How can we build up our future society and communication through a family aircraft transportation system?

From personal cars to personal planes [Part 2]

This is the second part of the roundtable discussion on what technology is necessary for personal planes to become a common everyday tool. Part 1 was a rousing conversation about "how much can be left up to machines." We will continue starting with a discussion of the division of roles for people and machines. What would you want to do with a personal plane? Would manual steering be okay? Let's try and imagine it.

How should people and machines collaborate?

Susuki Aren't human judgments intervening in instrument flight rules (IFR)?

Kobayashi Right now, air traffic controllers are giving instructions. Research is advancing to allow future controls to transfer the human judgment portion to computers, so wouldn't machines cover the increasing amount of air traffic?

Susuki Then, how people and machines should cooperate will become the key, right?

Kobayashi The pilot displays outstanding abilities in situations where visibility is good, but machine support is required when we try to leverage those abilities in poor weather. However, I think that it is just support and is not intended as a replacement.

Hirano Although current aircraft flight control systems must have redundancy(*1), I think they must be developed with the idea that the possibility of accidents be as close to zero as possible by placing humans in the final stage of the redundancy. What type of decisions will be needed to achieve the same redundancy in flight control systems without any human decisions?. For example, if the control system or autopilot goes into a dangerous situation, the pilots can cancel it and perform the operations themselves. In this way, I think the safety of current systems is ensured. Without a system to replace that, I think it would be difficult to entrust all operations to autopilot.

Kobayashi With the concept of decision height (landing decision altitude), whether landing will fail below a certain altitude is determined by the reliability of the system. For example, with CAT(*2), reliability varies completely depending on the system. Rather than never failing and therefore never being touched by people, CAT3, which has the highest reliability, is an extremely large system with triple or quadruple redundancy. As a result, it can only be put on large airliners. What is chosen varies depending on the needs. Currently, for example, pilots can operate aircraft themselves if they have no confidence in the equipment, therefore, the system can be smaller and less expensive. Systems that can operate technologically without going through a person are actually being used throughout the world.

Hirano I see. Then, why are people even there?

Kobayashi It is because, for example, a large system like CAT cannot be mounted on aircraft, depending on their size. My understanding is that the pilot is providing cover.

Susuki In personal planes, the common man or woman would be the pilot, right?

Kobayashi I think we should go in the direction of simplifying licensing. Then, we could increase the part entrusted to machines.

Kubo I think that since the current system was created based on an average pilot, the involvement of no people is not one of the options in the first place. Especially with CAT3-but some requirement for a pilot is necessary. (Tsuda / Kobayashi : Right.) In other words, there must be a person to bear the responsibility.

Susuki I wonder if qualifications required of pilots would change once CAT3 was put into operation.

Kobayashi I think you first need the ability to fully trust the machines. After all, when visibility is poor, we cannot see until landing. You feel a little like "whoa, let's get there already." (laughing) For me, we must start by trusting. Incidentally, when people flying with visual flight rules (VFR) get qualifications for IFR, they must practice trusting the instruments instead of their own eyes.

Susuki Is it not so easy to trust?

Kobayashi Take vertigo, for example. When you enter a cloud, you don't know your own attitude, but you must trust the instruments. Then, I remember "instruments are a singular system." If I think "there is a fraction of a chance that the values shown on the instruments are wrong," I will have a problem. I think it is necessary to practice operating aircraft without such thoughts.

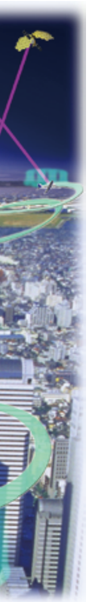
Susuki For CAT3 to be put into operation, the reliability of the system was fully recognized, right?

Kobayashi I believe so. Simply put, this is recognized as an infrastructure, similar to mobile telephones. It does not have the reliability to allow personal planes to become commonly used.

Kubo Returning to the conversation about automation and the need for pilots, just because the current system is changed a little, it would not immediately be pilotless. At ICAO (International Civil Aviation Organization), "unmanned aircraft" are called "remotely piloted aircraft". Instead of truly "unmanned", the unmanned aircraft with current technology has the concept of "remotely piloted aircraft", where the pilot is on the ground. Right now, I wonder if we are not at the stage where a system with absolutely no human intervention is being studied. Such a debate has not yet been spurred as an extension of the current

(*1) Redundancy: In preparation for a malfunction occurring in a part of a system, spare equipment or circuits are pre-installed so that operation of the entire system will be maintained, even after a malfunction occurs.

(*2) CAT: Landing support equipment is divided into five levels according to operation accuracy. These levels are called categories (CAT).



aircraft system. We will not struggle to arrive there if the current system continues to be discussed rigorously. I think that maybe the answer is one where the current design philosophy is completely different, and that what we have been discussing will be impossible if that is not realized.

Hirano Since even cars are at a point where they are now finally making progress in that direction, autopilot may be too much of a leap for personal planes from the beginning. Cars are fully widespread in the common household, and driving assistance has just become available for them. I do not think it is inconceivable for a phase where personal planes are first fully controlled by oneself, then assistance control would come next.

Kubo How are small aircraft controlled?

Nishizawa It is difficult. Since a car advances by turning a steering wheel, wouldn't that be intuitive? But aircraft are different. In my case, during my first training flight, I unintentionally moved my body in the direction I wanted to go before moving the control stick. Just by drumming the combined operation of the control stick and rudder pedals into my head and practicing repeatedly, I wouldn't be able to fly if I hadn't taught my body.

