMBO

—— With D-NET2, how do you utilize the information from satellites and aircraft?

Ishikawa Satellites are very helpful when it comes to evaluation of terrain changes and flood damages. 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 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 aid collision-avoidance as well. We might also use all collected information to predict the weather in local airspace more accurately, too.

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

Left: Kobe municipal fire department helicopter equipped with a D-NET-compatible terminal

Below: Evaluation of D-NET2 at the DMAT office through a wide area medical transport drill

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 haven't had before. D-NET2 is a good example on how to make use of satellite information, and we do very much welcome such satellite application.

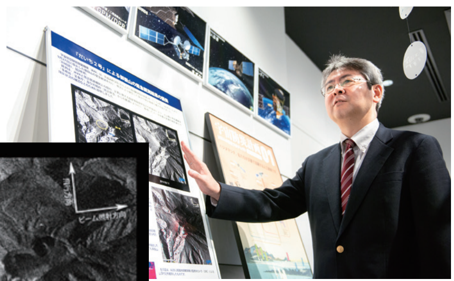
FIVE-YEAR-GOAL FOR A USABLE ON-SITE SYSTEM

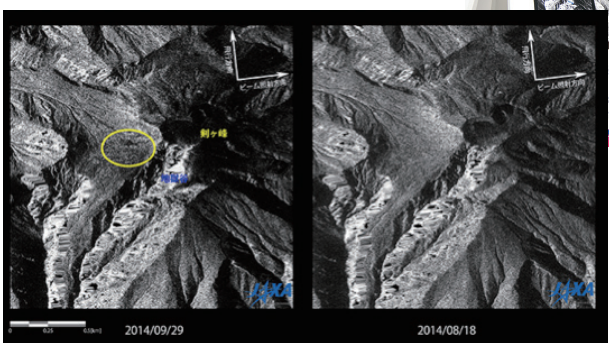
—— How far has D-NET2's R&D progressed thus far?

Ishikawa The Cabinet Office conducted its "wide area medical transport drill for 2014 fiscal year" on August 30, 2014. This was a comprehensive medical transport drill based on a scenario that a giant tsunami from an earthquake in the Nankai Trough hit Oita, Miyazaki and Kagoshima prefectures, causing extensive damage. We took D-NET2 terminals to the Disaster Medical Assistance Team (DMAT) office in Tachikawa, Tokyo and an EOC set up in Miyazaki Prefecture, and validated our system.

In the future, we aim to collect comments and opinions from potential end users of D-NET2, steadily improve D-NET2's systems, and in five years begin to gradually make D-NET2 features viable while prioritizing the end users' needs.

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.





DAICHI-2 images in the vicinity of Mt. Ontake's peak. Comparing imagery taken before (right) and after (left) the eruption revealed a depression (circled in yellow) that was not present prior to the eruption.

—— Other than aerial observation, are there any plans for tie-ups between aeronautics and space?

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-8, the Engineering Test Satellite VIII, to provide satellite communications lines in the disaster areas. 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 ?

Ishikawa 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.

Disaster relief decision support system based on diverse data integration and analysis

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-NET2) 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-NET2 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 DNET-2 to find out how everything comes together to aid disaster relief.

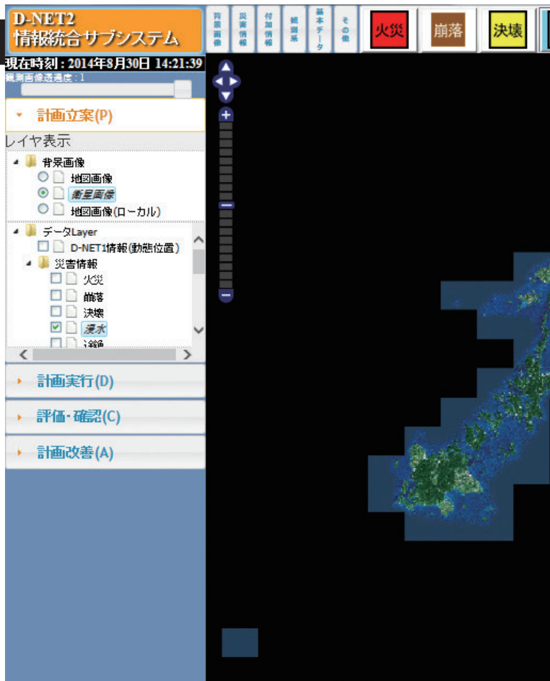
Shift from "passive" to "active"

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 mainly. On the ground, on the other hand, 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 air 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 slow-down in information gathering and situation awareness which in turn resulted in rescue operation delays.



A screenshot of the main screen of D-NET2's Information Integration Subsystem. Blue areas indicate flood zones vulnerable to tsunami, estimated by using observational data from "Daichi-2" (ALOS-2).

Adriana Andreeva-Mori, a researcher on the D-NET2 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-NET2, 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. This allows 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

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Associate Senior Researcher, Disaster Relief Operation Control Technology Section
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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 statues, 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

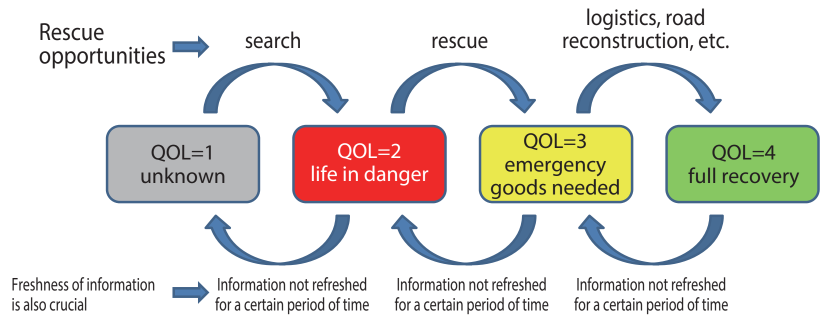
of the above diverse information.

