

To promptly conduct disaster-relief activities by helicopter

Disaster-relief helicopters were used in unprecedented numbers to cope with the South Hyogo prefecture Earthquake of 1995. Their high effectiveness for disaster response has been widely recognized since. There are, however, practical and logistical problems to address when deploying large numbers of helicopters around a disaster site. In joint work with the Fire and Disaster Management Agency (FDMA) of the Ministry of Internal Affairs and Communications, JAXA is developing a system to efficiently conduct operation control for disaster scenarios in which large numbers of helicopters rally around a disaster-stricken area. In October 2009, JAXA and FDMA began evaluating the operation of a prototype system with a view to improved practicality.

Supporting human judgment

When an earthquake or another type of large-scale disaster strikes, fire stations, police organizations, the Self-Defense Forces, and other competent authorities from all over the country dispatch helicopters to the disaster-stricken area to perform rescue functions such as first aid, the transport of personnel and supplies, aerial firefighting, information collection (Figure 1). In the Mid Niigata Prefecture Earthquake of October 2004, more than 70 helicopters rallied around the affected area. A major earthquake directly under the Tokyo metropolitan area is very likely to occur in the near future. If and when this earthquake actually strikes, more than 400 helicopters are expected to fly in.

The prompt assignment of missions to helicopters individually will lessen the damage. The thing to do, you may think, is simply to fly the helicopters into the disaster site without a moment's delay. Yet not just any helicopter will do. Different agencies use different types of helicopters, and the types they use differ in both performance and the equipment they carry. While several tens of helicopters can be assigned within relatively little time, the assignment of several hundreds of helicopters requires considerable planning and thought. An enormous amount of information must be considered before decisions can be reached.

JAXA's Operation and Safety Technology Team is developing a system to support the personnel who dispatch aircraft. The computers in this system will optimize mission assignments by processing huge amounts of information in



Helicopters that rallied around Hanamaki Airport just after the Iwate-Miyagi Nairiku Earthquake of June 14, 2008



Fig1. Disaster-relief activities by helicopter

mere seconds.

The operation control system JAXA targets

There are many things to consider in selecting rescue helicopters. What damage has the disaster caused, and where? What missions are required, and what are the performance and equipment requirements of the helicopters deployed on the missions? Can a helicopter land and take off at and from a hospital which is accepting disaster victims? Fuel supply and maintenance are another important dimension to helicopter service. Fuelling is possible only in limited places. As a result, the large numbers of helicopters dispatched to an area may be forced to wait for inordinately long periods. To use helicopters effectively, mission

planners must minimize waiting time by determining which helicopters to fuel at which site, and at what timing.

The systems in operation nowadays collect this type of information by telephone and facsimile. An appropriate helicopter is selected from collected information and the information is sent to the helicopter by radio communication (Figure 2).

The operation control system JAXA is developing will collect the information necessary to operate helicopters, computerize the information, and use advanced optimization algorithms to deduce the most efficient solutions.

Starting the user evaluation of prototypes

Organization	Quantity
Self-Defence Forces	660
Firefighting and disaster-prevention helicopters in the prefectures	72
Police	95
Japan Coast Guard	46
Doctor helicopter	18
Total	879

As of July 2009 (except civilian aircraft)

Number of helicopters available in the event of a disaster.



Fig 2. A scene from operation control just after the Mid Niigata Prefecture Earthquake of 2004

The Fire and Disaster Management Agency (FDMA) of the Ministry of Internal Affairs and Communications has started test operations to evaluate the practicality of the prototype operation control system (Figure 3).

The fire departments of Japan's regional governments own and operate a total of 71 disaster-prevention and firefighting helicopters. In the event of a large-scale disaster, the FDMA will be responsible for selecting the helicopters most suitable for the missions required and sending the orders through. To prepare, the agency is collecting information on the 71

disaster prevention and firefighting helicopters available and evaluating its technology for selecting the helicopters most suited for different types of missions. Once the results from these evaluations are available, JAXA will be using them to improve the practicality of the system. JAXA will be gradually adding new functions up to the scheduled completion of development by fiscal 2011. The next task, from them, will be to put the operation control system to practical use.

