



Aiming at realizing an optimum operation management system for fire and disaster management helicopters

During the Tohoku earthquake, more than 300 helicopters were engaged in rescue operations around the disaster site. They included those from the Self-Defense Forces, fire and disaster management, Japan Coast Guard, police and Doctor-Heli. The fire and disaster management helicopters are those operated by the fire departments of major cities and prefectures all over the country. Their tasks cover a broad range, for example, information gathering, search and rescue, emergency medical support, transportation of personnel/supplies and aerial firefighting. Currently, there are 70 aircraft throughout the country; on the day after the earthquake (March 12), 45 of them were gathered in the three Tohoku prefectures (Iwate, Miyagi and Fukushima). There are various types, from small-size ones to larger ones, and they are equipped with rescue hoists (suspension equipment) while some are equipped with video transmission systems. Since the tasks that



can be efficiently performed differ depending on the aircraft's capabilities and equipment, it is essential to assign the most suitable task to each helicopter based on the disaster information collected from one moment to the next. In addition, if support near the disaster site is insufficient, based on the request

from the affected prefecture, the Fire and Disaster Management Agency will dispatch the appropriate aircraft, selected from all of the nation's fire and disaster management helicopters, to the disaster site (mutual aid). Establishing and executing the plan concerning which tasks are assigned to which aircraft and how they will be flown is called "operation management". In this Special feature, we will introduce an optimum operation management system for fire and disaster management helicopters, whose research and development JAXA is advancing with the cooperation of the Fire and Disaster Management Agency and Kobe City fire department.



Fig.1 : Flow of helicopter operations for a large-scale disaster
Helicopters are mobilized from all over the country and assigned various tasks depending on the aircraft's capabilities and equipment.

Expected effects of the operation management system

When a disaster occurs, depending on its scope, disaster-response headquarters are set up by the prefectural municipalities or national authorities. Additionally, the operation bases for the helicopters are set up at airports and/or heliports near the disaster site (fig. 1). With the Tohoku earthquake, operation bases were set up at locations such as the Iwate Hanamaki Airport, Yamagata Airport and Fukushima Airport. At the operation bases, in addition to being a location where helicopters took off/landed and were parked, fueled and maintained, tasks were assigned to each helicopter and instructions were dispatched, based on requests received by phone and fax from the disaster-response headquarters. Task instructions and information were transmitted between the operation base and the aircraft through voice communications using aviation radio (air-to-ground communication).

With a large-scale disaster, the number of necessary tasks and mobilized helicopters dramatically increase. Currently, operation management is being performed solely according to human decisions. However, if the information could be converted into data and a system could be realized where that data is processed by a computer to assist in determining the optimum operation management, the mobilized helicopters could be managed more efficiently.

At JAXA, we are continuing research and development of the "Disaster Relief Aircraft Management System Network (D-NET)". The following are the two main objectives of this research.

- Establish standards according to which information necessary for operation management is shared as data between aircraft and disaster-relief headquarters during a disaster, and submit them to disaster-related agencies and equipment manufacturers.
- Conduct research and development of a system for performing optimum operation management using shared information, and demonstrate its validity.

If this type of system could be

implemented, it would be the first such system in the world.

The operation management system for fire and disaster management helicopters, currently being researched, will have two functions: one on-site and one regionally.

(1) On-site operation management system

Possesses the function of instructing aircraft mobilized near a disaster site on their optimum task, flight route, timing for beginning the flight, etc. This is expected to reduce "wasted time" (such as waiting for refueling, takeoff and landing), which is not directly necessary for accomplishing tasks, as well as reduce the number of aircraft flying in close proximity of each other, thereby reducing the risk of mid-air collisions.

(2) Regional operation management system

Possesses the function of selecting the aircraft (from all of the nation's fire and disaster management helicopters) suitable for the task required at the disaster site, and calculating the optimum flight route, etc. while considering the following conditions.