Kobayashi Wouldn't it be great to be able to fly using brain waves?

Nishizawa That would make flying very easy if a computer was inserted in-between, and you twist a lever in the direction you want to go in order to go there.

Susuki The other day I tried the Boeing 787 simulator and it felt like playing a game. It is a system where you can control the aircraft attitude and land safely by holding a symbol at one point in a circle in the head-up display. I think that this may be the future.

Nishizawa It is just whether or not it will be fly-by-wire[*3]. Most small aircraft are not.

Susuki Is it a cost issue?

Hirano It is also about the weight. Because actuators are heavy.

Kobayashi The size too. A system that can use this technology requires a triple system as far as reliability is concerned, increasing the resulting volume. If this was made small and inexpensive, it could be installed on small aircraft.

Susuki Will a double or triple system also be necessary in the future?

Kobayashi Considering that we are flying near public places, wouldn't we need a certain amount of reliability? The aircraft just cannot fall-because the impact on urban areas would be too great if something were to happen.

Hirano Because of mechanical troubles, we cannot afford to omit the redundancy system.

Nishizawa Reliability is costly indeed, but it can be recovered by force of numbers if it could be mass produced. Mass production is one of the answers.

Susuki Wouldn't a simple double system be good enough?

Nishizawa I don't think cars have a triple system. But they wouldn't cause serious problems. Instead, they have the confidence to sell systems with sufficiently increased reliability. It seems we can learn about this area from cars and make use of it in aircraft.

A means of transportation or enjoyment?

Susuki What type of people would use personal planes for enjoyment?

Kobayashi I think it is great to be able to enjoy special aircraft in different places. But, in this case, isn't it a means of transportation?

Nishizawa I think so too. The topmost purpose for cars is probably shopping, in terms of frequency. The main use of aircraft also is as a means of transportation, and wouldn't flying for enjoyment be a small percentage?

Susuki If the method was one of pressing the button for a destination, then the shortest length of time and route being calculated and the flight altitude determined while taking congestion into consideration, flying in this way would be ideal. What you gain, compared to a car, is time.

Nishizawa When the Chuo Shinkansen (linear motor car) is realized, it will take about 1 hour to travel between Tokyo and Osaka. When this becomes commonplace, I think our awareness of time will change even more. We are already becoming familiar with the value of moving quickly. Aircraft are optimum to satisfy that. Walking or travelling by boat would take several days, making it impossible.

Hirano Because there are fixed destinations with the linear motor car, the domestic disparity really becomes apparent. While we can go to Osaka in one hour, regions requiring several times longer for the same distance will emerge. For such places, I would guess there will be high demand for personal planes.

Moderator

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Joined JAXA in 2005. Pursuing research of composite materials and structural design. In charge of structural design of experimental aircraft for the Supersonic Transport Team since 2008.

Technology linked to personal planes

Susuki What are the technological issues to consider for reaching that point?

Nishizawa As Mr. Kobayashi said, low cost and simplicity are the biggest, I think. Otherwise, it should be a transportation system that can be operated safely, even if planes are flying in large numbers.

Kobayashi If you are going to improve reliability only by increasing redundancy, this is already being done. However, to consider bringing them to a level where they are popularized, they should be made small and inexpensive.

Susuki What's the appeal of personal planes in the first place? What I have heard from young people about the appeal of airplanes is that "they can control them themselves in a three-dimensional space." I think them saying they want to fly through the sky comes from the world of the propeller beanie.

Kubo Since its image will be limited once it is called a personal plane, it becomes "fun

(*3) Fly-by-wire: In this flight control system, movement of the control stick and rudder pedals is converted to electrical signals to move control surfaces according to those signals. In the past, aircraft flight control systems transmitted movement of the control stick and rudder pedals performed by the pilot to hydraulic actuators via cables to move each control surface.

to fly", and then this debate may have a somewhat different conclusion.

Kobayashi Even if they are called something different, it is the same system that is used. Whether people want to enjoy flying over wide parks or businessmen use them for transportation, the purpose is different for everyone. The principle may not be the same.

Nishizawa It is like with cars, right?

Hirano If we are close to achieving anything like a safe personal plane, I think we will have greatly lowered the height of the hurdle, namely airplane operation. If flying freely is relatively easy to obtain, wouldn't there be a different demand at that point in time. I think the desire to use them will spread rapidly. Even if they were not too aware of it, wouldn't manufacturers advance in a direction where-as long as a system for safe flying was provided, which creates a demand-they would try to develop aircraft to meet that demand and add this functionality?

Kobayashi The way of thinking about autopilot may change, right? Because we are not free to go to a destination at the touch of a button, it is technology that can simplify operation and allow us to fly as we wish. But, isn't this already being done with fly-by-wire?

Hirano Yes. Then, it is a matter of whether or not the user can obtain it relatively easily.

Nishizawa Establishing an infrastructure will also be necessary.

Susuki Are there any ideas from the propulsion side?

Nishizawa I am researching electric aircraft, and the main appeal of making them electric is the lower costs. Fuel and maintenance costs will be reduced to one-quarter. Since it is a simple combination of an electric motor, a controller operating it and a battery as the power source, it may also reduce the aircraft price. Another thing is that, in terms of safety, since there is a motor, the computer, namely the controller, is already running automatically, so if something happens, the plane can be operated in a safe way automatically. Therefore, even if small aircraft are not fly-by-wire, using an electric motor for the engine can partially improve safety. Also, since there are fewer gauges, the pilot's workload is reduced, and the aircraft is less likely to fail since the electric motor itself has an extremely high reliability compared with a conventional engine.

