



Special feature ● Reducing sonic booms

Start of the low-boom design concept demonstration project

Out of the supersonic aircraft technology research that JAXA has tackled since 1997, the project "D-SEND"^(*), which will demonstrate key technology, began this spring. The D-SEND project will demonstrate, through drop tests, that our original airframe design concept can reduce sonic booms—the noise characteristic of supersonic aircraft—by half in comparison with the Concorde. The project is being implemented in two stages at a test range in Sweden through 2013.

The first stage (D-SEND #1), where we succeeded in generating a sonic boom with an axisymmetric test body, was conducted in May. The objectives of D-SEND #1 were to prepare for the reduction effect demonstration with D-SEND #2, planned for two years from now, by measuring sonic booms with a proprietary measurement system and by verifying the operational procedures of the test. With D-SEND #2, a zero-thrust aircraft designed and manufactured with an original design concept will be dropped. After the data obtained in the first stage is extensively analyzed, it will be reported to ICAO for the purpose of contributing to the creation of noise standards for supersonic civil transport.

Succeeding in sonic boom measurement, the first step to a reduction concept demonstration

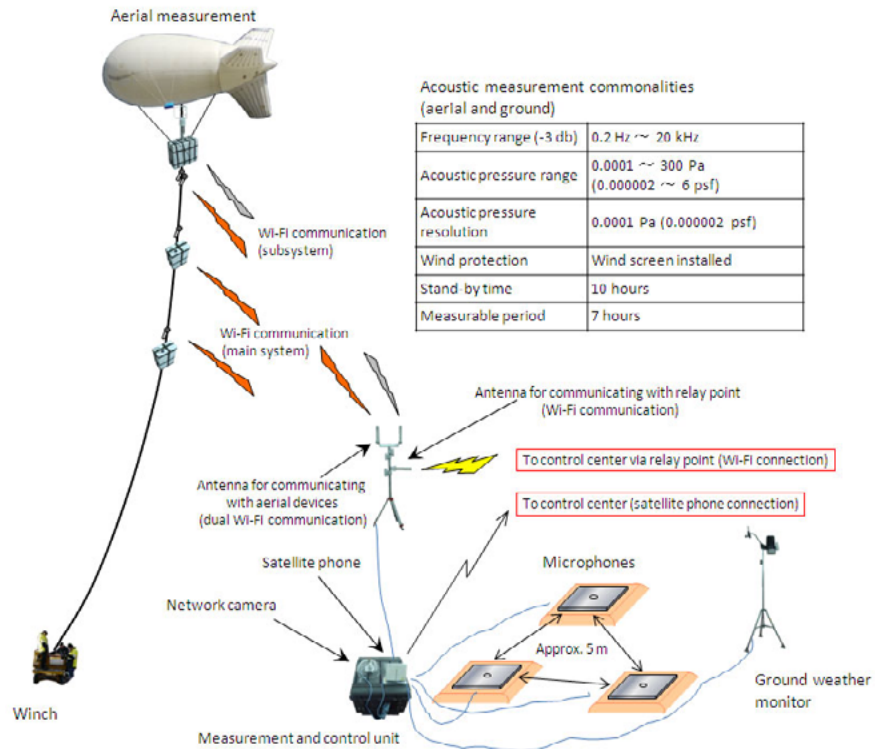
"We are relieved to find out through simple analysis that the pressure waveforms measured as calculated," says Masahisa Honda, assistant manager to the site general manager.

The first stage

The first stage was conducted in May at the Esrange Space Center in Sweden. Supersonic speeds were achieved by dropping a test body carried to an altitude of 30 km by a blimp. The sonic boom that was generated was measured by microphones in the air and on the ground.

In order to obtain two types of sonic booms, two types of axisymmetric^{(*)2} test bodies were prepared to be dropped. One (NWM: N-wave model) was designed to generate a conventional sonic boom; the other (LBM: low-boom model) was designed to generate a reduced sonic boom. A test where both of these were hung from a single blimp and dropped successively was performed twice.