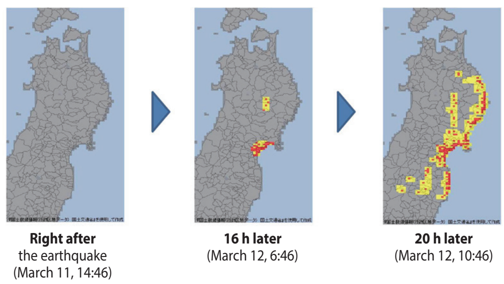
Another difference between D-NET and D-NET2 is the expected user scope. D-NET is developed to be used in the direct proximity of the disaster site, while D-NET2 will enable optimal disaster relief planning and management at EOCs in control of multiple disaster areas. D-NET2 is not a replacement for D-NET: it is a system with a wider range of users.

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

What is QOL





Chronological change of QOL distribution following the Great East Japan Earthquake (Evaluation based on results of JAXA research)

Quality of Life (QOL) is a general indicator of lifestyle quality and comfort. In the field of medicine it is used as a ballpoint figure of a patient's lifestyle. Medical workers say that "QOL has fallen" when a disease progresses, an injury is sustained or a patient otherwise faces a major health problem. With D-NET2, emergency responders will, for example, categorize an uncertain situation as "QOL=1" and a dangerous situation where staying alive is difficult as "QOL=2". This estimation is to be done by matching emergency rescue operations with QOL and quantifying the need for rescues and the situation, and will suggest responses appropriate to each level.

Considering the first 72 hours after a disaster as being critical, JAXA has defined D-NET2’s performance goal as a 66% reduction in the areas with QOL 2 and under. 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.

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

treat patients and disaster victims, even if relief requests have not been sent from them to the EOC. Furthermore, if no information has been received from a hospital in a flooded area, D-NET2 makes an educated guess that the hospital is for some reason isolated and requires rescue. In addition, D-NET2 improves the information accuracy and provides estimates of rescue needs when no information from the EMIS is available. Furthermore, D-NET2 ensures that information is first collected in areas where rescue is most likely to be needed and allocates search helicopters and UAVs accordingly.

Masato Shindo, the associate senior researcher in charge of D-NET2's Information Integration Subsystem, says, "D-NET2 will take in any useful information, whether the source is a satellite or an aircraft, and process and display that information." JAXA is also considering including additional information such as meteorological data sent from weather satellites, power consumption levels recorded by electric companies, and positional information and route histories of ambulances, fire engines and other emergency response vehicles running on the ground. Analyzing and displaying information not directly related to disasters will help predict the damage scope.

Moreover, an expansion to the D-NET Data Specifications in use so far has allowed D-NET2 to also handle observational data recorded by satellites like "Daichi-2" (ALOS-2). Mr. Shindo says, "Instead of just getting satellite data, we are also considering placing observational requests as well, so that D-NET2 can obtain satellite imagery of the disaster area of interest."

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 (see page 7) 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 are indicated on the map as being those areas 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. Andreeva-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 Miyazaki Prefecture's capitol 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.

A review of D-NET2 at an EOC set up in Miyazaki Prefecture's capitol building during a wide area medical transport drill.

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. And 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 data allows us to make more accurate decisions. However, it requires the development of a system with advanced processing capabilities, and the ability to deal accordingly 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.

Section Leader Kobayashi spoke enthusiastically about D-NET2's development. "If we bring together satellites, manned aircraft and UAVs and combine them with JAXA's technological expertise in aeronautics and space, then we can create truly useful technology for disaster prevention and mitigation as well as emergency operations. I think the public expects this from JAXA. We are looking beyond D-NET2, and our goal is to make all this come true as soon as possible."

An emergency operations system like D-NET2 may be able to save many lives in disaster-prone areas outside Japan, not only at home. R&D will continue to make D-NET and D-NET2 available for use in various different disaster settings.

Adriana Andreeva-Mori
Researcher, Disaster Relief Operation Control Technology Section
Operation Systems and Safety Technology Research Group

The Growing Lineup of D-NET-Compatible Airborne Terminals

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

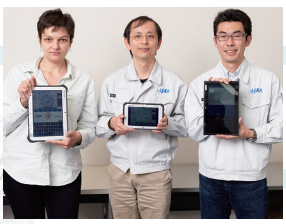
With this type of terminal, satellite communication equipment and an input/display device are preinstalled inside the aircraft. Upgrades and modifications are costly, and after the upgrade a modification and alteration review (to guarantee post-upgrade airworthiness as prescribed by the Civil Aeronautics 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 fire department helicopters.

Partially Preinstalled

With this type of terminal, the transmission device is installed in the aircraft, but the input/display device is carried on board and connected only when needed. It is designed for non-pilot crew members to operate and is considered appropriate for aircraft that have already undergone a modification and alteration review for onboard satellite communication equipment.