Susuki Would it be a possibility that it seats 2 to 4 people with both a total length and wing span of a dozen meters?

Nishizawa Yes. At that scale, we should be able to realize it in a period much shorter than 50 years.

Susuki What about reducing its weight?

Nishizawa Since the battery is heavy, how much the energy density of the battery can be improved is extremely important.

Susuki There is also a solar plane that can fly for 24 hours, so how can that be used in conjunction?

Nishizawa Since solar cells to be used as the power source for propulsion inevitably require a large area, I think it would be difficult in private applications where a small size is required. If the power generation efficiency of solar cells was increased by several orders of magnitude, it could be significant.

Susuki Is an electric/petroleum-fuel hybrid plausible?

Nishizawa A two-seater has already been made. Because its energy efficiency is greater than that of a gasoline engine alone, the reduced fuel costs have already been demonstrated.

Seed of technology!

Susuki What about creating a better propulsion system?

Nishizawa The battery's energy density and the motor's power density must be raised. Right now, the output per unit weight for an electric motor is larger than for a gasoline engine. So, if the gasoline engine could be converted to an electric motor, the performance, except for that of the battery, would improve. Speaking about replacing a jet engine, to be able to make the business jet class electric is still a long way in the future. But, I don't think that is unrealistic. If we are only talking about output density, a motor equivalent to that of a jet engine does exist. The output is still very small, but it is the seed of technology.

Susuki What is the outlook from the perspective of construction and material technology?

Hirano It is the same for both large and small aircraft; I think making them stronger and lighter is the fundamental demand. But, the most important thing is how can it be made inexpensively. I think, unless it is a construction method that is overwhelmingly hassle-free compared with now, it will not be a good fit for personal aircraft. The bathtub that is in everyone's house is one type of composite material(*4). Resin is injected onto randomly arranged short glass fibers and the form is made with a single shot into a hydraulic press, but an airplane body cannot be made in this way unless it is simplified. I feel, for that, a state-of-the-art material such as carbon nanofibers should be used, or a newer type of material will be necessary.

Susuki And what about the research for adding functionality to structural materials?

Hirano The so-called structural health monitoring (SHM) technology-like the sensing carried out by sensors such as optical fibers wired through the strucure-is about to be introduced into airliners. I think that if reliability can be ensured, they will also be put in small aircraft. But, I think that further technological leaps are needed when putting high added value things at such a high cost into products that require a lower cost. Rather, functional materials, for example, self-healing technologies where microcapsules break if the material they are in breaks, which results in automatic repairs, may be promising.

Susuki Most composite materials used nowadays in aircraft and spacecraft are of the thermoset type(*5) and are gone if they break. If they could do something like self-healing, we could use materials that can be used many times, like thermoplastics.

Hirano Although Japan has come to excel at composite materials with a thermoset resin system, research has recently been advancing in thermoplastic materials centering on automobiles. In the future, new materials may come from that field. Europe has focused on thermoplastic CFRP (carbon fiber reinforced plastic) and it is already being utilized in the leading edge of wings for the A380. I think the scope of its use will expand more and more in the future.

Susuki With the thermoplastics being used now, do you mean they can be melted and reused if they become old, or recycled?

Hirano The objective is impact damage resistance. We are using materials, taking advantage of the property that they don't suffer brittle failure when they are hit by a foreign object during flight, such as in a bird strike.

Susuki So, keeping damage as localized as possible is the aim of improving reliability?

Hirano Yes. Such materials are suited for personal planes. Since thermoplastic resins have the property of becoming soft when heat is added and hard again when cooled,

(*4) Composite material: Material where different materials are combined to bring out the best in each. In the aerospace field, CFRP (carbon fiber reinforced plastics) from carbon fibers and plastic are mainly used.
(*5) Thermoplasticity/thermosetting: Thermoplasticity is a property where a material becomes easily deformed when heat is added. Thermosetting is a property where a material hardens when heat is added.

they may be easily repaired if an object hits them, for example, by heating them with a dryer to undo their deformation. This is technology that should be tackled in the future.
Susuki It seems, then, that recycling composite materials is necessary.
Hirano That's right. An airliner can fly for 20 to 30 years, but the lifecycle of personal planes may be quite shorter. Wouldn't it be expected that those materials can also be recycled?

Would that be interesting?

Susuki To achieve such new flight control that enables various aircraft to fly at a high density, what features are needed in the aircraft?
Tsuda I think that, instead of the current ground-to-aircraft system, flying by directly interacting with other aircraft is necessary.
Susuki In that case, what information should be passed between airplanes?
Tsuda I think your own position and speed would be the minimum necessary. Also, I think it would be good to also know the flight path-including path alternatives. For example, when two aircraft come in from different directions to land at the same airport, I would hope that information such as "Please go first." or "I have selected a roundabout path." would be sent.

Earlier, I heard someone say that flying must be orderly and not free, and I wondered if that would be interesting. It couldn't be a vehicle, like a car, where although you may have gone out with a destination in mind, you may want to suddenly change it or try arranging it differently.
Nishizawa Certainly, I don't know that it would interesting if that was not acceptable. Maybe that is more difficult technically.
Tsuda It should be possible if the rules change.
Nishizawa A car navigation shows directions when an address is entered, even if it is a place unknown to the driver. With so many choices, the destination can even be changed midway. It would be great if airplanes had a system like that.
Tsuda It would be fun if it was like that.
Nishizawa Because convenience drops if it is otherwise, it would also prevent popular use. Being able to change the destination with a considerable degree of freedom is essential as a system requirement.