The measurement system was tethered using another blimp. Four locations were set up to allow measurements to be taken over an expansive allowable drop area extending 100 km north-south and 70 km east-west, and measurements were taken with the measurement system at the location nearest the drop point. Since entry into the drop area during the



ConfigShindotion of the sonic boom measurement system (example of one location)

test was not allowed for safety reasons, the measurement equipment could be controlled and monitored from the control center.

It is not because the measurement system and communication preparations were completed that the drop was possible at any time. The wind determined whether or not a good drop was possible in an area where the measurement system could pick up the sound. "It was difficult for team members to perform the installation

work at measuring sites and relay points for many days in the falling snow, but the most difficult for me was determining the test date. Every morning, a meeting about the weather was held and, based on the historical weather patterns for the area as well as the day's weather forecast, I calculated the trajectory of the balloon after it would be launched and studied the timing for the launch. It took until the last day of the four-week test period to conduct the two drop tests," assistant manager

(*1) D-SEND: Abbreviation for "Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom". Refers to the drop tests for simple assessment of asymmetric sonic booms.

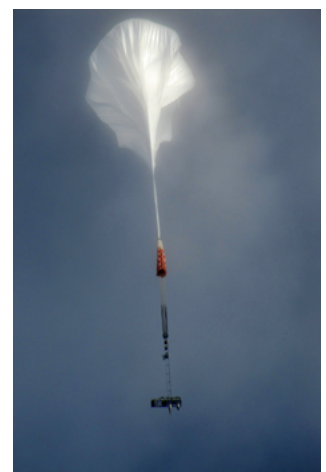
(*2) Axisymmetric: Typically a conical or cylindrical shape



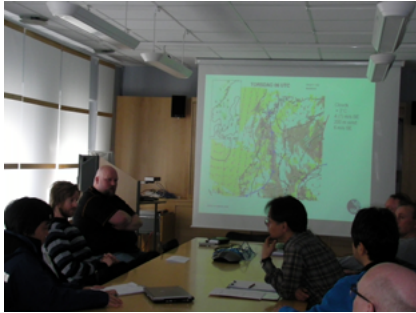
Preparing for launch. The test bodies are hanging from the crane. The low-boom model is on the left; the N-wave model is on the right.



Start of ascent



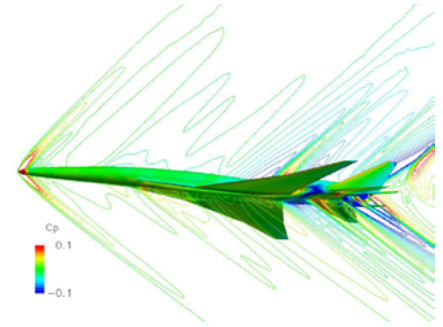
Ascending



Meeting about the weather



Relay points were set up in order to network the expansive area.



Numerous shock waves with the natShindol shape of a sonic boom are generated from the aircraft (analysis diagram). The data for the sounds obtained in this test will be useful in estimating and assessing the sonic boom strength for a complex aircraft shape and verifying the design technology that will be reflected in the aircraft shape

Honda says. After taking a pass on account of the wind many times, it became possible to measure the pressure waveforms of sonic booms in this mission.

Why is sonic boom measurement necessary?

A sonic boom is the change in air pressure observed when the shock wave produced by the sharp compression of air around an aircraft flying faster than the speed of sound propagates and reaches the ground. This pressure change vibrates a person's eardrum and is perceived as a sound. Because a sonic boom is attributed to a shock wave, it is accompanied by rapid pressure changes and is heard as an

explosion-like sound.

The sharp pressure increase is known to be the result of the accumulation on the ground of shock waves produced by the various parts of the aircraft. Many countries are conducting research on what is considered to be effective in reducing the sonic boom through innovation of the aircraft shape to disperse the shock waves reaching the ground.