- The helicopters must be periodically inspected. If a helicopter soon due for its inspection is dispatched, it cannot properly perform the activity.
- The possibility of another disaster occurring simultaneously must be considered, and the minimum necessary aircraft must remain in each area of the country.
- Helicopters tend to fly under visual flight rules^(*); however, when flying in bad weather, the aircraft will be required to fly under instrument flight

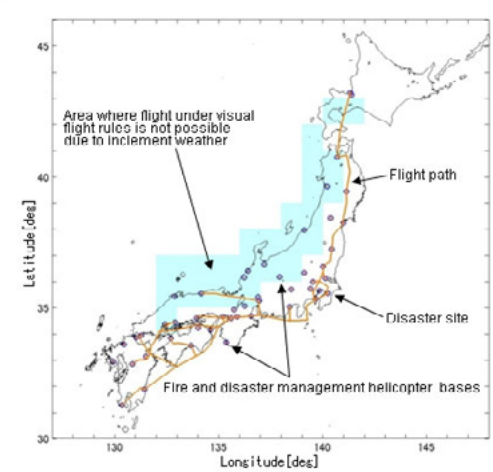
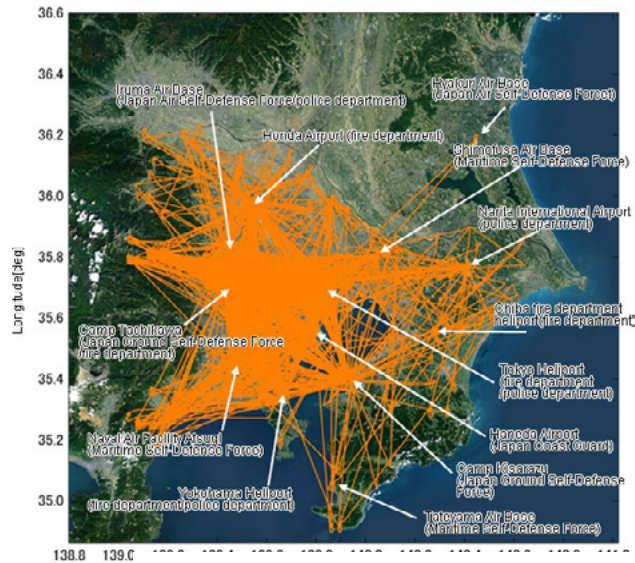


Fig. 2: Simulation of disaster-relief aircraft operations assumed for an earthquake occurring directly below the capital (Top) Flight trajectories of helicopters (all 425) near the disaster site (Bottom) Flight trajectories of regional support by fire and disaster management helicopters

	Area near the disaster site		Regional support
	Wasted time (hr/machine)	Near misses (occurrences/hr)	Time required (min.)
Without D-NET	2.9	0.82	317
With D-NET	1.4	0.28	228
Effect of implementation	53% reduction	66% reduction	28% reduction

Table 1: Example of effects of D-NET implementation, determined through simulations

rules^(*).

(*1) Visual flight rules: A method where pilots confirm safety visually and fly based on their own decisions
 (*2) Instrument flight rules: A method of flying a predetermined route according to the controller's instructions

Verification of the effects through simulations

Figure 2 shows a computer simulation of helicopter flights, assuming an earthquake occurred directly below the capital. Considering the damage anticipated by the Central Disaster Prevention Council in the Cabinet Office and the operation plan based on that, as formed by the Fire and Disaster Management Agency, the conditions were established by JAXA itself, and then the flow of operations, such as the flight performance of each aircraft, task assignment and execution, takeoff/landing and refueling, were simulated.

Figure 2 (top) shows the flight trajectories of helicopters near the disaster site during the 9 hours immediately after the disaster occurs. A total of 1,100 flights are simulated for all 425 aircraft. This example shows that conducting optimum operation management using D-NET can reduce wasted time by 53% and reduce the number of helicopter near misses (where TCAS^(*) avoidance commands are activated) by 66% (table 1).

In order to calculate the optimal solution, a method called "genetic algorithm" is used. This is a calculation method that simulates optimization of the evolution of organisms with regard to their environment. A feature of this calculation method is that it can flexibly respond to unpredictable situations, such as a disaster.

Figure 2 (bottom) shows the flight trajectories of fire and disaster management helicopters throughout the country on the first day of the disaster. The light-blue portion of the map indicates the area where flights are assumed to be possible only by aircraft that can fly under instrument flight rules. This example shows that conducting optimum operation management using D-NET can reduce the time to complete deployment by 28% (table 1).