Agent functions supporting operation

Susuki How is this likely to relate to Mr. Kubo's research?
Kubo VTOL (vertical takeoff and landing) technology has various issues, such as fuel costs, but if there is somehow a breakthrough, it would become much more convenient in the future. Because the need for runways is a big limitation, I think this is the direction in which we are aiming for in the future. Since, with unmanned aircraft technology, autopilot-related technology should mature and become more reliable, I think more easy-to-use aircraft should be made. Afterwards, it is necessary to establish legal constraints and achieve a sense of security for the user.
Susuki What is needed for the airplane to become autonomous?
Kubo In a nutshell, I think it would be artificial intelligence, but confirmation of its safety is still untapped. Conversely, because it is recognized as an issue, it may gradually emerge. In the laws of control, there is adaptive control, but that is not used much with aircraft. Aircraft whose output in relation to the input is uncertain cannot obtain airworthiness certification under current aviation laws. Because artificial intelligence is more drastic, we don't know how airplanes will fly. I think it is important to properly confirm and recognize its safety.
Kobayashi I think that all of the technology being worked on at JAXA goes into this. Is research to enhance autonomy being done at JAXA? Shouldn't aircraft be made robotic?
Kubo The fundamental definition of autonomy is ambiguous, isn't it? The American military definition is the ultimate form of autonomy-flying in collaboration in a group. I think that would mean working together, but it is aircraft flying themselves under their own traffic control so as not to hit each other in a crowded sky.
Kobayashi Shouldn't this become a conversation on collision avoidance technology and guidance/control systems?
Kubo You could say that. I think that taking security measures automatically in case a failure occurred is also autonomy. Shouldn't automation and machines be able to make decisions?
Susuki I guess that, with autonomy, the end is not a human judgment, but is entrusted to the machine.
Kubo I think there is such an implication to some extent. It might be to the extent that humans do not intervene...after all, the definition of automation is ambiguous.
Susuki When they become autonomous, will humans ask airplanes "Why did you do that?" Then, is communication necessary for the airplane to explain the reason to humans?
Kubo That is human interface technology. Even in cars today, navigation has a function to search again on its own. Although, I think it is on its own from the viewpoint of the driver.
Kobayashi The explanation given is that it is because you are in a dangerous place.
Susuki So, you think that the airplane should also give an explanation like "Sir, I am going to do this for you."?
Kubo The agent-like ones are for supporting operation, for example, but such interfaces may be possible.
Hirano If so, it will become like a world with HAL from "2001: A Space Odyssey."
Kubo Precisely. I imagine something like a more developed Siri(*6). It seems to be a direction where it can also be put in cars. I wonder if that development would be possible.

*

Thank you for staying with us till the end. This discussion about aircraft was encouraging and exciting. The days of flying personal planes may not be so far in the future. At that time, I hope that you will remember that there are people researching aircraft.

(*6) * Siri: Voice recognition application software installed on mobile phones by Apple Inc. It recognizes human conversation and can perform operations such as making a phone call or sending e-mail without going through the touch panel.

Research Report

From the research field

Research and development of real-time monitoring technology for runway snow and ice

Operation and Safety Technology Team

Immediately determining whether or not takeoff/landing is advised through real-time monitoring of the runway during winter-JAXA has begun research and development of component technologies together with Kitami Institute of Technology and Sentencia Corporation in order to realize such a system. In addition to improving winter operation efficiency, it is expected to be valuable technology, which can also help prevent accidents such as overruns during landing (runway departures).

■ Issues with winter operation

Contaminated runways covered by snow and ice cause them to become slippery and increase the stopping distance. For this reason, delays, flight cancellations and diversions frequently occur. There are even some airports in Japan with hundreds of flight cancellations every year due to snow and ice. Winter operation has a large impact on users and causes a major cost burden on airlines.

The decision of whether or not to permit takeoff/landing depends on the operation regulations of each airline, but a JAXA study has found that poor real-time capabilities and excessive safety hinder efficient operation. Since 2010, JAXA has been tackling collaborative research of technologies to resolve these issues with the goals of 1) developing a monitoring sensor for snow/ice conditions, 2) building a friction coefficient database and 3) developing a friction coefficient measuring device. With 1) and 2) working together, "whether or not takeoff/landing is advisable now" can be instantaneously determined. Goal 3) is necessary for building the database. With these technologies, we aim to reduce flight cancellations and diversions.

■ Determining snow / ice conditions with light

The current focus is on developing a monitoring sensor for snow/ice conditions. We will develop a sensor that can measure the conditions on the runway without human help in real time. This is a mechanism that uses light to determine the snow quality and amount of snow accumulation. The sensor is embedded under the runway and fitted with glass at the road surface. It detects the light that is emitted from below toward the snow, is scattered and comes back. Currently at the stage where tests are being conducted in a laboratory, we are planning tests to be set up outdoors as of next year.

Until now, the snow/ice conditions of runways were measured whenever necessary by people using a dedicated measuring vehicle. Instead of people, it is the monitoring sensor for snow/ice conditions that collects real-time data. Furthermore, these values are linked with the friction coefficient database (described below) to make calculations by taking into account the aircraft weight, flight speed, wind speed and runway length in order to make landing decisions for each flight.

■ Estimating the friction coefficient and building a database

The friction coefficient is an indicator for the slipperiness between the runway surface and the tires on the aircraft landing gear. By determining the friction coefficient, we can calculate the distance necessary for the aircraft to come to a stop. We aim to be able to determine whether or not takeoff/landing will be possible for each flight by using this friction coefficient to calculate the stopping distance for each aircraft and checking whether that distance will exceed the runway length.