For more efficient operation control

National air-traffic management system

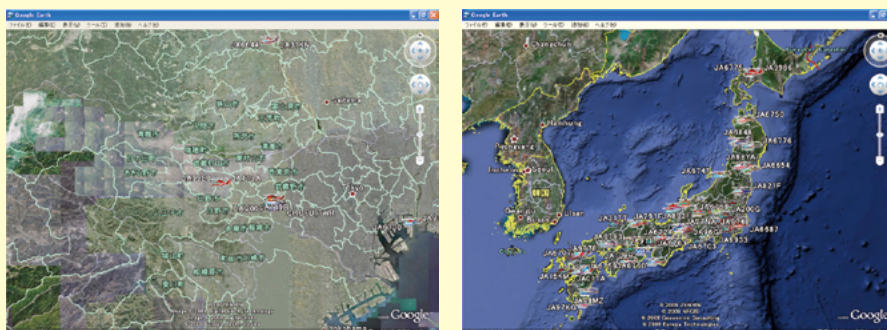


1. The system displays the various types of information on the firefighting and disaster-prevention helicopters in service throughout Japan, including the performance specifications, equipment on board, maximum flight times before maintenance, and so on.

2. Information on helicopters deployed at operation bases (helicopter bases) set up in the disaster-stricken area. The information is used to check the helicopter deployment balance. The system displays a warning when there are too many or too few helicopters at a helicopter base.

3. Deployment status of firefighting and disaster-prevention helicopters in each prefecture. The green marking indicates that one helicopter is deployed; red, that two are deployed; blue, that three or more are deployed. This information is used to check the nationwide deployment balance as a precaution against another disaster in a different area while the rescue operations are being performed. The country is divided into seven blocks. In the event of a large-scale disaster such as a major earthquake directly under the Tokyo metropolitan area, at least one helicopter should be kept in each block.

Local operation control system



4. Operation condition (flight route, mission completion condition, etc.) of each helicopter in the disaster-stricken area. The FDMA uses this information to check whether an appropriate number of helicopters are conducting rescue operations in the disaster-stricken area. If there are few or too many helicopters, they are increased or decreased.

5. Nationwide operation condition of firefighting and disaster-prevention helicopters. The FDMA uses this information to learn the operation status of each helicopter when it asks the flying corps of local governments for aid.

Fig 3. Screenshot of the operation control system



■ Freshness is everything in information. Data links between helicopters and the ground.

The activity and position of a helicopter change from moment to moment. If you can send flight information from the helicopter to the ground as data, not voice, in real time, the information will be incorporated into the operation control system more efficiently. There are already a number of data link systems available for sending and receiving data between helicopter and ground. Most, however, rely on communication methods not compatible with the others. To solve this problem, JAXA and the Disaster Prevention Research Institute Kyoto University have formulated and propounded a standard "D-NET" for sharing data from multiple types of communication systems over a network.

JAXA's ultimate goal is to develop an operation control system to facilitate the safe and efficient execution of disaster-relief activities. To achieve this, all of people involved in the helicopter operations, from the staff at the disaster



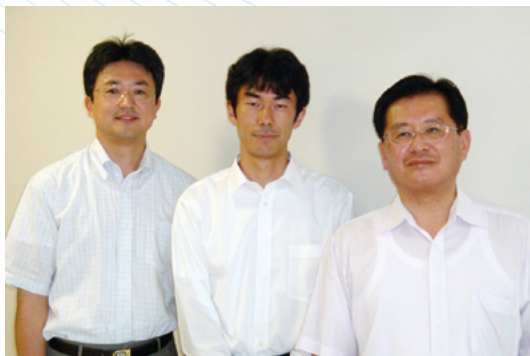
Fig 4. Conceptual diagram of the information-sharing and operation control system

countermeasure headquarters (central and local) and helicopter base personnel to the pilots themselves, share information over the network in real time and select the most suitable helicopters available (Figure 4).

We want to apply our technology toward the efficient use of Japanese disaster-relief helicopters!