In the calculation of the optimal solution for regional operation management, a method called "Dijkstra's algorithm" was used. This method is also used by routing

(*) TCAS:

Mid-air collision avoidance equipment widely utilized by aircraft (abbreviation of Traffic alert and Collision Avoidance System)

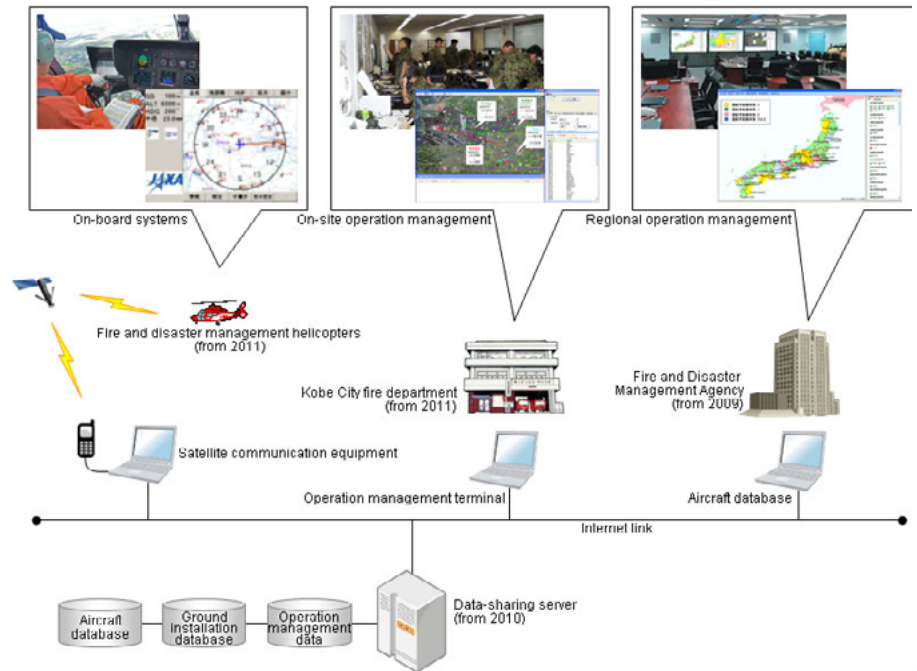


Fig. 3: Configuration of a system for evaluating D-NET. The years within parentheses are the years when development/evaluation began.

assistance software.

In the future, we plan to conduct a simulation of the helicopter flights for the Tohoku earthquake, then verify it by comparing it with the actual flight logs in order to improve the accuracy of simulations.

Responding to issues made evident by the Tohoku earthquake

With the cooperation of the relevant organizations participating in rescue

operations during the Tohoku earthquake, JAXA continues to investigate technical issues. The following are the major issues that have been made evident until now.

1. When the operation base is stricken, it is difficult to respond according to previously theorized manuals, making improvised and impromptu decisions necessary.
2. When a number of aircraft are mobilized to an operation base at the same time, the wait time for refueling and assigning tasks is longer, and it is difficult to



Fig. 4: Installation of D-NET on-board system

The D-NET on-board system was mounted on a Kobe City firefighting helicopter (BK117 C-2 model). The image on the right shows the display for inputting/outputting the necessary information for operation management.

operate efficiently.

- Examples of missed dispatches (the necessity for tasks had already disappeared) and duplicated dispatches (multiple helicopters were assigned to the same task) have been reported.
- When the disaster site extends over a wide area, examples have been reported of blocked air-to-ground communication between the operation base and aircraft due to obstacles such as mountains as well as communication difficulties when multiple aircraft send communications at the same time.

It is conceivable that implementing D-NET can respond to these issues. For example, concerning issues 1. through 3., computer-supported operation management would enable the optimum decisions to always be made in response to the ever-changing circumstances. In addition, concerning issue 4., using satellite communications instead of aviation radio (air-to-ground communication) as well as data communications instead of voice communications would enable information to be simultaneously shared between multiple helicopters and the disaster-relief headquarters, regardless of the location.

Developing a system for evaluation

In order to realize an optimum operation management system, development of the following equipment and software is

required.

- System for sharing data between aircraft and the disaster-relief headquarters
- Calculation algorithm for optimum operation management
- Human interface (displays, etc.) so that the pilot and operation manager (dispatcher) can input/output information

Currently, with cooperation from the Fire and Disaster Management Agency and Kobe City fire department, JAXA has made a prototype of this system and is continuing plans to evaluate and demonstrate it (fig. 3). The Fire and Disaster Management Agency is a national agency that brings together the fire and disaster management helicopters from all over the country and builds upon the experiences of the Great Hanshin-Awaji Earthquake, which occurred in Kobe City in 1995. Since then, Kobe City has actively tackled the effective use of helicopters during large-scale disasters. In September 2011, the Kobe City firefighting helicopter "KOBEL-11" was equipped with the D-NET on-board system (fig. 4). This system consists of equipment such as on-board displays for the pilot and crew (firefighters, etc.), a computer and satellite communication equipment. The basic equipment configuration is the same as the on-board system for Doctor-Heli, which was introduced in No. 20 of this magazine.