It is difficult to theoretically determine the friction coefficient; therefore, it must be measured. Since the friction coefficient for each flight cannot be measured, it would be useful to measure the friction coefficient in various snow/ice conditions, then store them in a database. By doing this, if the current snow condition is known, the friction coefficient can be found in the database.

■ Developing a friction coefficient measuring device

Even in current operations, the friction coefficient is used as one piece of information for determining takeoff/landing advisability, and it is measured using a dedicated measuring vehicle called the surface friction tester (SFT). We are continuing research on a friction coefficient measuring

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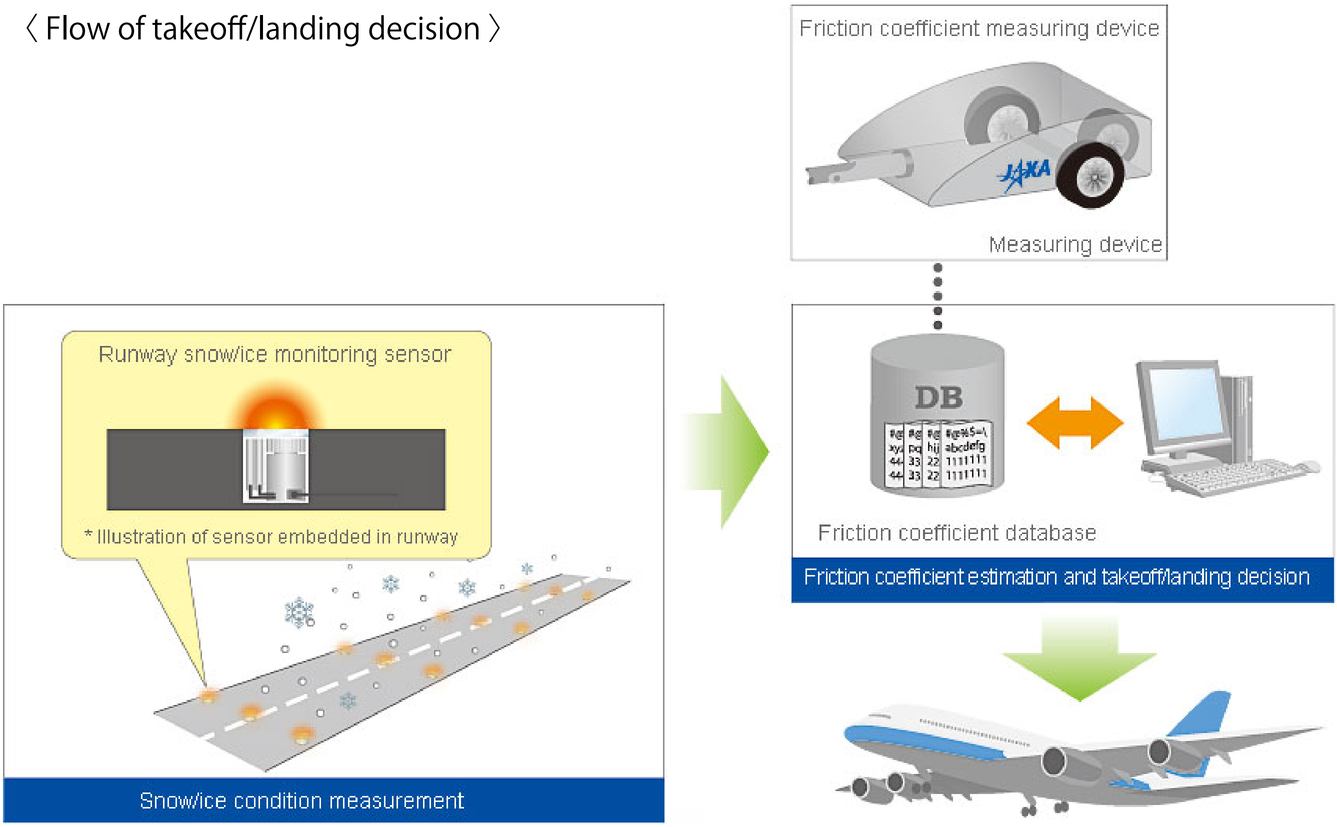
device to obtain friction coefficients more accurately than with the SFT. A device towed by a car will be able to measure the friction coefficient more accurately. We have already completed its design.

However, since a friction coefficient obtained using a measuring device is simply the "friction coefficient between the device and runway surface"and not that for an actual aircraft, we must estimate the"friction coefficient between the aircraft tire and runway surface"from the friction coefficient obtained using the measuring device. It is also necessary to verify whether the estimates are properly simulating the current situation. For this reason, by analyzing and comparing actual friction coefficients obtained from aircraft flight data, we will verify the correlation. This correlation data will also be taken into consideration when building the database.

■ Improving efficiency while maintaining safety

Maintaining safety is extremely important; however, an operation method based on excessive safety is also linked to an increase in flight cancellations as a result. If we could determine safety more precisely with the above-mentioned technologies, we should be able to not only keep flight cancellations at the necessary minimum, but also reduce the amount of time that runways are closed since we will also have an understanding of the appropriate timing for snow removal. With the goal of realizing the world's first system of this type, we aim to start by demonstrating this technology.