We have proposed a unique concept based on which we have designed and analyzed aircraft by using computers, and we have confirmed that it can reduce the sonic boom by more than half compared with the Concorde. What aircraft shape is best differs depending on the ideas (design concepts) of each country. Among them, JAXA's concept provides the highest reduction effect "based on calculations". "D-SEND" will demonstrate this.

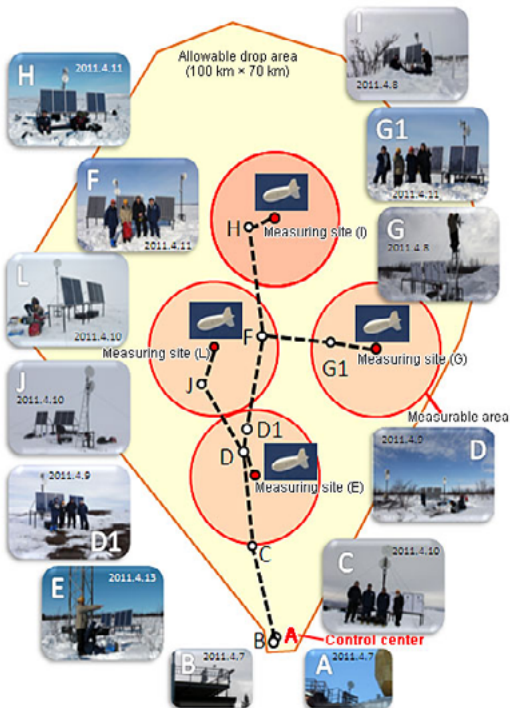
The design effects of dispersing shock waves are verified with the pressure waveforms measured near the ground. Conventional sonic booms have an N-shaped waveform, where two pressure increases occur. The pressure increase can be limited by creating a waveform where this N shape is disrupted. With D-SEND #1, test bodies were designed to generate two different waveforms, and we

confirmed with our original measurement system that a subtle change in the waveform could be obtained. In addition, we could establish the procedure for measuring sonic booms in the air and on the ground.

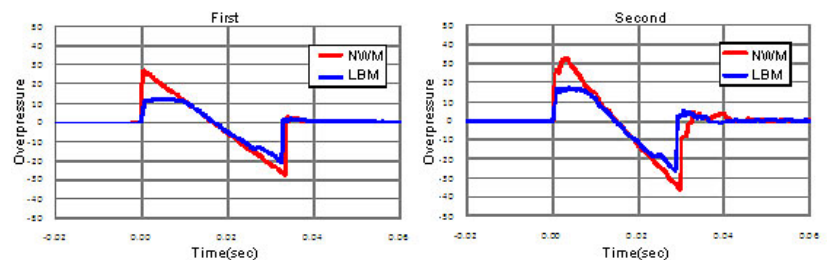
What can be understood from axisymmetric test bodies

Why were the test bodies dropped in these tests simplified axisymmetrically shaped aircraft? Assistant manager Honda provides the following explanation. "The mission of D-SEND #1 is to confirm that the measurement system we constructed is able to measure accShindotely. For that reason, the test bodies were given the simplest shape possible. The approach that an axisymmetric shape produces a low sonic boom is a long-held theory, and the test bodies for D-SEND #1 were designed based on that theory. If the test bodies have a simple shape, it is easier to consider the effects of atmospheric turbulence on the sonic boom signature."