The D-NET on-board display (fig. 4, right) shows the flight information for the aircraft

that it is mounted on as well as others, task information and information on nearby ground installations. In addition, we are continuing development of new functions in response to the needs of fire and disaster management helicopters. Figure 5 shows a screen for on-board inputting of data for the disaster information. Currently, aircraft equipped with video transmission systems, called "Heli-tele", are primarily sharing the task of information gathering; however, if these D-NET functions could be implemented, the status of the disaster could be sent as data from helicopters used for search and rescue, emergency medical support as well as for transporting personnel/supplies. However, the issue is to develop a human interface that can convert the necessary information into data with simple operations, without increasing the workload for the crew.

Future plans

The evaluation of this system using fire and disaster management helicopters is expected to extend for about 1 year from December of this year. During this time, through training and actual operations, we plan to determine the issues with this system and evaluate its effectiveness. In 2013, we aim to develop a more practical system that reflects the results of these evaluations.



Fig. 5: Sample screen from the D-NET on-board display (disaster information input screen)

Possesses functions for inputting data for information such as the location, range and type of disaster detected from the air.



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Imagining environmentally friendly passenger aircraft

- Conceptual study of future passenger aircraft aimed at reduced CO₂ emissions -

From the research field

Civil Transport Team

Reducing the CO₂ produced in our daily lives is effective in curbing global warming. Therefore, hybrid cars, which use energy regeneration to reduce fuel consumption, have been developed by automobile manufacturers, and electric cars with zero CO₂ emissions have already been realized. Meanwhile, efforts by airframe and engine manufacturers have continued in order to reduce fuel consumption with improved aerodynamic performance, lighter airframes and highly efficient engines for passenger aircraft, which appear to have undergone no changes compared with automobiles.

Reducing fuel consumption of the most advanced passenger aircraft is highly dependent on the engine; however, we are nearing the limits of increasing the performance of turbofan engines, which are

mounted on passenger aircraft. Therefore, we have examined further reducing the fuel consumption of passenger aircraft by equipping them with an open rotor, which increases the propulsive efficiency with a large contra-rotating fan that has been laid bare from the engine, as well as a fuel-cell-powered propulsion system with a propeller driven by fuel cells and an electric motor.

■ Focus on propeller engines

The magnitude of fuel efficiency with the open rotor was demonstrated by NASA and others in flight tests during the 1980s; however, the loud fan noise made meeting noise regulations a major issue. Therefore, we have conceived the 120-seat JAXA Open-Rotor Craft (JORC) with the open rotors placed on the top

of the wing to shield the fan noise. The airframe concept drawn out is the sketched form shown in figure 1 (a). However, the requirements of a passenger aircraft cannot be met with this sketched form. Corrections to the fuselage configuration and wing position and an increased area of the canard (small wing at the front of the fuselage) and tails are shown in the conceptual design form in figure 1 (b). A sound source model for the fan noise was created from data obtained in noise measurement tests conducted in the 1980s by NASA and others. By placing this sound source model on top of the wing of the conceptual design form and estimating the noise at takeoff and landing, we determined that their levels meet the current noise regulations. However, the fuel consumption of JORC can only be reduced by 20%,