〈 Flow of takeoff/landing decision 〉



Research Report

From the research field

D-SEND#2 full-scale structural strength and stiffness evaluation test

D-SEND Project Team

■ D-SEND project steps up to second stage

JAXA is studying supersonic technologies for implementation of silent supersonic transports with the keyword "environmentally friendly."In order to demonstrate one of the key technologies, JAXA is proceeding with the D-SEND project. D-SEND is the abbreviation for "Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom." Through drop tests, the D-SEND project will demonstrate and evaluate that our original airframe design concept can reduce sonic booms by half in comparison with the conventional one, such as the Concorde. After the first stage (D-SEND#1) success in May 2011, the second stage (D-SEND #2) is being prepared now (fig.1). The detail of the D-SEND project can be referred to on the Aviation Program News No.21. In this report, the full-scale structural strength and stiffness evaluation test for D-SEND #2 is introduced as one of the many preparation processes (fig.2).

■ How many times its own weight is the test body able to withstand?

An overview of D-SEND #2 is as follows: After the test body is lifted to an altitude of about 30 kilometers by a stratospheric balloon (inflated to a size over 100 meters), the test body is released, starts dropping vertically, and is accelerated with a speed exceeding the speed of sound. The on-board computer controls the test body's speed and attitude, and the test body flies over the measurement equipment on the ground with 1.3 times the speed of sound (Mach 1.3). The sonic boom (isolated booming noise from the shock waves generated by an object exceeding the speed of sound) is measured by the measurement equipment. The test body is an unmanned aircraft with a length of about 8 meters and a weight of 1,000 kilograms. The test body has a delta wing, a fuselage and tails, which are made mainly of aluminum alloy.

When the test body flies, aerodynamic lift and drag, the maneuvering force and the gravity force are working on the test body, which suffers several times the force of its own weight. In addition to those forces, the lifting force from the balloon, the force from truck transportation on the ground, and other forces work on the test body. Inorder for the test body to withstand these forces, materials of every part are selected, and the thickness and shape of every part are designed. Five severe cases of combinations of these forces are selectedand defined as the design load conditions of the test body.

The full-scale structural strength and stiffness evaluation test isas follows: Before flight, the test body is placed under a load of as much as that in each of the five load cases by hydraulic actuators. The strains(*) and deformations of the test body are measured. Using the measured data, it is shown that the test body is able to support the design loads without detrimental permanent deformation, and the test body is able to withstand the ultimate loads (which are the safety margin added to the design load) without failure, in comparison with calculated data. As the test body is planned to be used in the actual flight test,

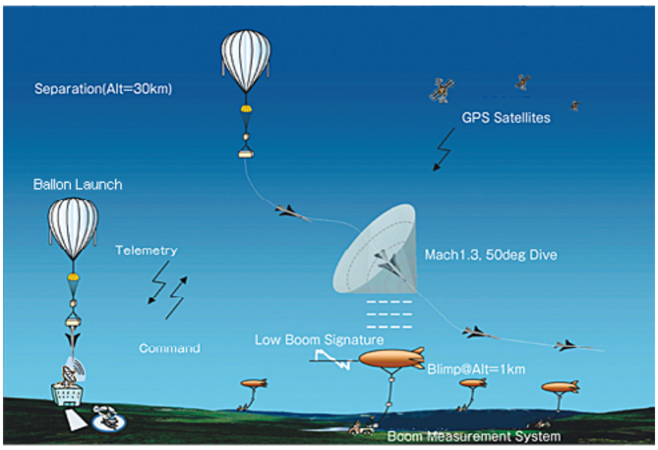


Fig.1: Overview of D-SEND#2 drop test
This project will evaluate our original design concept for implementation of silent supersonic transports.

Fig.2: Configuration of the full-scale structural strength and stiffness evaluation test

Participating members of the structural test
(The author is on the right end.)

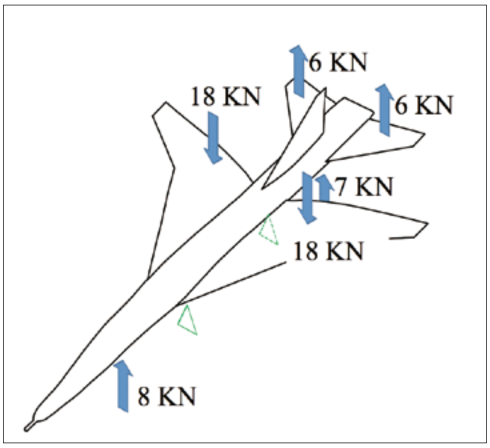


Fig.3: Overview of the applied loads to the test body for the maximum longitudinal fuselage and main wing bending case
(The sum of these loads is not equal to zero since the support points support some loads for balance.)

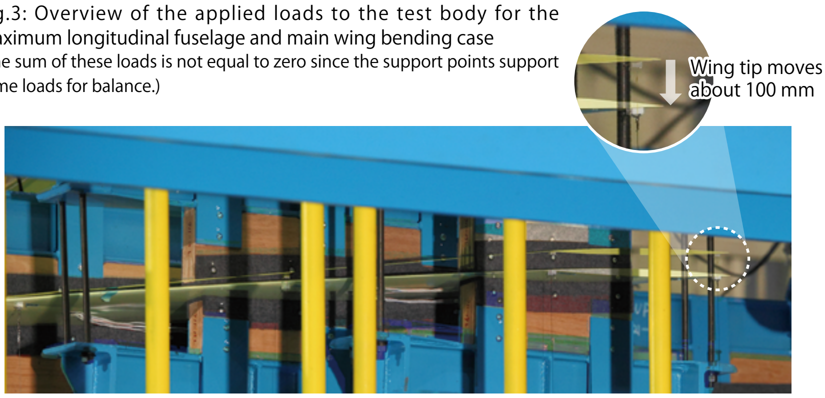


Fig.4 :Displacement of the wing tip in the maximum longitudinal fuselage and main wing bending case
(composite photograph before and after loading)

the applied load is no greater than the design loads and the final failure test was not carried out.