In other words, when verifying the design



Measurement network for the allowable drop area



Test measurement results: Pressure fluctuations over time from atmospheric pressure measured with a microphone set up 500 m overhead

JAXA's unique low-boom concept



Alleviates atmospheric drag at the top half of fuseiage, and adates shock waves at the bottom half

Feature

- Tip like a duck-billed platypus
- Slightly more constricted at the back than at the center of the fuselage
- Two-step curve at the back (rear) of the fuselage



D-SEND #2 test body

effects, the previously mentioned pressure fluctuations caused by shock waves are seen, but, in actuality, it is the phenomenon of "atmospheric turbulence" that affects those pressure waveforms. Atmospheric conditions are not uniform, and complex fluctuations exist in the area from the ground to an altitude of nearly 1,000 m. According to test data for the Concorde, a different sonic boom signature measured on the ground was observed from one measuring day to the next, even when the measurement methods, measurement time, flight altitude and weather were the same. This is called the atmospheric turbulence effect. How the shock wave propagates through space to reach the ground is still not well understood, but we are also working on clarifying that.

When considering atmospheric turbulence, it is easier to analyze the factors affecting the waveform if the shape of the test body is as simple as possible. With an aircraft shape, for example, if it has wings, it is difficult to assess whether

it is the atmospheric turbulence or the wings that produce a change in the wave. When developing an actual supersonic civil transport, it is necessary to design the aircraft while taking into account how much of an impact the complex atmospheric movements below 1,000 m have on how the sonic boom is heard.

The test bodies for the D-SEND project were analyzed and designed by computer. In order to verify that technology, "it is extremely beneficial to be able to obtain data from the actual environment, instead of with wind tunnel tests," assistant manager Honda says.

Contributing to establishing noise standards

Currently, we are tackling extensive analysis of the measurement data that was obtained. "At the International Civil Aviation Organization (ICAO)^(*3), studies have begun to establish noise standards in preparation

for supersonic passenger flights. As reference for establishing these standards, we plan to provide our findings from this research and D-SEND," assistant manager Honda says.

We aim to prepare materials that will enable the development of new supersonic civil transport. We hope to steadily advance preparations to succeed with D-SEND #2 in order for Japan to proactively advance development.

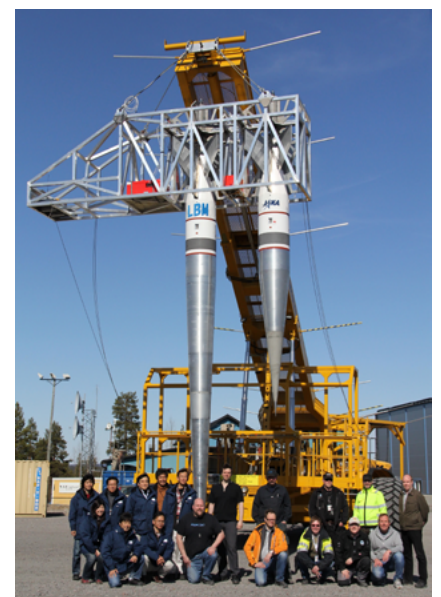
(*3) International Civil Aviation Organization: As a specialized agency of the United Nations Economic and Social Council, it draws up treaties concerning international air transportation services as well as establishes international standards, recommendations and guidelines for international air transportation, so that international air transportation services are operated soundly and economically based on the principles of equal opportunity.

(*4) NEXST-1: Project implemented with the objective to demonstrate design technology that alleviates atmospheric drag. The flight test of the compact supersonic experimental aircraft NEXST-1 was conducted



Masahisa Honda
D-SEND Project Team
Assistant manager

With the flight test in Australia in 2005 for our first project^(*4), we were able to show the world that Japan is seriously tackling research of supersonic aircraft technology. At that time, the door leading us to realize new supersonic civil transport finally opened, and we are now climbing those stairs. We don't know how many steps there will be. Nevertheless, by revealing our technology results and receiving global approval, someone may emerge with an extended hand and an offer to work together. We hope to steadily gather force so that Japan can lead technologically when future international collaborative development of supersonic civil transport begins. D-SEND is the best chance to call attention to our results.



JAXA team (left) and local team (right)

In the previous volume of this publication (No.20), we introduced the development of on-board equipment for the Doctor-Heli flight management system. In this volume, we will introduce the flow for the advanced flight management utilizing this system.