Researchers are working to apply helicopters to disaster prevention. As of this writing, they have already pushed their way through the trackless fastness. Test operation has begun with a view to commercialization. How has it been going, if we may ask?

- Mr. Nakachi is a deputy fire marshal of the Hyogo Fire Station in Kobe City, and visiting JAXA researcher. A former aviation specialist at the Fire and Disaster Management Agency (FDMA) of the Ministry of Internal Affairs and Communications, he is a pioneer in the effective use of helicopters to respond to large-scale



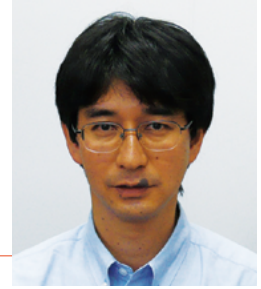
Disaster-Prevention and Operation Control Engineering Section
(From left) Yoshinori Okuno, Keiji Kobayashi, Hiroyuki Nakachi

disasters. Here are his comments: "Aircraft dispatchers make sure that a helicopter will be available at a given time, then assign the helicopter to a specific mission. They deploy the helicopters as they would the pieces on a chessboard. The operation control systems now in place require a lot of manpower. But human beings can overlook mistakes. If this new system is developed, operation control will be much easier."

- Dr. Kobayashi is a leading authority in the research sector. "Disaster countermeasures agencies have accumulated know-how on the operation of disaster-relief helicopters through the disasters we have lived through so far. It is very important to skillfully incorporate these valuable experiences into the technology. I would like Mr. Nakachi and the people in charge of operations to offer their advice on how to develop user-friendly operation technologies."

- Dr. Okuno is leader of this research team. "The design development technology for the fabrication of outstanding aircraft is closely connected to the technology for the effective use of the fabricated aircraft in aviation research. Technological development to adequately meet the users' requirements is very important, especially in the latter sector. The FDMA has started to evaluate its new operation control system. This is a big step forward for this research."

Improving Production Technology for Low-Cost, High-Quality Composite Materials!



Civil Transport Team

Structure Material Engineering
Section
Yutaka Iwahori

In June 2009, JAXA concluded an agreement with Airbus, the European aerospace manufacturer, to engage in collaborative research on composite materials. The two parties have commenced a relationship in pursuit of low-cost, high-quality composite materials for aircrafts structures. JAXA's research on composite materials, work in which takes pride, is heading for the next stage. In this issue we interview Dr. Yutaka Iwahori, a JAXA researcher.

Q What is a composite material?

Iwahori A composite material is produced by combining raw materials with different properties. The properties of a composite material are more excellent than the properties of any single material composing it. Carbon Fiber Reinforced Plastic (CFRP), a typical composite material for aircraft, is produced by forming a plastic (epoxy resin) in which carbon fibers are arranged in a sheet configuration or woven into a texture as a reinforcing component. By complexing carbon fibers and plastics rather than using them singly, manufacturers can fabricate materials lighter and stronger than metal (aluminum alloy). The Civil Transport Team is researching to use CFRP in new ways for aircrafts structures.

Aluminum alloy have so far been the main material for aircrafts. The use of CFRP in place of metals lightens the airframes and eliminates the problem of corrosion. These properties have already been taken advantage of, to some extent, in aircraft design and manufacture. Yet the high cost of fabricating CFRP by conventional methods has limited the adoption of this material. To take fuller advantage of composite materials for aerospace application, it will be important to find ways to produce a composite of high quality at lower cost. Our team is researching and developing VaRTM (Vacuum-assisted Resin Transfer Molding), a method to enable the production of a composite material of high quality for less money.

Another disadvantage of composite materials for aircraft is the risk of peeling, a problem caused by the structure of CFRP as a stack of fibers in layers (Fig. 1). When a foreign object collides against the surface of a composite material, the interior may sometimes be broken even if no change appears on the surface. When damage occurs between fiber layers (Fig. 2), the strength of the composite as a plate structure is dramatically reduced. An important research goal, in airframe manufacture and maintenance, is to develop a method for reliably and immediately finding internal damage, identifying the type of damage, and determining its magnitude, before severe strength reduction will be occurred by these hiding damages.