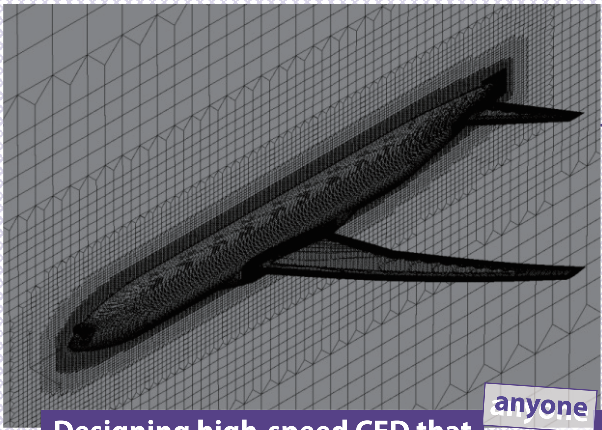
Fully Portable (no preinstallation necessary)

This variation features carry-on satellite communication and information display devices to bring on board when needed. The range of applications and information transmitted is limited, but it does keep the cost of introducing the technology low. This version is for institutions which normally do not 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 understood manner. D-NET2 terminals will continue to evolve to suit the needs of their users.

A computational grid created with HexaGrid



A 3D printer-based visualization of a numerical simulation of flow fields around an aircraft

Designing high-speed CFD that anyone can use

How JAXA is breaking new ground with HexaGrid and FaSTAR

Aircraft design hinges on understanding how the airflow around an aircraft shapes its aerodynamic characteristics. Researchers have used wind tunnels to conduct airflow measurements ever since the dawn of aircraft development, but impressive advances in computer technologies have made computational fluid dynamics (CFD) the prevailing approach in the contemporary context.

CFD technology provides convenient resources for understanding the relationships between aircraft and airflow conditions. In order to make this valuable technology easy for anyone to use, JAXA has developed two new technologies—"HexaGrid," an automatic grid generation tool, and FaSTAR, a high-speed fluid analysis tool—and launched initiatives designed to establish a broader application base for these CFD tools.

Making CFD easier to use through HexaGrid and FaSTAR

Deriving accurate explanations of how air and other fluids move involves performing calculations via complicated Navier-Stokes equations. Even today, these equations are still basically impossible to decipher—there is no general solution for the partial differential equations that come into play.

Computational fluid dynamics, which first emerged in the 1960s, use computers to solve these elaborate equations and thereby give users a way of understanding how fluids flow around an object. Although the CFD approach has several different forms, the most common method in aviation sphere involves generating a grid by splitting the surfaces of and spaces around the aircraft body, the wing, and other parts, and then approximating air movement and changes in air pressure around the aircraft by solving simplified equations. Smaller grid segments produce more precise overall results, but with that precision come more extensive, time-consuming calculations. As increasing numbers of research institutions and manufacturers have brought supercomputers into their operations over the last two decades, however, CFD technology has overcome those computational hurdles to reach a workable, practical speed.

JAXA has been using CFD to analyze the flow and force of air around aircraft and spacecraft for many years, beginning back when the organization was still the National Aerospace Laboratory of Japan (NAL). However, researchers tended to create CFD programs for the purposes of their own individual studies—there was never much of an effort to make programs commonly available. "We eventually decided to start working on practical CFD software that would be accessible to more people," explains Section Leader Takashi Aoyama. "That meant lowering the bar and breaking down some of the barriers to using the CFD technology that we'd been accumulating over the years."

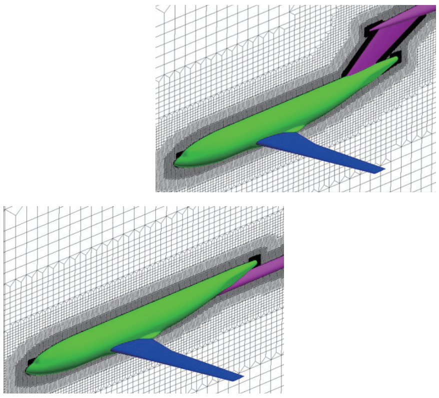
In order to lower that bar, researchers had to grapple with two key issues. First, it takes quite a bit of time to generate computational grids. CFD technology has to create the grids using 3D CAD data for the target shape configuration, setting the stage for CFD. As explained earlier, smaller grid segments produce more precise overall results. For parts like wings, which have flat, generally even surfaces, creating a grid is relatively simple; for areas with complex shapes, areas with many parts, components that lie near the surface of the airframe, areas where the wing and fuselage connect, or any other area that requires more detailed analysis, on the other hand, the grid pieces need to be small. Due to the meticulous nature of the job, it normally takes even the most experienced engineers around a month to generate a grid. The other issue that complicated the effort to provide easier access to CFD was that it takes an extremely long time for CFD solvers* to do their calculations.

JAXA has developed two technologies to get around these issues: HexaGrid, an automatic grid generation tool, and FaSTAR, a high-speed fluid analysis tool.

Why HexaGrid and FaSTAR are so fast and easy to use

With HexaGrid, all the user has to do to generate CFD analysis-compatible grids automatically is load the CAD data for the object and input a few parameters. By utilizing our experience and the know-how we have obtained from years of research and creating effective combinations of simple orthogonal and hexahedral grids, JAXA has created software that "does in less than 30 minutes what used to take a whole month to do," says Researcher Takashi Ishida. The technology enables users to generate fine grids for regions that require high precision, such as near the surface of the aircraft.