What is flight management?

Doctor-Heli is operated by a team of a doctor, nurse, pilot, mechanic in addition to a communications specialist (CS), who is in charge of flight management. The role of the CS is to provide support from the ground in various ways in order for the mission to be accomplished safely and efficiently. When a dispatch request is received from the fire department, dispatch orders are sent out to the pilot and doctor. After dispatch, contact is established with related agencies, such as firefighters/police or rescue workers at the scene of the disaster, and the pilot and doctor are informed of the landing site and the patient status. Hundreds of possible locations, such as school grounds or public spaces, have been selected

in advance as Doctor-Heli landing sites within the operation area. Depending on the condition of the disaster site or the patient status, they may land directly at the accident site.

Merits of data communication

Currently, communication between the CS and helicopter is by radio voice communication. Making data communication possible has the following merits.

1. Information diversification and reduced communication time
Various information can be shared in real-time between the disaster site, CS, pilot, doctor, etc.
2. Computer-aided evaluation support
The computer can process a vast amount of information in a short time, and provide support for the optimum operation.
3. Fewer human errors
Miscommunication can be reduced.

Advanced flight management flow

Figure 1 shows the advanced flight management flow through data communication using D-NET^(*) and GEMITS^(**).

1. Dispatch instructions from information center
A dispatch request is received by the emergency information center, the optimal Doctor-Heli or Doctor-Car nearby is quickly selected, and the dispatch instructions are sent by data communication.
2. Dispatch from base hospital
The Doctor-Heli that received the dispatch instructions departs from its base hospital.
3. Site information displayed for pilot
The landing site is shown in the helicopter's display with GIS (Geographic Information System). Changes in the status such as the landing site are immediately reflected in the display.
4. Patient information sent from accident site
Based on the patient information (status, blood type, medical history,



Fig.1: Flight management flow using D-NET and GEMITS



Members of the Disaster Prevention and Small Aircraft Operation Technology Section
(From left) Keiji Kobayashi, Yoshinori Okuno

medication history, allergies, etc.) sent by the rescue worker on site, the doctor begins preparing for treatment in the vehicle before arriving at the landing site.

5. Arrival at accident site
After arriving at the accident site, initial treatment is performed immediately.
6. Admitting hospital selected by information center
The patient information and availability for admission at nearby emergency hospitals are considered, and the optimum admitting hospital is selected automatically. The location of the admitting hospital is shown in the helicopter's display, and the estimated arrival time is automatically calculated.
7. Optimum preparation at admitting hospital
Based on the time when the patient is estimated to arrive by helicopter and the patient vital statistics (electrocardiogram, blood pressure, arterial oxygen saturation measurements, etc.) measured with vital signs monitors, the optimum admittance preparations continue at the admitting hospital.
8. Arrival at admitting hospital
After arriving at the admitting hospital, full-scale treatment begins immediately.

implementing it from 2013.

Doctor-Heli is mainly operating on a daily basis at each base hospital, but it will operate more broadly if a large-scale disaster occurs. Of the 25 Doctor-Heli from around the country, 18 were mobilized to the disaster area immediately after the Tohoku earthquake occurred on March 11, 2011. They operated at the disaster area

together with numerous helicopters from fire and disaster management and the Self-Defense Forces. The final goal of this research is to realize information sharing through data communication between all these helicopters and the disaster-response headquarters and to conduct overall rescue operations more efficiently.
(Yoshinori Okuno)