Q What do you do in the collaborative research?

Iwahori Airbus may also be taking part in research and development on the above issues with composite materials. The purposes of the collaborative research are to evaluate the strengths of composite materials produced by the low-cost production technologies owned by the two parties, to carry out basic studies on damage detection techniques for the materials, and to apply the results to the research and development work of each party. Under the framework of the research agreement, neither party is required to disclose its know-how in low-cost composite material production. Instead, we will evaluate the strength of the composite materials produced and carry out basic studies on damage detection. Once our results are complete, we will compare and review the strength data and damage-detection data we have each collected. A series of evaluation tests is scheduled to be completed within fiscal 2010.

Q What is the advantage of the collaborative research?

Iwahori JAXA and Airbus will compare the characteristics and qualities of the low-cost composite materials they have respectively researched and developed, on the same evaluation basis. The two parties will therefore learn about their respective technology levels for composite materials. In addition, we expect to have a good opportunity to show Airbus the properties, qualities, and molding capabilities of the composite materials produced by the low-cost composite material production technology we have been researching at JAXA. Airbus is also searching for a low-cost, high-quality composite material which can be used for their aircraft structures.

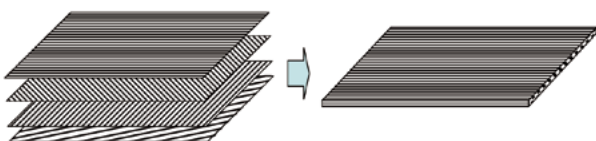


Fig. 1: Construction of Composite Material

A sheet of laminate plate is produced by stacking fibers at various angles.

A weight collides against the location shown with the arrow.

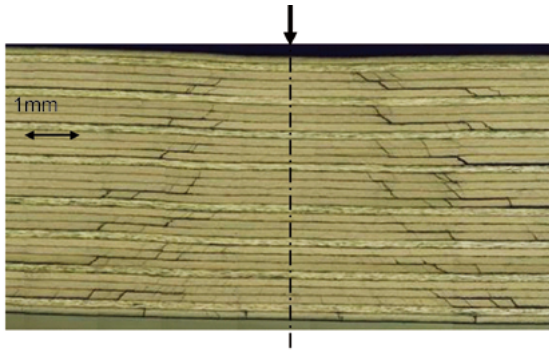


Fig. 2: Appearance of Internal Damage Generated by Impact to the Surface of a CFRP Plate

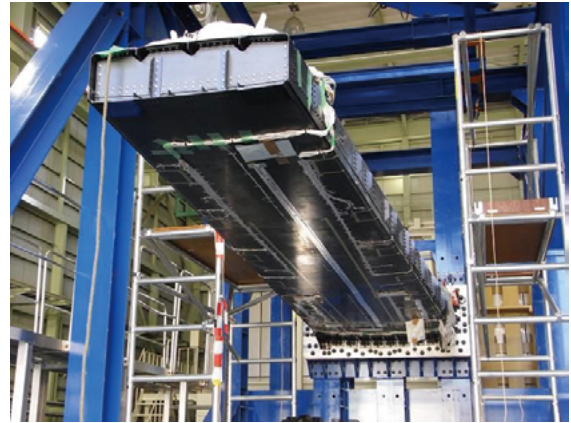


Fig. 3: VaRTM Strength Test

Q Are we to understand that your collaborative research on composite material production focuses not on the conventional production method, but a new low-cost method?

Iwahori The production method we are developing at JAXA is called VaRTM. Airbus produces composite materials with its own low-cost production method. Presumably, the two parties will adopt more or less the same method for producing the composite material with an oven (a simple heating furnace) and atmospheric pressure. The conventional production method requires high facility investment, as it uses a massive pressure vessel, an autoclave, for pressurization and heating. Researchers in the United States are also proceeding with R&D on a similar method for producing composite material at low cost. All in all, many countries are researching and developing ways to develop composite materials of the highest possible quality and lowest possible quality for use in aircraft manufacture. Because VaRTM can considerably reduce the facility investment, we believe that it will be adopted as a very effective production method not only in the aerospace industry, but also for manufacturers aiming at new entry into the industries that require high-quality composite materials. Composite materials are also used for various other applications, such as sporting equipment, medical equipment, antiseismic reinforcement for bridges and highways, and so on.