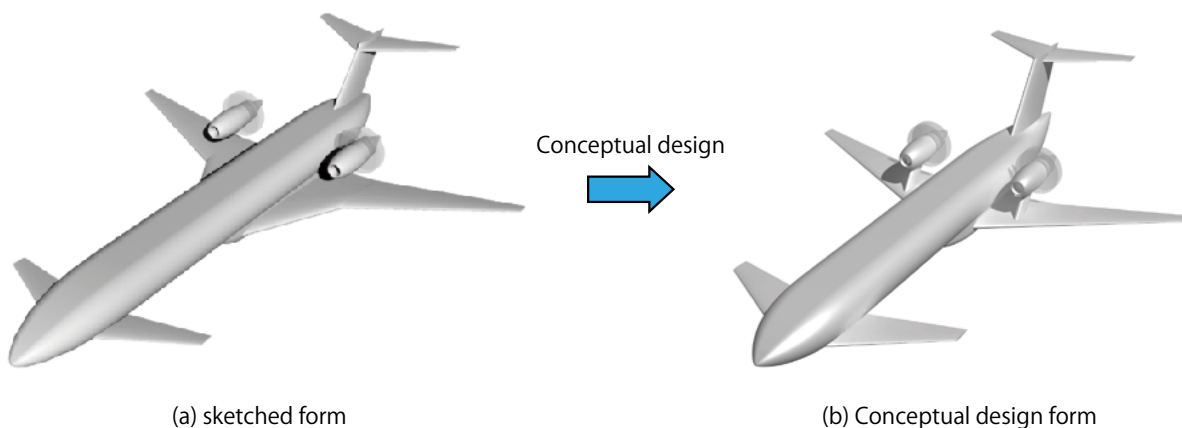
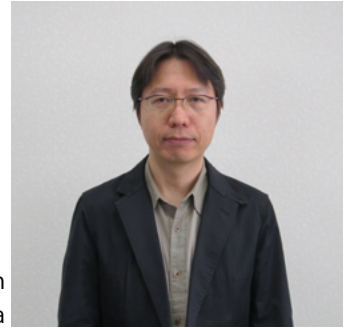


Fig.1 : JAXA Open-Rotor Craft



System Concept Section
Toshiyuki Nomura

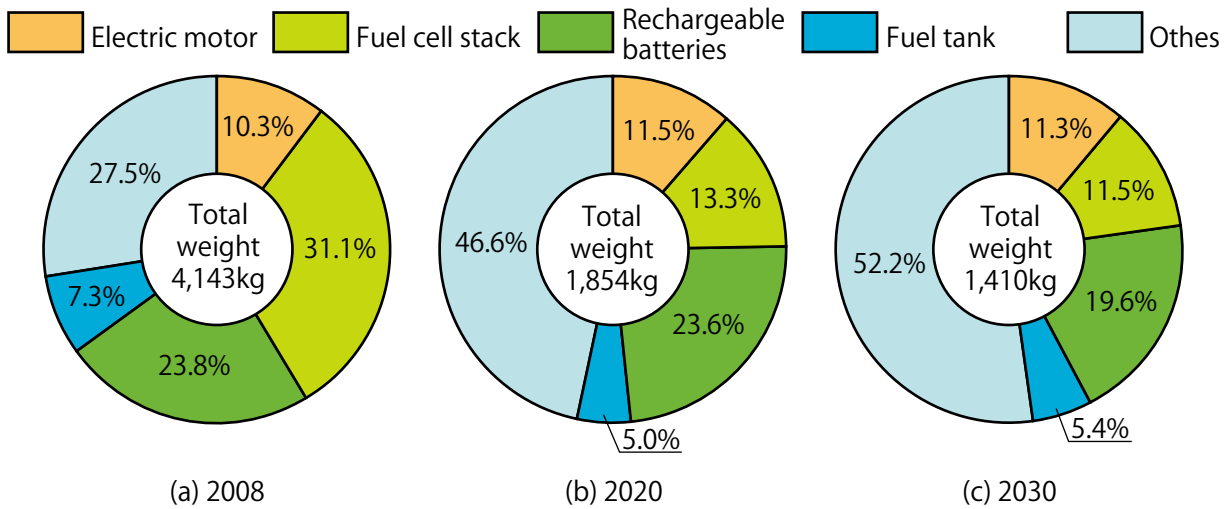


Fig.2: Total weight of the Do228 fuel-cell-powered propulsion system and its breakdown

compared with existing aircraft in its class, even when the improved fuel efficiency of the open rotor and a lighter aircraft weight from using composite materials are considered, so improving the low aerodynamic performance, a drawback of this reduced fuel consumption, is a future issue to be resolved.

■ Are aircraft that fly with electric power a possibility?