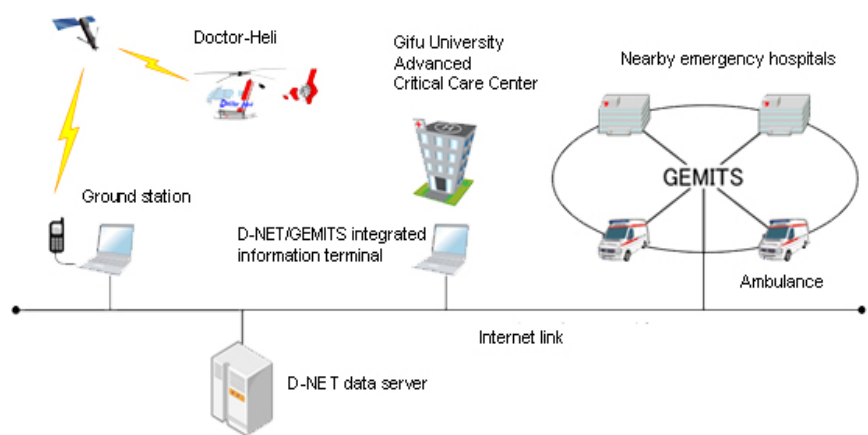


Fig.2: Overall configuration of flight management system for Doctor-Heli

Future plans

Figure 1 shows a simulated operation using JAXA's research helicopter, conducted in 2009. From 2010 to 2012, the overall system is being developed, evaluated and demonstrated, for actual use as shown in figure 2, with the aim of



Fig.3: Patient being transported by Doctor-Heli

(*1)D-NET: Disaster relief aircraft management system NETWORK; JAXA is playing a central role in the research and development being conducted on this system for sharing information between the disaster-response headquarters and numerous aircraft during a large-scale disaster in order to optimize flight management.
(*2)GEMITS: Global Emergency Medical support Intelligence Transport System; Gifu University is playing a central role in the research and development being conducted on this system for sharing information between the ambulance and emergency hospitals to quickly select the optimum hospital for admission according to the patient status.

What is flutter?

Everyone knows the meaning of "flutter". When a strong wind hits the blinds blocking sunlight through a window, an intense oscillation persists. This phenomenon is "flutter". Flutter on aircraft is linked to major accidents. Therefore, research is continuing at JAXA so that aircraft will fly safely and flutter will not occur during flight.

Flutter occurring in an aircraft wing is related to the following three forces (fig. 1).

1. Inertial force due to wing oscillation
2. Elastic force due to wing deformation
3. Aerodynamic force due to flows around a wing altered by wing deformation

When an aircraft flies through calm skies at constant flight conditions, the three forces are balanced with no oscillation (the force of 1: is zero). If the flight condition suddenly changes (for example, when the aircraft is hit by a gust of wind), the aerodynamic force working on the wing suddenly changes. Afterward, the above-mentioned forces 1: through 3: are vibrationally combined and applied to the wing. Safety is not compromised if the wing's oscillation can be

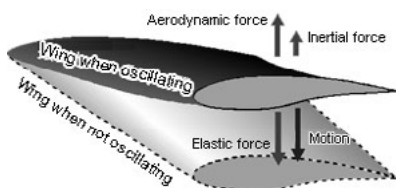


Fig.1: Three forces working on an oscillating wing

suppressed—a safe flight is possible. However, flutter will occur if the wing's oscillation increases over time. (Flutter will occur with any wing if the flight speed is increased.)

Flutter analysis

In aircraft development, flutter is seen as an extremely dangerous phenomenon. Therefore, when developing aircraft, numerical analyses and wind tunnel tests with miniaturized models of the actual vehicles are conducted to design the aircraft so that flutter does not occur within a flight speed range, allowing for a certain margin. Finally, with a flight test of the aircraft prototype, it is confirmed to meet the established safety regulations. As a result, there is no danger of flutter during flight with aircraft that we board.

However, aircraft design is not limited to constructing it to be safe. There is no interest in "making the aircraft so solid that flutter does not occur!!" This would cause the aircraft to become heavy, reducing the passenger and luggage capacity. Airline companies would not purchase such aircraft. Designing aircraft to be lightweight while meeting the established safety standards is essential to aircraft development. Therefore, how to increase the reliability of testing technology and analysis methods used in design is an essential branch of flutter research, and one being studied by the Aviation Program Group.