Q Aren't composite materials produced by low-cost production methods already in practical use for aircrafts?

Iwahori Airbus and Boeing use composite materials extensively for the Airbus A350-XWB and Boeing B787, aircrafts scheduled to go into actual service in the near future. But these composites are said to be produced by the conventional production method. The airplane makers are starting to use aircraft parts produced by the low-cost composite material production method for the doors of cargo bays, rear pressure bulkhead, and elsewhere. We have also heard that Mitsubishi Aircraft Corporation will be using low-cost methods developed by Mitsubishi Heavy Industries, Ltd. (VaRTM Production Method) and Toray Industries, Inc. (A-VaRTM® for some of the major structures in its aircraft under development.

Q Is it possible to produce the main wing with these

composites?

Iwahori JAXA is conducting strength evaluations of two main wing structures (6 m each) produced by a VaRTM production method, one for an assumed full-sized airliner and one for a simulated supersonic research aircraft. These strength tests confirmed that the strength of structures made from low-cost composite materials is as per design (Fig. 3). Yet to use these materials in actual aircrafts, safety regulations dictate that it will not be enough to satisfy the design strength with a structure manufactured only one time. Instead, a manufacturer must verify that the 10th structure, 100th structure, and 1000th structure manufactured must all have the same design strength. A quality assurance method has been already established for the autoclave production method, but there are delays in the establishment of a comparable method for the new production process by VaRTM. To use the materials for aircrafts, these process and qualities will be required to obtain a certificate from the Civil Aviation Bureau of Land, Infrastructure and Transportation Ministry and from competent authorities overseas. This certificate must state that the composite material parts and structures of the same design strength can be manufactured by the new production method, and that the composite materials may therefore be used for aircrafts. To secure this certificate we must trial produce many components, from small test specimens to full size structures, and carry out many confirmation tests.

JAXA is also studying methods for producing composite materials of more stable quality.

Q What are your ambitions in the future?

Iwahori JAXA and Airbus have created an opportunity to enter their first collaboration relation for the research and development of composite materials. We hope that the collaborative research will spread recognition of Japan's technical capabilities and promote a good and advantageous relationship beyond borders. We also hope to expand our collaborative relationship into other aircraft technologies besides composite materials.

Model Base Control-The Favorite Candidate for Advanced Engine Control

The advanced FADEC (Full Authority Digital Electric Control) for the jet engines of today and tomorrow will be designed to realize not only stable thrust control, but also improved engine performance, enhanced reliability, extended service life, high environmental acceptability, and other requirements. The coming FADEC may be

capable of selectively providing a host of functions and properties to suit flight missions, such as robust thrust control, TET control, SFC control, turbine metal temperature control, surge margin control, fuel/air ratio control, and so on. Better still, it may produce useful information for engine health diagnostics and maintenance. Rather than simply calling it an "engine control system (ECS)," it can be more accurately described as an "engine performance management system (EPMS)."