When a fuel-cell-powered propulsion system, consisting of fuel cells, rechargeable batteries, an electric motor and liquid hydrogen tanks, is mounted on the passenger aircraft, its weight becomes a major problem. Therefore, we referred to the propulsion systems

of existing aircraft, and estimated the weight of a fuel-cell-powered propulsion system configured with the same performance. We considered that, if the fuel-cell-powered propulsion system was heavier than the propulsion systems of existing aircraft, the fuel-cell-powered propulsion system could be mounted if that additional weight was subtracted from the payload (weight of passengers and cargo) of the existing aircraft and that payload was not reduced to zero. Figure 2 shows the weight of the fuel-cell-powered propulsion system, estimated with reference to the Dornier Do228, servicing the Chofu-Kouzushima route. At 2008 technology levels, no payload remained; however, we concluded

that a payload of 50% that of the Do228 at 2020 technology levels inferred from literature, and a payload of 86% that of the Do228 at 2030 technology levels would remain.

Examining the validity of an aircraft concept is a conceptual study, which is the starting point in the development of passenger aircraft. The agent of passenger aircraft development is the manufacturer; however, JAXA is focused on clarifying technology useful to improving the performance of passenger aircraft by conducting conceptual studies, and on contributing to passenger aircraft development with research and development of that technology.

(Toshiyuki Nomura)

■ Advantageous instrument approach system

In order to land on a runway, even when visibility is poor such as in fog or rain, aircraft are operated using a system called instrument approach. The instrument landing system (ILS) is the most generally used; from the ground along the aircraft approach path, it sends out radio waves that are modulated depending on the horizontal and vertical deviation so that aircraft receiving these can detect the deviation from the approach path (fig. 1). With these deviations appearing in the instruments or by entering autopilot, flight along a precise path is possible, even if nothing can be seen outside, or the aircraft can be landed automatically, even in heavy fog where there is absolutely no visibility.

However, in order to land using an

instrument approach in this way, various requirements, for example, concerning aircraft systems and crew training as well as ground installations, must be met since it may be necessary to respond to radio wave disturbances or equipment malfunctions during approach. For example, the straight section immediately before landing on the runway must be a minimum of about 5 km. As a result, there are some airports where an instrument approach system cannot be established, because this straight section cannot be secured for some reason, for example, due to a steep terrain or densely populated areas around the airport. If this final straight section could be shortened, these types of airports would enable an instrument approach, which is linked to an increased service rate as

well as reduced CO2 emissions, less noise and reduced fuel consumption due to shortened routes.

■ Aircraft generating their own straight-in approach path

One method being considered as a way to realize such a curved approach (fig. 2) is to fly a route where the curved section