Using numerous CPUs in large-scale computers, the oscillation of an aircraft in flight is analyzed with high

accuracy. Recently, it has become possible to also analyze complex shapes with an aim for application to the entire aircraft (fig. 2). However, not all of the analysis is satisfactory. For an analysis, the perimeter of the aircraft is covered by millions of grids (computational grid), and the calculations are repeated for each grid. Furthermore, the analysis is done so that the computational grid moves together with aircraft oscillation. Since this must be repeated tens of thousands or hundreds of thousands of times, it takes an extremely long time to complete the analysis with specific flight conditions. On top of that, this must be repeated with a number of flight conditions. In addition, if the computational grid is of poor quality, calculations may no longer be possible midway through.

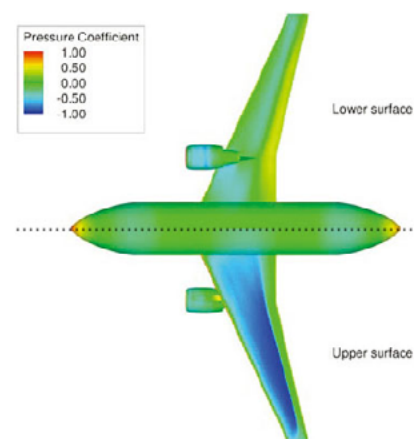


Fig. 2: Sample calculation for a complex shape Regular computational results around a regional jet. The pressures are shown. Shock waves are occurring at the border between the blue and green regions. Source: H. Arizono, et al., "TRANSONIC FLUTTER ANALYSIS FOR WING-PYLON-NACELLE CONFIGURATION,"

(From left) Kenichi Saitoh, Norio Yoshimoto, Masato Tamayama
 (Upper right) Hitoshi Arizono (on long-term assignment to the United States)

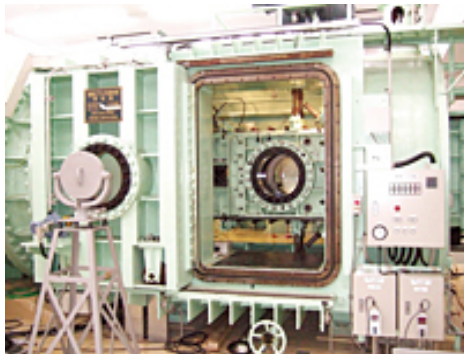
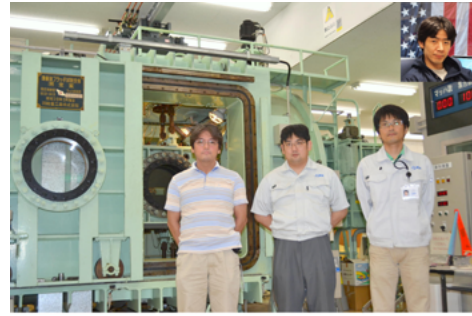


Fig.3: JAXA's transonic flutter wind tunnel
 Capable of creating a high-speed flow up to Mach 1.2
 in a 0.6 m × 0.6 m test section

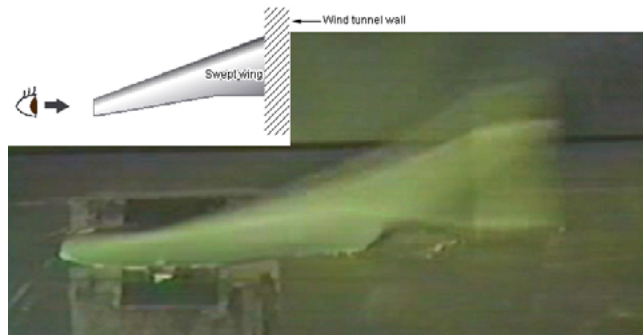


Fig.4: Photo of flutter occurring in the wind tunnel test
 The wing tips are oscillating severely.