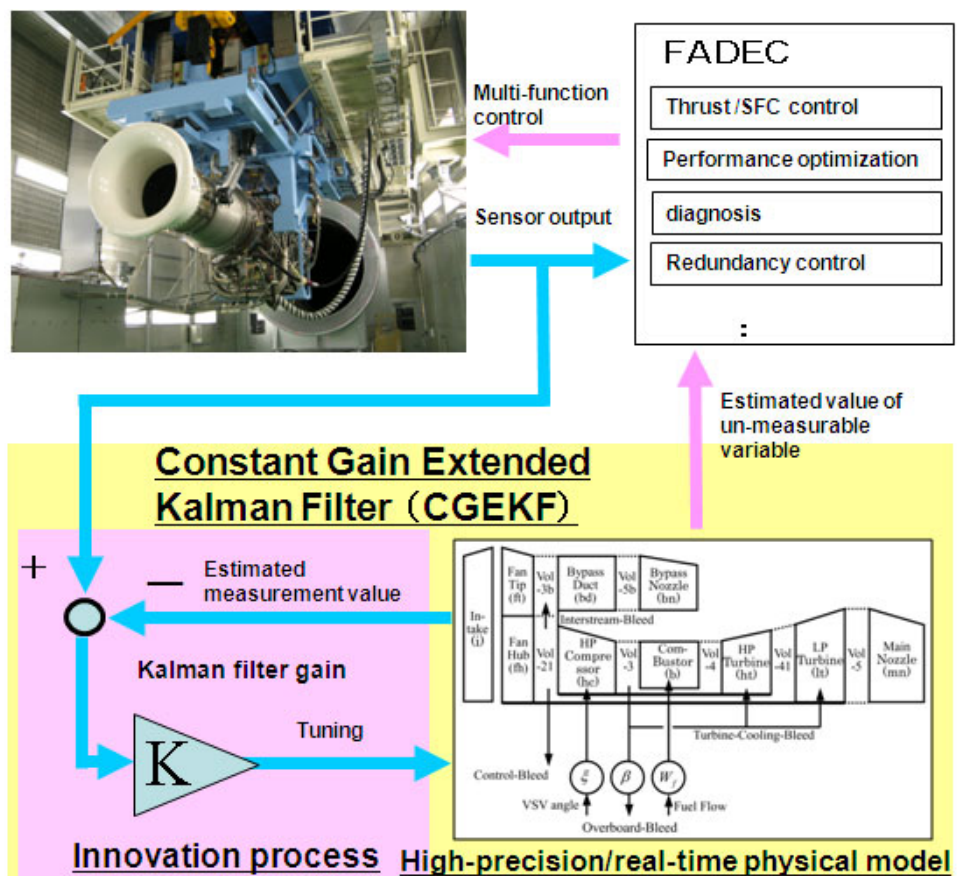


Fig.1: Conceptual Diagram of Model Base Control

The CGEKF is almost entirely a nonlinear dynamic simulation of the system, except for the so-called "innovation process," the Kalman filter gain multiplied by a difference between measured variables and estimated variables.

The computing load of the Kalman Filter Gain K is quite heavy, but higher speeds can be achieved with the CGEKF by calculating K in advance. The uniquely developed real-time physical model is designed for high-speed calculation, and the calculation of the whole CGEKF is operable within 1/100th of real time or shorter.

The ESPR turbo fan engine developed by the New Energy and Industrial Technology Development Organization (NEDO) can be seen in the background. This engine is used for tests to realize advanced control.



(From left) Takeshi Tagashira, Tatsuo Zaima, Hisao Futamura, Yasushi Nakata, Yusuke Yamazaki, Keiichi Okai, Nanahisa Sugiyama, Shizuo Sekine, and Takuya Mizuno

The key technologies of the advanced FADEC are a high fidelity, robust "engine model" to accurately simulate the dynamic and static behavior of an actual engine, and an online self-tuning capability to reflect changes in engine performance resulting from deterioration, damage, and other influences.

Research on the simulation model base control should be carried out not with simulations, but with actual engines.

As described above, the real-time estimation of engine performance is the most fundamental and

important element technology for the realization of a model-based control system capable of engine control via both measured values from sensors and estimated values from an engine model.

Drawing from its extensive research experience, JAXA has developed a highly precise physics model capable of real-time computation. This model is now in use at the agency together with the CGEKF (Constant Gain Extended Kalman Filter), another system suitable for fast computation.

Experiments to develop the control technology are underway at JAXA with an array of advanced equipment, including a single-spool turbo jet engine and two-spool turbo-fan engine for research. The research is conducted in an enclosed test facility at ground level, in an open cell, and in the ATF (Altitude Test Facility), where researchers can test the engine operation under conditions of high-altitude flight.