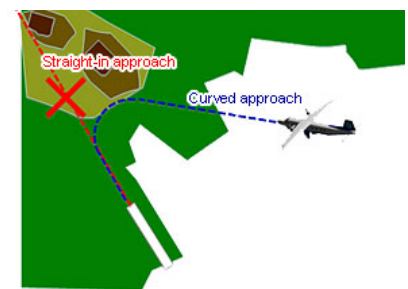


Fig.2: Curved approach

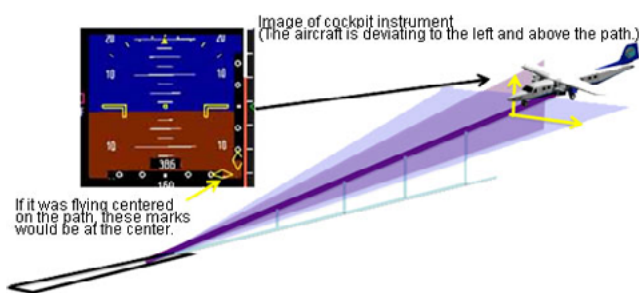


Fig.1: Straight-in approach with ILS

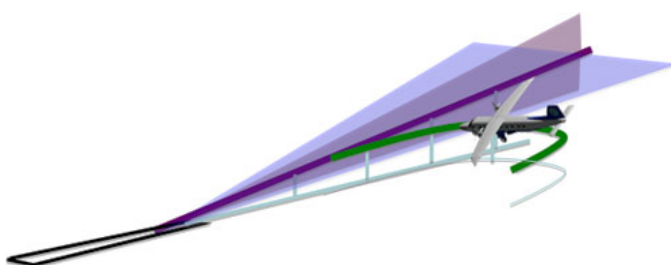


Fig.3: Curved path meeting ILS

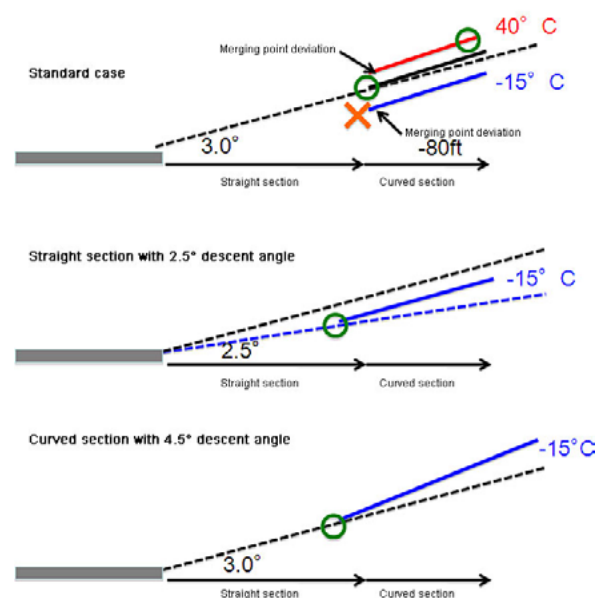


Fig.4: Ambient temperature changes and meeting of ILS and curved paths

Next-Generation Navigation Unit
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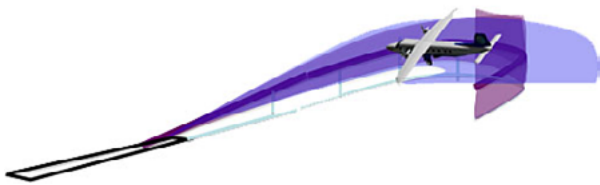


Fig.5: Curved approach using GLS/TAP



Fig.6: Approach and landing test using GLS

is established by the aircraft, then meets with ILS at a low altitude (fig. 3). However, this method has the problems that the junction point changes according to the ambient temperature and that the curved path and ILS path do not meet in some cases. Aircraft use the altitude-related changes in the atmospheric pressure to determine the altitude at which they fly. However, since the changes in the atmospheric pressure differ depending on the atmospheric temperature, 500 m at 15 ° C, for example, actually becomes 400 m at -25° C.

Therefore, at JAXA, we are using a flight simulator to research how atmospheric pressure changes affect the junction with the curved path and how the aircraft can fly so that the curved path merges without being affected by the ambient temperature. As shown in figure 4, with a standard route, the curved path meets ILS at 15° C and 40° C, but not at -15° C. We have determined that a route can be established where the two paths meet at low temperatures if the path angle of the straight section of ILS is set at 2.5 ° and the descent angle of the curved section is increased.

■ Beginning evaluation of an instrument approach system that uses

satellite navigation

A method using a GNSS landing system (GLS) for realizing the curved approach is being anticipated in the future. The introduction of GLS is gradually beginning around the world with instrument landing systems using satellite navigation such as GPS. The operating principle is quite different, but it can be used by aircraft in the same way as ILS. However, unlike ILS, because information on the standard route is sent by radio waves to the aircraft, a curved approach is possible by constructing this standard route with multiple segments that include curves rather than straight lines. The technology for creating the GLS route with multiple segments is called TAP (fig. 5), and research is only just beginning in many areas such as autopilot and instrument displays as well as pilot procedures.

In collaboration with the Electronic Navigation Research Institute, JAXA is conducting research aimed at realizing a curved approach that uses TAP. First, in order to confirm that information

for landing using GLS could be generated by aircraft, an actual GLS was used to conduct flight tests (fig. 6 and 7) with experimental aircraft, in collaboration with the Electronic Navigation Research Institute. Currently, we are still at the level for a straight-in approach, but we plan to conduct evaluations of the curved approach from 2012.

(Kouhei Funabiki)



Fig.7: Test equipment showing the path transmitted from the ground with GLS

Overseas Researcher's Report

From Toulouse, France

In March 2011, I came to Toulouse, France, as an overseas researcher with a long-term training program funded by the Aerospace Research and Development Directorate (ARD) and the Aviation Program Group (APG) of JAXA. Now, I'm working for Airbus in the field of numerical simulation technology on composite materials. Although it was hard to settle into a new life at the beginning, my research activities are now going well and, thankfully, I have a fulfilling life here. This report describes my current activities and my life in Toulouse.