The CAD data that provides the basis for generating grids might not always be an accurate, exact representation of the shape of the target object: data sets sometimes include gaps, overlaps, and other defects. HexaGrid, though, manages to produce grids even if there are some deficiencies in the CAD data. HexaGrid users can also replace or remove specific parts without any hassle; they can change the shape of an aircraft's main wing by replacing portions of a given CAD data set with different data, modify the placement and configuration of supports

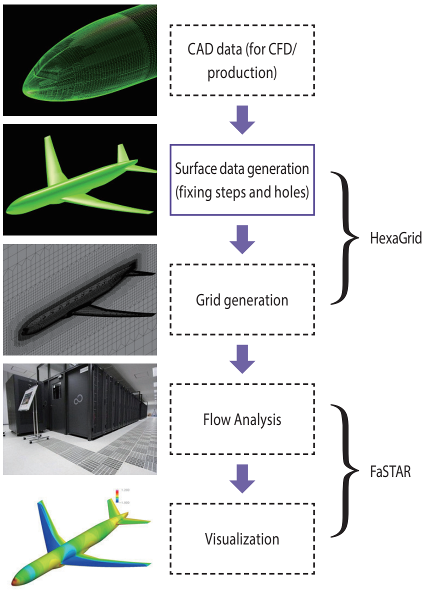


A model that incorporates supports into the calculations to simulate wind tunnel experimentation. An example showing conditions when the support goes through plates (top) and when the supports are attached directly (bottom)

* CFD solver: A piece of software for solving fluid dynamics equations (Navier-Stokes equations); these solvers use iterative procedures to solve massive systems of equations involving a wide array of variables for every grid, including density, speed, and energy.

Numerical Simulation Research Group (from left)
Takashi Aoyama, Section Leader, Unsteady Aerodynamics Section
Atsushi Hashimoto, Researcher, Unsteady Aerodynamics Section
Takashi Ishida, Researcher, Unsteady Aerodynamics Section
Keiichi Murakami, Section Leader, Applied Computation Section

CFD analysis procedure



to be used for simulations of wind tunnel experiments.

The goal for FaSTAR, meanwhile, was to create the world's fastest fluid analysis software. Researcher Atsushi Hashimoto, one of the main developers behind FaSTAR, says that the team set out to "take a close look at all the CFD software suites available around the world and combine the techniques that they used to create the ultimate CFD software." In building FaSTAR, developers used the "multigrid" method algorithm to achieve the software's stunning calculation speeds and tuned the program to their computers to get even faster results.

Calculations that used to take a whole day to complete with the code on the market are all done in less than an hour with FaSTAR—the fastest software of its kind in the world.

No matter how well a piece of software performs, however, it needs to have a good, intuitive user interface to make any impact on the market. That was another focus area for FaSTAR developers, who worked hard to ensure that the software could generate grids and perform numerical computations with minimal data entry requirements. In the end, the team created an interface that brought the learning curve down substantially—a user experience so simple and intuitive that students on two-week internships at JAXA were able to generate grids for their own aircraft configurations, perform CFD analyses, and find out how well their designs would perform before their internships came to a close.

FaSTAR is also extremely versatile, boasting compatibility with grid data formats from non-HexaGrid software suites and seamlessly integrating its output with several visualization applications. If a user needs to add special features, meanwhile, FaSTAR offers the extensibility to make that happen.

HexaGrid and FaSTAR are already in use throughout the 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 (DAHWIN), which actually played a role in accelerating the development of the two software suites.

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.

JAXA's CFD technology starts making inroads into a wide variety of fields

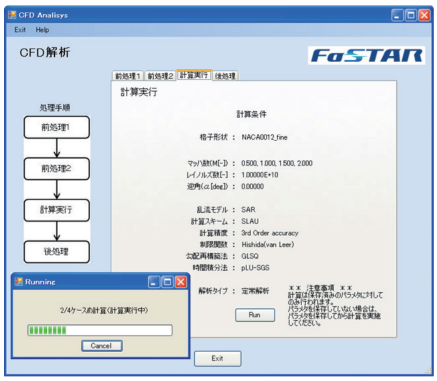
As JAXA was working on FaSTAR, Nagoya University contacted the researchers about using the software in class settings. Up to that point, CFD had rarely ever been more than a topic of one-sided classroom lectures—opportunities to use the technology in a hands-on format had been few and far between.

"We worked with the Japan Society for Aeronautical and Space Sciences to set up the Forum of Aeronautical Education Support, which introduced lots of audiences to possible ways of using the technology in different educational settings," says Section Leader Keiichi 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." Aiming to reach educational environments that lack easy access to supercomputers, JAXA has also developed software that functions on regular personal computers. If FaSTAR continues to carve out a place in the classroom and give students chances to get real, hands-on experience with technologies that incorporate cutting-edge research, JAXA's software will be able to play a vital role in nurturing human resources for the future of Japan's aviation industry.

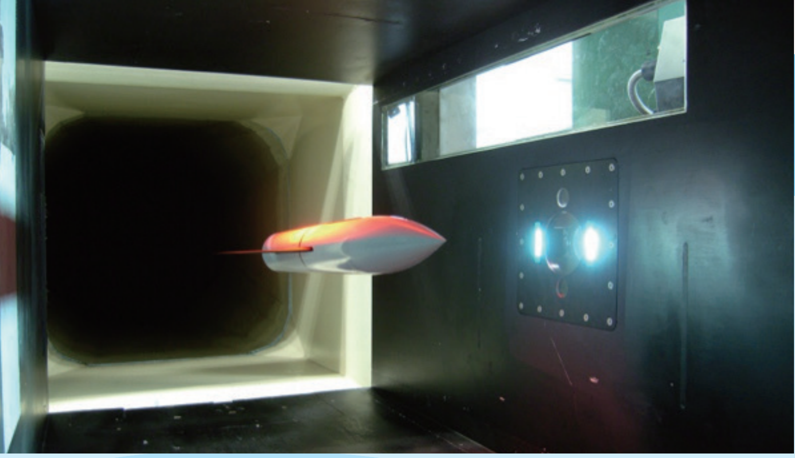
Applications of JAXA's CFD software are already growing beyond the realms of educational support and aerospace applications: JAXA has also started to license its technologies to commercial software in hopes of making the benefits accessible to those outside educational institutions.