By the way, most aircraft currently flying in Japan have their design confirmed by means of this kind of structure evaluation test. It is guaranteed that the aircraft will not break within the scope of the design, so please continue to fly without any worries.

■ Confirming structural design

The structural tests were conducted from November 22 to December 25, 2012 at the Utsunomiya plant of Fuji Heavy Industries, Ltd. in Utsunomiya, Tochigi prefecture. The test body was suspended in steel frames to adjust for gravity. The distributed loads for simulating the flight loads were applied to the test body by hydraulic actuators with test jigs. The deformation of the test body, such as at the wing tip, was measured with a total of 84 displacement sensors, and the strain was measured with a total of 305 strain gauges attached to the test body.

At the time when the test body dives toward the measurement equipment, the load applied to the fuselage and main wing is assumed to be the largest in the negative direction; this load case is called the maximum longitudinal fuselage and main wing bending case. In this case, each side of the main wing has 18 kN (equivalent to a gravity force of about 1.8 tons) applied (fig.3). The wing tip moved about 100 millimeters down as shown by the white arrow (fig.4).

The obtained strain and deformation were close to the calculated ones, and visual inspection after loading showed no detrimental permanent deformation. It is confirmed that the structural design has been adequate and the test body is able to withstand the load.

After the test, the test body was painted white for reducing sunlight absorption while the test body is lifted by the stratospheric balloon (fig.5). Currently, we are continuing preparations such as checking onboard components. If the weather condition is suitable for flight, the drop test will be conducted in northern Sweden in the summer of 2013.

(Takeshi Takatoya)

Fig.5: D-SEND#2 test body after painting

(*) "Strain" is the normalized value of the deformation of an object when a force is applied to the object. For details, refer to "Sora To Sora No.50".

Gaining a better understanding of aircraft

Aviation Technology Cource - No.3 -

A way of flying without spreading aircraft noise more than now

Interviewee
DREAMS Project Yeam
Leader of the Noise abatement technology section
Hirokazu Ishii

■ Preparing for 1.5 times the traffic volume

Q I heard that, even when more airplanes than now will be flying, the way of flying will be able to prevent an increase in the impact of noise. What is that way of flying? Is it flying at a greatly reduced speed?

Ishii Certainly reducing the speed will be quieter, but I think it would take longer and be inconvenient. The correct answer is "flying while taking the effects of weather into consideration."

Q This is the first I've heard of that. I knew weather is being used to determine whether or not flight is possible, such as when it is "cancelled due to a typhoon," but how is it also related to noise?

Ishii Weather conditions such as wind, temperature and humidity affect sound propagation. Haven't you been surprised to very well hear a distant school bell that can normally not be heard? That is a phenomenon caused by changes in the wind direction, temperature etc. The air traffic volume is increasing now, and the traffic volume for Japan in 2027 is expected to be 1.5 times that of 2005. If the way of flying is the same as now, the noise impact will increase, and we will have a problem that must be seriously considered. What I mean by not increasing the noise impact in the first place is not enlarging the area of noise propagation around airports more than now.

Q Specifically, how is that done?

Ishii By changing the approach path of each airplane according to the weather conditions at the time.

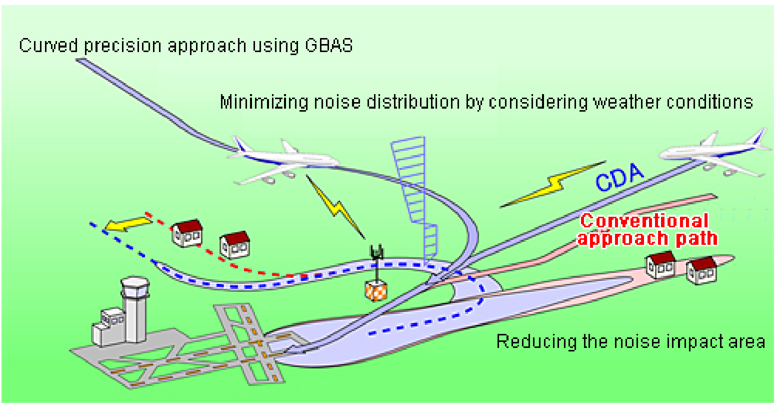
Q Currently, aircraft are flying on set flight path, don't they?

Ishii That's right. Airplanes cannot fly anywhere they want. So that many airplanes can be flown safely, a flight path with as little as possible of a noise impact is set, in consideration of land use around the flight path. Also, there are several paths set.

Q So, the sound propagates to the ground below that path?

Ishii If there is no wind. But, there is no such thing. If the wind direction, for example, changes, even if all airplanes are approaching on the same route, the location where sound propagates will also change. Therefore, the area where sound propagates to the ground in actual operation must be considered as having a certain degree of spread.

Furthermore, even though the approach paths are set, there is a little deviation by each airplane. Because, with the current way of flying by relying on radio waves from the ground, although there is a straight path just before landing, there is some irregularity like the place where the airplane turns beforehand. Therefore, if we look at the trajectories where airplanes have actually flown, the area will have become significantly wider. Considering these dispersions, an area must be determined that is good even with sound propagation. But, if the number of airplanes that continue to fly in this way increases, the area where sound propagates will become wider as a result.