■ Research activities at Airbus

As you already know, Airbus is a leading aircraft manufacturer with the highest level of innovative technology and research capabilities. Airbus is a truly global enterprise with more than 54,000 employees and has a presence all over the world. Although I'm working as a researcher for JAXA, I endeavored to study practical and operational requirements because these are the essence of the research activity. Fortunately, I have been given an opportunity to work with Airbus. Now, I'm working for the Vulnerability team, which is one of the most successful teams in the Structure Analysis division of the Engineering department. Here, we're mainly dealing with state-of-art simulation technology for aircraft vulnerabilities, such as impact damage, bird strikes and aircraft

crashworthiness, with a particular focus on composite structures. Recently, composite materials, typically carbon fiber reinforced plastic, have been commonly used for aircraft structures because of its light weight and high-strength material properties. However, many technical challenges still remain to fully utilize its advantages in practical aircraft applications. My research topic is one of these challenges and we will try to establish operational simulation technology to capture damage in composite materials.

The team is transnational and consists of 12 people (5 French, 4 Britons, 2 Germans and 1 Spaniard), which reflects the global presence of Airbus. What surprised me is that each person is highly motivated and productive. At meetings, they focus on a lively discussion and draw out specific output. In the beginning, I felt it was a different working style than in Japan, but now I really enjoy working with the people at Airbus. Taking this opportunity, I'm keen to establish further cooperation between Airbus and the Japanese aerospace industries.

■ The city of Toulouse

Toulouse, which is where I am living, is a central city in southwestern France and, with its population of about 440,000, is the fourth largest in France, after Paris, Lyon and Marseille. Its old district is made up of many brick buildings, earning it the nickname "La Ville Rose". In addition, a mass of violets in the outskirts has also given it the name "City of Violets", and a sweet aroma wafts through the air with shops selling violet perfume and other bath products all over the city. The city boasts Toulouse University, the third-

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Airbus S.A.S.



largest university in France, which attracts nearly 100,000 students each year. As a result, it is a bustling city, where many energetic young people can be seen. On weekends, morning markets are set up throughout the city, and vegetables, fruits, cheeses and meats are sold at surprisingly low prices, compared to Japan. Toulouse is rich in cuisine with specialty products like duck, foie gras and Roquefort cheese. The most well-known local dish is cassoulet. The cassoulet of Toulouse is a slow-cooked bean stew containing typically Toulouse sausage, duck and white haricot beans, which is served in a deep round bowl. Since it is a quite heavy (copious) dish, one must have determination to eat the whole thing.

The well-known Aeropostale (the predecessor of modern Air France), where Antoine de Saint-Exupery, the author of the "The Little Prince", worked as a pilot, was founded in Toulouse and provided air postal services to Northern Africa and South American countries. Toulouse was also the development base for the Concorde, the supersonic airliner developed jointly by France and the UK. At the heart of Europe's aerospace industry, even today, is where Airbus S.A.S. built their headquarters. Here, state-of-the-art aircraft are being developed, flight tests are being conducted, and the world's largest passenger aircraft,



Cassoulet, a local specialty of Toulouse

the A380, is assembled. Furthermore, with France's National Center for Space Studies (CNES), the French national aerospace research center (ONERA), Europe's largest aviation university (ENAC) and Arianespace SA

on the south side of the city, Toulouse is truly an aerospace industrial city.

■ Daily life

I live with my wife in an apartment near the city center. Here, on Sunday, nearly all shops are closed, except for the morning market, which focuses on vegetables, so we cannot purchase household items. In addition, stores close early on Saturday, so we are always hurriedly doing our shopping. (In Toulouse, there are so many last-minute shoppers on Saturday evening that there are very long queues at the cash registers.) At work, I communicate in English, but I must communicate in French in my daily life. I studied French before coming here, but it does not work out well when I use it. Now, I am studying at a French language school twice a week after work, but the daily struggles continue. Searching for housing, opening bank accounts and getting an Internet connection were quite formidable, but have now become a part of pleasant memories. Although there were such situations, after a few months, I was able to make friends with some French



City center of Toulouse

people that I could trust, who live in the same apartment building. They are very friendly and help us at every opportunity. On weekends, we go together to the market, go jogging, have parties at each other's homes, and get together with our families. The other day, we watched the final game of the Rugby World Cup (France vs New Zealand) together at home. Although France unfortunately lost the cup, it is through social situations like this that I am studying hard to learn about French culture and the French way of thinking.

■ Final comments

Through this valuable experience, I think that the ties between the Japanese and French aerospace industries will be further strengthened and that their joint development will be continued.