Looking outside the aerospace field, JAXA is taking part in a project to research and develop innovative auto combustion technologies as part of the government's "Strategic Innovation Promotion Program" (SIP) and using its CFD technology to help explain the mechanisms of engine combustion. JAXA's technologies are also making a difference in analyzing airflow around windmills, an effort that will make wind power more efficient.

JAXA has improved its CFD technologies, which have generally made few appearances outside the aerospace community, to a level that allows users to conduct high-accuracy analyses of aircraft, rockets, and other relatively streamlined objects. With its new tools for investigating the flow and force of air, however, JAXA now offers infrastructure technologies that will prove useful in fields of all kinds—not just the aerospace sector—and play crucial roles in a wide range of developments. Through HexaGrid and FaSTAR, which deliver world-leading performance in user-friendly packages, JAXA is looking forward to benefiting the aerospace world, driving advances in a variety of other industries, and contributing to the development of capable human resources.



Computer-based CFD analysis software for the educational field



Standard aircraft model
(AGARD-B model) testing photo

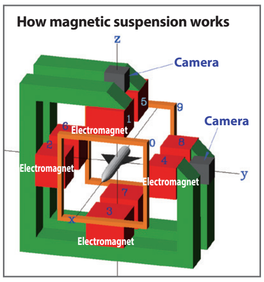
A wind tunnel that simulates in-flight conditions on the ground requires a support apparatus to fix in place the model being measured, but that apparatus has a considerable effect on the measured data. JAXA is conducting R&D on the "Digital/Analog-Hybrid Wind tunnel" (DAHWIN), which removes these effects from the calculations, in combination with a computational fluid dynamics (CFD), and now JAXA has become the first in the world to carry out a practical magnetic suspension wind tunnel test that has no support apparatus whatsoever, coming closer to actual flight conditions.

Suspending models in mid-air with magnetism enabled more realistic measurement

Magnetic Suspension Wind Tunnel

First-Ever Practical Magnetic Suspension Wind Tunnel

The idea of supporting a model in a wind tunnel with magnetism to get closer to actual in-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, succeeded in creating the first-ever practical Magnetic Suspension and Balance System (MSBS) for 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 is simple. When a current runs through the electromagnetic coils mounted to the sides, above, below, in front of and behind the measurement section where the model is placed, each electromagnet creates a magnetic field. Meanwhile, a permanent magnet (neodymium magnets) is mounted inside the model placed in the wind tunnel. When the model is set within the magnetic suspension device, it silently levitates due to the magnetic repulsion.

Two cameras are placed vertically and horizontally adjacent to the measurement section of the tunnel. When the air flowing through the wind tunnel causes the model to move even slightly, the system can measure the amount of movement from changes detected in the camera images. Through repeated attempts at stabilization—made by adjusting the force of the electromagnets in accordance with the amount of movement—and returning the model to its original position, the operators can maintain the model's orientation. We can also learn how much force is exerted upon the model by measuring the fluctuating force of the electromagnets occurring at this time. In other words, the magnets and electricity play a balancing role within this otherwise ordinary wind tunnel.

Tests in Magnetic Suspension Wind Tunnel Outdo Normal Wind Tunnels

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.

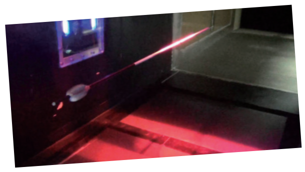
Yet another feature of the magnetic suspension wind tunnel is that operators can freely change the orientation of the model during measurement. One can also move a model on a support apparatus in a regular wind tunnel, but with the magnetic suspension wind tunnel it is easy to move the model as you wish—even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

Hiroki Sugiura, associate senior researcher at the Aerodynamics Research Group, explains, "We can take readings of movement when the model is being oscillated vertically or horizontally at any rate, or of a recreation of an aircraft's turning motion by altering the position and angle."

Because the magnetic suspension wind tunnel requires a powerful magnetic field to support and move the model, careful pre-test alignments are a must. Care is needed so that the model does not fall and damage equipment. Furthermore, when wind tunnel tests using large models representing real aircraft and the like take place, a heavy model containing 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.

Precise Readings of Challenging Objects: Fletched Arrows and Reentry Capsule Airflow

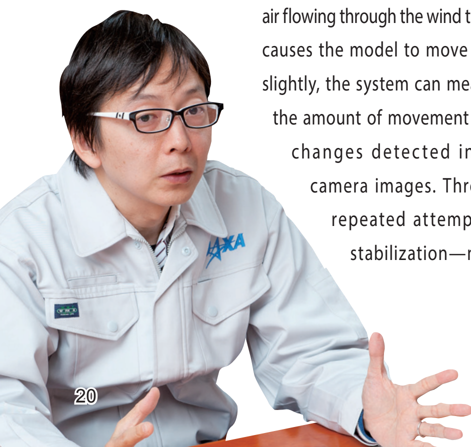
The magnetic suspension wind tunnel is also suited to tests on bodies that are thin like an arrow. JAXA and the University of Electro-Communications are currently proceeding with research relating to the aerodynamic properties of arrows. Until recently it had been thought that arrows with larger feather fletchings fly straighter, but tests with the magnetic suspension wind tunnel found that smaller fletchings offer greater stability. Discovering the mechanism behind this would be a first.