(Takeshi Tagashira)



Fig. 2: Altitude Test Facility (ATF)

Engine operation can be tested under high-altitude flight conditions at an altitude of 15,000 meters and speed of Mach 2.0.



Interview
People who fly dreams
Vol.14

Our dream of flying never fades away.

Civil Transport Team
Taro Imamura

✈ For this issue we have interviewed Taro Imamura, an associate professor at the University of Tokyo working with JAXA as an invited researcher. We asked him to describe the requirements for fabricating a silent airplane. His plain-spoken descriptions were illuminating. He is sure to become a good professor at his university.

Wind noise reduction will make aircraft quieter.

✈ What projects are you in charge of? Imamura Our team is researching technologies useful for the design of aircraft. I'm in charge of research on noise. Our main object is to reduce the noise generated from aircraft. First we determine what kinds of noise are generated, then we study how to reduce them. I'm also taking part in a joint research project with an aircraft manufacturer.

✈ What kinds of noise are generated? Imamura The biggest noise generated by an aircraft is the engine noise. The Clean Engine Team in the Aviation Program Group is also researching



Taro Imamura
Aerodynamic and Noise Engineering Section
Specialized in aeronautical engineering in
graduate school.
JAXA-invited researcher and associate professor
of the University of Tokyo (since July 2009)

ways to reduce engine noise.

The research so far shows that wind noise, another kind of noise generated by an aircraft, is a great nuisance. Let me explain wind noise. A familiar example of wind noise is the sound generated by wind when it blows along a laundry pole placed on a condominium veranda. The sound of a whistle is another kind of wind noise. When an air flow collides against a sharp edge, the whistle sounds. When you drive on a highway with the windows open, the wind roars. These are all wind noises.

As you surely know, the landing gear of an aircraft comes out of its housing when the aircraft prepares to land. This produces a deep roar. A car runs at about 100 km per hour at most, while an aircraft travels at speed more than 200km per hour even during the slowest parts of its flight, at takeoff and landing. For this reason, an aircraft makes a commensurately bigger wind noise than an automobile. In designing aircrafts, one of our goals is to ensure that residents living near airports won't be unduly disturbed by the noise during takeoffs and landings.

✈ Is wind noise bigger than engine noise?

Imamura The aircraft engine revs up to maximum power at takeoff to lift the aircraft into the sky. This is an unavoidable source of tremendous noise. Later, at landing, the aircraft almost glides in at low speed and altitude. The engine is working much less and producing much less noise. In some cases, noises from other parts of the aircraft stand out more than the

engine noise during landing. Of course, the level of wind noise depends on the type of aircraft.

Another source of noise at landing, besides the landing gear, is the high-lift device, the small wing that extends from the main during landing. Our team is studying how to reduce noise from both landing gear and wing. The measures we have taken so far against the engine noise have considerably reduced the noise level overall. Yet we have yet to take measures against the airframe aerodynamic noises. These noises are becoming a nuisance. The current global trend is to gradually tighten noise regulations, and this trend will continue in the future. The aircraft industry will be required to reduce noise levels further by reducing the aerodynamic noise.

✈ What are you doing to research noise?

Imamura There are two main approaches. One approach is to determine the mechanism of noise generation by creating CFD (Computational Fluid Dynamics) models to calculate the air flow fields from which noise may come. The other is to conduct wind tunnel experiments, that is, to place models of aircrafts and aircraft components into wind tunnels to study the noise. This latter approach is currently called Experimental Fluid Dynamics (EFD). My main job is to use the former approach, to determine the mechanism of noise generation by CFD. Our CFD findings will provide important information and guidance for conducting efficient wind tunnel tests in the future.



In Poitiers, France, where Imamura attended an academic conference.

✈ The information will be useful for aircraft fabrication, won't it?

Imamura Yes. This information is very important to understand which noise source is the dominant component to the overall noise. So we expect the information to be used for aircraft design. Japanese aircraft manufacturers will find it particularly useful. In my research, I expect to help these companies manufacture aircrafts with technological advantages over other aircraft in terms of low-noise design.