Concept of noise abatement

■ New way of flying made possible with GBAS

Q Then, the way of flying will change?

Ishii It's a way to predict where sound will propagate when flying on the usual route with the weather conditions at the time and, if that exceeds the range of current predictions, the route will be changed so that it is not exceeded. This is the research that we are tackling.

Q I see. So, you are flying while considering where you want it to propagate?

Ishii Even though we may say that we are changing the route, there is a basic route, so it is more like shifting it a little. This is referred to as route optimization. After the approach path of an airplane is set to some extent based on "where is it coming from" and "what is the wind direction," it is fine-tuned according to the weather conditions. That this can be done comes against a backdrop of changes to the mechanism of flying the aircraft. You may have heard of GBAS (ground-based augmentation system).

Q It is what provides information to correct GPS errors when airplanes fly using GPS, right? Isn't it set up at the airport?

Ishii BThat's right. It is at the stage where it is an operation on a trial basis at some airports with the aim to be introduced in the future. With this GBAS, even a curved approach path can be set, and the airplane will fly precisely along that path. As a result, noise dispersions can be kept at a minimum. Using this, we can modify the best route with the weather conditions at the time, so that noise does not spread more than now. That is what we are working on.

■ Balancing prediction accuracy and computing speed

Q What technologies are necessary?

Ishii A "noise prediction model" and a "trajectory optimization system" are being developed. We will try to further adjust them. But, the ultimate goal is to determine optimized approach paths so that the noise propagation area with 1.5 volume of air traffic in the future fits within the current noise propagation area. Since we cannot determine the optimized paths without knowing how much sound will be heard from the ground, technology for predicting the sound that can be heard from the ground is first needed. That is the noise prediction model. It can calculate how sound from an airplane changes as it propagates through the air and how large the sound will be when it arrives on the ground. The technology for optimizing approach paths based on those results is the trajectory optimization system. In November of last year, we conducted a test to obtain data necessary for verifying the noise prediction model. (Refer to the explanation in the box.) If noise cannot be predicted accurately, it just may be that "optimizing routes will have no effect."

Q What were the results?

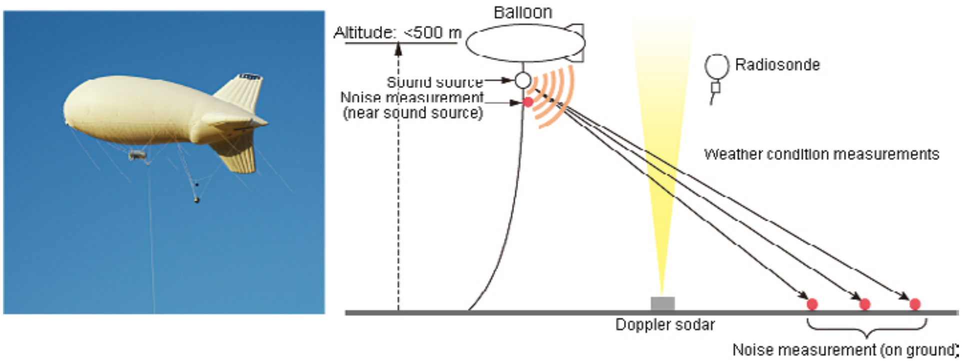
Ishii With this analysis, it will take a little more time to see extensive results. The initial results show that the predictions are fairly accurate, so I am looking forward to getting a lot of valuable data.

Q What is the technical point?

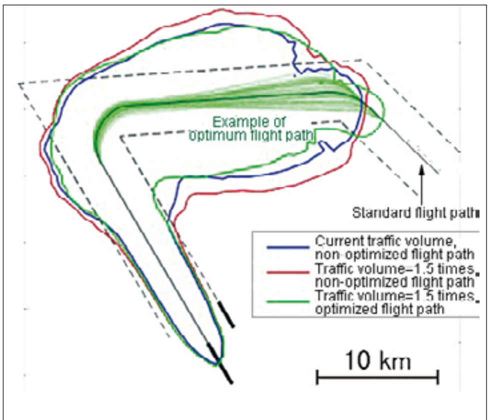
Ishii That we were able to balance prediction accuracy and computing speed. Multiplying the number of hourly landings at Tokyo International Airport (Haneda) by 1.5 will result in about 50 airplanes. That means an approach path must be determined in at least one minute. So, by setting 325 cases in advance based on patterns of weather conditions and the corresponding results of propagation calculation, we are able to find the closest case accurately with reduced computing time.

Next year, we are planning to perform a large-scale verification test at airports in Japan. After summarizing these results, we will make suggestions to relevant authorities in order for our noise abatement technology to be the worldwide standard for future operation technologies.

Test to study sound propagation



Noise measurements are differentiated in the following three ways. 1) How much sound is coming from the sound source? 2) How does it propagate through the air? 3) How is it heard by people on the ground? Question 1) is determined by a sound source model, 2) a propagation model, and 3) a noise index.
The test to understand the propagation characteristics of noise changing according to meterological conditions was conducted at Taiki Aerospace Research Field in Hokkaido. A sound source (loud speaker) was attached to a tethered balloon, whose altitude was changed to 500 m, 300 m and 100 m, and the noise that was produced was measured and recorded with microphones both immediately near the sound source and on the ground. Both before and after the test, whether conditions such as wind, temperature, humidity and atmospheric pressure were measured with Doppler sodar, a radiosonde, and experimental helicopter MuPAL- ε The obtained data will be used to verify the propagation model for 2). The results are currently being analyzed.



Results of noise abatement simulation

Flying on the modified flight path optimized for each aircraft