Archery arrow testing photo
(Arrow kept at 1,000 revolutions/minute)

Yet another feature of the magnetic suspension wind tunnel is its excellent suitability for non-invasive measuring, and the system already includes an instrument for measuring particle image velocimetry (PIV*). The absence of a support apparatus means that nothing stands behind 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 movement. These are the best conditions for testing shapes like reentry capsules that vibrates violently due to the flow of air to the rear. Speaking about reentry capsule wind tunnel tests, associate senior researcher Sugiura says they are "a subject that can fully demonstrate the magnetic suspension wind tunnel's capabilities, so we are currently focused on conducting these tests."

Currently, maximum speed is 45 meters/second in JAXA's magnetic suspension wind tunnel, but JAXA has plans to set up another tunnel in the future for speeds at or around the speed of sound (transonic speeds) that would be compatible for tests of faster aircraft, spacecraft and more.



Hiroki Sugiura
Associate Senior Researcher
Environmental Impact Reduction Technology Section
Aerodynamics Research Group

* This measurement technique visualizes the flow of air by firing laser light at particles in the air and comparing images of the reflected light—shot at short intervals—in order to analyze the movement of the particles. (See Flight Path No. 5/6.)

JAXA's Contributions to Civil Aviation Administration in Japan

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 for 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 advisor to the MLIT since 2001. The ICAO 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 to consider the formulation of sonic boom standards and proposed regulations on aircraft engine emissions (NOx, PM, CO_2, etc.) have taken up research findings and data accumulated by JAXA thus far.

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 time of the panel's predecessor body, the Unmanned Aircraft Systems Study Group [UASSG]). Many suggestions and proposals made by JAXA researchers are incorporated 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 omission of redundant inspections during the Certificate of Airworthiness inspections for each aircraft. This is done by conducting design and production process inspections in advance, during the development stage. Type Certificate inspections are necessary, including for the MRJ, the first domestically produced passenger aircraft since the YS-11. With the numerous new materials and technologies incorporated into the MRJ, along with the half-century since the last Type Certificate inspection of a Japanese-made aircraft, the inspection method needs revisions to be applicable to the array of advanced technologies. JAXA is providing the MLIT's Civil Aviation Bureau with technical materials and data that will form the basis for establishing safety review methods and standards that are applicable to these new technologies. In addition, maintenance requirements must be properly defined in order to maintain airworthiness after a passenger aircraft commences operation, so JAXA acts as a technical advisor and otherwise helps the Civil Aviation Bureau's formal review group, which reviews the content of maintenance requirements.

In the event of an aircraft accident or serious incident (i.e. an incident involving circumstances indicating that there was a high probability of an accident), the Japan Transport Safety Board (JTSB), an independent organization reporting to the MLIT, conducts an investigation into the causes of the accident/incident as well as the causes of damage incidental to the accident. Depending on the nature of an accident/incident, JAXA researchers assist the JTSB in various forms, such as by joining in the investigation as expert advisors 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, and have now set up a system enabling smooth cooperation.

Furthermore, JAXA has been conducting an R&D project called DREAMS (see page 3 for details) to develop a next-generation air traffic management system, which is to make a major contribution to the MLIT to implement its longer-term vision for future air traffic systems: the Collaborative Actions for Renovation of Air Traffic Systems (CARATS). To play a leading role within the CARATS roadmap promoted by the MLIT, JAXA is developing key technologies under the DREAMS project in the five fields: weather information technology, noise abatement technology, high-accuracy satellite navigation technology, trajectory control technology and aircraft operation technology for disaster relief.

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.

(Background image: provided by Narita International Airport Corporation)

Flight Path Topics

Verification of the effect of applying Krueger flaps

JAXA is undertaking research to reduce friction drag on wings and improve the fuel efficiency of aircraft.

It is known that an effective way to reduce friction drag is a natural laminar flow design that maintains laminar boundary-layer flow*1 over the surfaces of the wing. However, because insects get stuck to the leading edge of aircraft wings during landing and takeoff, the effect of natural laminar flow design may be reduced. Therefore, we have applied Krueger flaps*2 to the leading edge of the wing and tested its effectiveness at preventing insects and other materials from sticking.

In an experiment conducted in October 2014, a model was created with Krueger flaps with different cross-sections arranged side-by-side and placed atop an automobile, which was then driven. The results confirmed that the effectiveness of preventing insects from sticking differs depending on the shape of the Krueger flap's cross-section and its positional relationship with the main wing to which it is attached.

The results of this experiment will lead to the development of technology to maintain smooth leading edges of wings in order to reduce friction resistance.

This experiment was conducted with public donations given during fiscal 2013.

*1: Refers to a state in which air flows evenly and smoothly over the surface of a wing.

*2: A forward flap device to generate lift for the wings. Such flaps are stored under the wing when cruising, then deployed in front of the wings while landing to generate the necessary lift at lower speeds.

A car equipped with model Krueger flaps. It was preliminarily driven at the Tsukuba Space Center.

Flight experiments using MuPAL-α to enable precise curved approaches performed

The MuPAL-α at Sendai Airport

From December 15 to 19, 2014, JAXA conducted flight experiments with MuPAL-α research aircraft at Sendai Airport to verify how GBAS*1 could enable precise curved approaches.