From robocon to toricon (Japan International Birdman Rally)

✈ We hear that you started a new career as an associate professor at the University of Tokyo this July. And you have also been working with JAXA for some time as an invited researcher.

Imamura My new university position hasn't yet led to big changes in my day-to-day routine. My workload at JAXA has been cut, but I'm trying not to slow down the pace of my research at the agency. I'm not yet lecturing at the university. My posting there is quite recent, so I'm still trying to look for new things. After the breaking-in period, I will be off and running next fiscal year. I will be joining an aircraft design laboratory at the university. It will be interesting to study noise from

an aircraft design perspective.

✈ How did you spend your campus life back in your student days?

Imamura Rather than devoting all of my energies to one specific theme, I tried doing a bunch of different things instead. I participated in robocon, and attended the Japan International Birdman Rally with about 20 other students in the Aerospace Engineering Department of my school. I also did some home tutoring part-time. To keep fit I joined the badminton circle. I'd been playing badminton since junior high school.

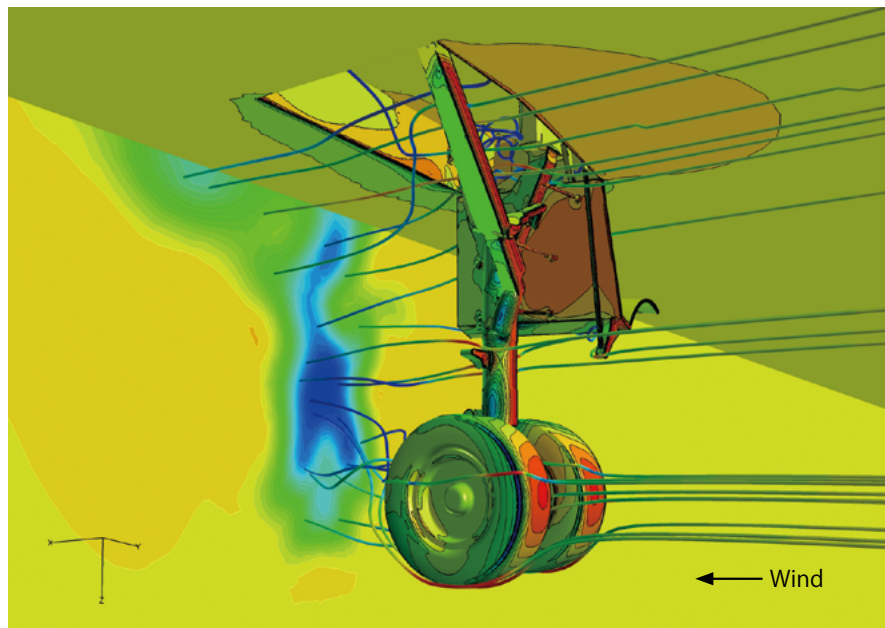
✈ What made you major in aerospace engineering at your university?

Imamura From boyhood, I've had a sort of longing and fascination for big things that move fast, such as airplanes and rockets. I lived in the USA from age five to ten, when my father moved us there for his job. I remember seeing real airplanes on exhibit at a museum and at the NASA Kennedy Space Center. This may have sparked

my interest in aerospace engineering. If I were to look at it from a negative standpoint, I could say that nothing sparked a stronger interest (laughter). So a vague longing in childhood convinced me to major in aerospace engineering. I'm happy to have come across such an interesting research theme.

✈ What is your future goal?

Imamura When you get on a plane, you can see unfamiliar landscapes and travel go places you have never been before. In this sense, the dream of flying has not yet lost its luster for me. Airplanes have many different shapes, all with their own various meanings. The airplane will provide great new potentials we have yet to anticipate. For various reasons, engineers have had no chance to produce a whole aircraft domestically in Japan I hope there will be more opportunities in the future. If there is something I can do to contribute to the production of a domestic aircraft, I would like to contribute as much as possible.



An example of a CFD air flow analysis around landing gear

The color of the gear surface indicates the pressure distribution (red shows an area with high pressure) and the color of the cross section of the gear backwash indicates the distribution of pressure loss (blue shows an area with large pressure loss).