In addition to creating the need for shorter intervals between take-offs and landings, escalating airport traffic levels are also leading to increased turbulence around airports and exacerbating noise problems for local residents. Tailoring operations to weather conditions and mitigating the noise around airports will require technology that enables curved paths and other types of flexible approaches.

For its recent experiments, JAXA teamed up with the Electronic Navigation Research Institute (ENRI) to send TAP*2 data containing curved and multiple approach segments from ENRI's ground-based GBAS at Sendai Airport to the MuPAL-α. Based on the path information it received, MuPAL-α then used its fly-by-wire feature to make a straight-in approach and a curved approach via simulated autoflight system. The results of the experiment will aid in the verification of the automatic control system that the DREAMS Project has developed and help verify in-cockpit display devices. The success of the study owes a great deal to the wide-ranging support and cooperation of ENRI, the Tokyo Regional Civil Aviation Bureau, the Sendai Airport office, the Civil Aviation College, and other organizations.

*1: GBAS: Ground-Based Augmentation System; see page 9 for details.
*2: TAP: Terminal Area Path; see page 9 for details.

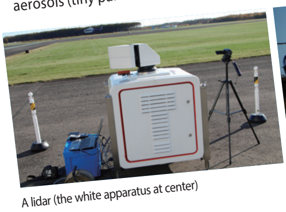
Measurement of wake turbulence with JAXA's research helicopter

JAXA conducted an experiment from October 21 to 31, 2014 to measure the wake turbulence of JAXA's research helicopter at Taiki Aerospace Research Field.

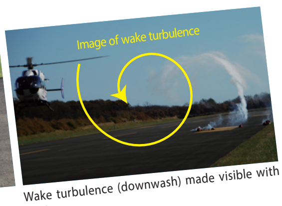
When a helicopter flies, this wake turbulence (downwash) can exert an adverse effect on aircraft flying behind it. Small fixed-wing aircraft have even crashed because of this. JAXA is studying to find out how a helicopter's wake turbulence moves and disperses in order to help small fixed-wing aircraft fly safely when near helicopters.

For this experiment, two lidars* and four ultrasonic anemometers were placed around a runway, where researchers measured the wake turbulence of JAXA's research helicopter (BK117C-2) as it hovered, taxied (moved slowly), performed a level flight pattern and executed other maneuvers over the runway.

* A sensor that measures wind speed by observing laser light's backscatter from aerosols (tiny particles in the air).



A lidar (the white apparatus at center)



Wake turbulence (downwash) made visible with smoke

Main wing deformation measured during Hisho flight

During flight, the shape of an aircraft's wings is altered by the force of the air. This in-flight change is taken into consideration when designing an aircraft, but there used to be no technology to check whether a wing would actually change shape and perform as expected. By using the jet flying test bed "Hisho," JAXA aims to establish a method to optically measure how main wings deform during flight.

Via this method, JAXA uses two cameras to record footage of 26 target markers placed on Hisho's portside main wing and process the imagery to compute a 3D geometry of the target markers' positions. During a test conducted in November 2014 over the waters near the Noto Peninsula, the results indicated that the difference between the measurements of Hisho's 7-meter wing taken on the ground and those recorded during the flight test indicated maximum bending of 160 mm and torsion of about -1.0 degrees.

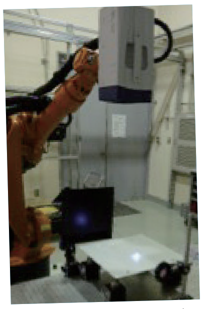
Footage of target markers on the main wing as seen through a window

This method will take on greater importance because in the future more aircraft are expected to use main wings made from composite materials, which experience even greater deformation than Hisho's duralumin wings.

FLIGHT PATH No.7/No.8
JAXA Aeronautics Magazine
March 2015

Published by: Institute of Aeronautical Technology, Japan Aerospace Exploration Agency(JAXA)
7-44-1 Jindaiji Higashi-machi, Chofu-shi, Tokyo 182-8522
Website: www.aero.jaxa.jp

Demonstration experiments on a Lamb wave-based, non-destructive inspection method conducted using MaVES


The MaVES-c unit for measuring vibrations

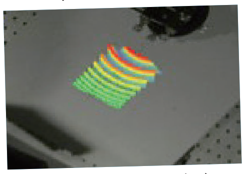
JAXA is collaborating with the Shibaura Institute of Technology and Hokkaido University on research into a Lamb wave-based, non-destructive inspection method that would make it possible to examine aircraft damage in an efficient, extensive manner.

Ultrasonic wave has driven most of the conventional approaches to non-destructive inspection, but ultrasonic-based tests can only cover a limited scope at a time and also involve placing the testing instrument in direct contact with the test object. These drawbacks can reduce accuracy and hurt overall efficiency.

From September 2014 through December 2014, JAXA conducted experiments in which it vibrated objects using lasers—which do not require physical contact with the objects—to generate ultrasonic elastic waves called "Lamb waves." Researchers then used JAXA's MaVES-c (a compact version of the Multi-axis Vibration Evaluating System)* to measure how the elastic waves propagated across the objects.

Lamb waves propagate for long distances with minimal attenuation across flat plates and bar-like objects. However, the time constraints and limited capabilities of conventional testing equipment have made it difficult to measure and visualize Lamb wave propagation on planar surfaces. By applying its MaVES technology, JAXA succeeded in visualizing Lamb wave propagation over a short period of time.

In hopes of eventually applying the method to aircraft damage inspections and thereby improving maintenance (testing) efficiency, JAXA plans to demonstrate the method's ability to detect various types of damage types.


Lamb wave measurements (ex.)

* : A system that automatically measures the vibration of an object with lasers (See Flight Path No. 3/4 for more information)

Official launch of the aFJR and FQUROH projects

In January 2015, JAXA officially launched two research and development projects: aFJR and FQUROH.

The aFJR (Advanced Fan Jet Research) project aims to develop and demonstrate technologies for the ultra-high bypass ratio engine with lower weight by making fans and low-pressure turbines lighter and more efficient. This is in response to the growing requirements for aeroengines with improved fuel burn and lower noise emission. JAXA will develop and demonstrate technologies for a lightweight fan with improved aerodynamic efficiency and a lightweight, low-pressure turbine—two component areas where Japanese engine manufacturers have considerable experience. (See Flight Path No. 1/2 for more information.)

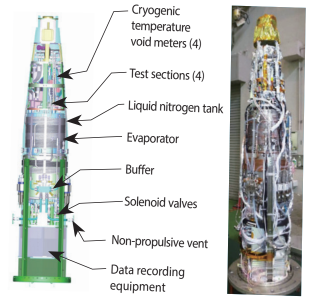
The FQUROH (Flight demonstration of QUiet technology to Reduce nOise from High-lift configurations) project, meanwhile, focuses on developing and conducting flight tests on technologies that reduce airframe noise, which begins to exceed engine noise when an aircraft commences its approach procedures. Moves to apply more stringent noise regulations on aircraft are gaining momentum around the world as part of an effort to reduce the environmental burden of aircraft noise on the communities around airports. Some airports, in fact, charge take-off and landing fees based on aircraft noise level; these fees create operational cost for airliners. The FQUROH project will develop noise-reduction technologies for high-lift devices (flaps and slats) and landing gears (legs), which represent significant sources of noise. (See Flight Path No. 1/2 for more information.)

Through demonstrations of their respective technologies, the aFJR and FQUROH projects aim to provide viable new solutions that will help Japanese manufacturers in the aviation field secure a major edge in the development of next-generation aeroengine and aircraft. As a result, JAXA will enhance the international competitiveness of Japan's aviation industry through the aFJR and FQUROH projects.

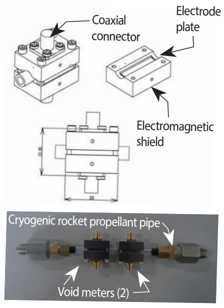
Behavior of two-phase flow with liquid rocket propellant in space observed with sounding rocket

Sounding rocket S-310-43 lifted off from JAXA's Uchinoura Space Center at 23:00 on August 4, 2014. The sounding rocket test used the low-gravity environment created when putting the rocket into ballistic flight*1 for the purpose of investigating such behavior as boiling and flow of cryogenic liquid rocket propellant (liquid nitrogen used for this test) in an environment simulating coasting flight*2 in space. For this experiment, JAXA's Institute of Aeronautical Technology was in charge of developing cryogenic test equipment to be loaded onto a sounding rocket. This test equipment included a two-phase flow sensor (a cryogenic void meter)*3 that JAXA developed with Waseda University and Tohoku University.

This sensor is a new design to achieve flow rate measurement in a two-phase state,*4 generally considered a challenging task. It contributed to improving launch capabilities in JAXA's H-IIA upgrade project. In this sounding rocket experiment, JAXA performed the first-ever cryogenic void measurement in space and later confirmed from analysis that it had obtained enough cryogenic two-phase flow data to examine the precision of a chill-down analysis tool for Japan's new flagship launch vehicle. JAXA and its partners hope to apply this void meter to the new flagship launch vehicle's onboard flight sensors and ground infrastructure sensors.



Cryogenic temperature test equipment loaded onto the sounding rocket



Overview of the cryogenic void meter

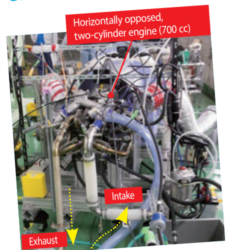
*1: A falling motion along a trajectory that traces a parabola as a bullet does.

*2: Flight in a state of no acceleration. Satellites fly around the Earth via coasting flight.

*3: A sensor that detects the proportion of gas and liquid (void ratio) within a pipe.

*4: A state in which different states of matter (gas and liquid, etc.) mix and flow together.

Operating tests on a high-altitude, turbocharged engine for a high-altitude, long-endurance aircraft performed



Equipment for testing high-altitude, turbocharged engines using a reciprocating engine

In March 2015, JAXA performed operating tests on a high-altitude, turbocharged engine at its Chofu Aerospace Center.

While the most common type of aircraft engine is the gas turbine type, with its compact size and high levels of output, JAXA is exploring the idea of using reciprocating engines (diesel engines) in unmanned aircraft with long-endurance capabilities. Reciprocating engines may be heavier than their gas turbine counterparts, but they also boast high levels of fuel efficiency that make it possible to reduce the amount of fuel that aircraft need to have on board for long flights.

For the recent operating tests, JAXA created a prototype for a light-aircraft reciprocating engine with a two-stage turbocharger to boost the density of the air flowing into the engine. The tests involved assessing operations in a low-air-pressure environment to simulate the thin air conditions that characterize high-altitude flight.

Using these test results and data from simulations, JAXA will verify whether the engine can produce enough output for the high-altitude, long-endurance unmanned aircraft currently under consideration for development.