Resolving these problems is the current issue with flutter analysis.

Conducting tests safely

Even though advanced analysis methods have been developed, those methods cannot be called effective if they cannot be verified to provide highly accurate results. For verification, a comparison with wind tunnel tests using a reduced-scale model of the machine aircraft is normally conducted (fig. 3 and fig. 4). Furthermore, as previously mentioned, it is necessary to finally check with actual flight tests that no flutter occurs (i.e., that the oscillation that occurred is suppressed quickly and sufficiently). The scope of the flight tests continues to expand in order to slowly approach flutter. In order to perform these flight tests safely, the test progresses while confirming that there is an adequate margin until flutter occurs. Research and development is continuing at JAXA on a program to use this application (fig. 5). With this program, we will pursue

a parameter representing flutter risk from the test results (when the value is zero, flutter occurs). Using the value of this parameter, we can estimate after what amount of change in the flight conditions flutter will occur.

Flutter is a dangerous enough phenomenon that the aircraft will

be damaged if it occurs. We are continuing research every day so everyone can safely travel the skies in aircraft without the dangers of flutter.

(Masato Tamayama)

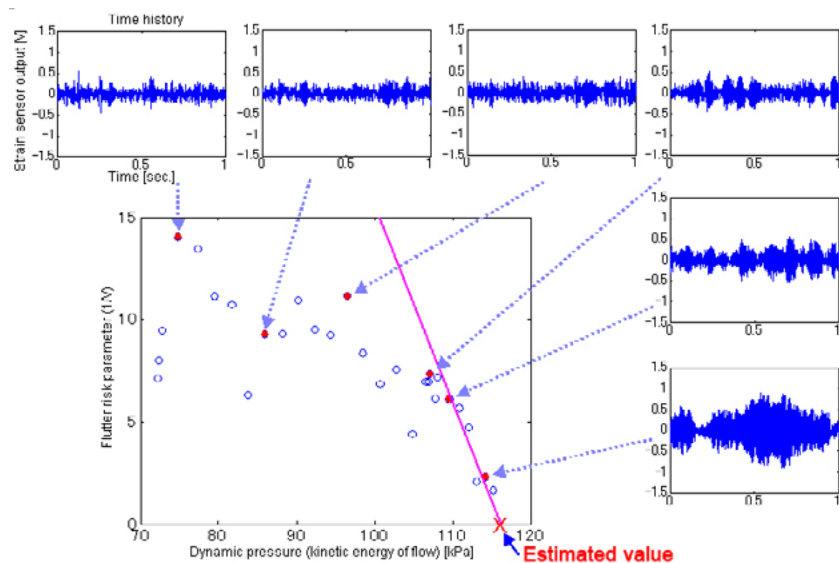


Fig. 5: Sample calculation of the flutter risk parameter (example of peak-hold method)
 The parameter representing the flutter risk is graphed with respect to dynamic pressure (kinetic energy of flow). This relationship is approximated by a straight line so we can determine the conditions under which the parameter becomes zero.



Interview
 People who fly dreams
 No.19

The perfect system for measuring sonic booms

D-SEND Project Team
 Associate Fellow
 ● Shigemi Shindo

✈ In May of this year, the first stage (D-SEND#1) of the D-SEND project was completed successfully. The "sonic boom measurement system" assumes an important role in this project. Associate fellow Shigemi Shindo was in charge of its development. He went to the test site in Sweden as the sonic boom measurement team leader for D-SEND #1. We spoke with him about it. (Refer to the Special feature.)

Monitoring throughout the night in the control room

✈ Congratulations on the success of D-SEND #1. Please tell us how you feel.

Shindo Thank you. I am relieved that we were able to complete two drop tests within a limited window and obtain clear sonic boom signatures.

✈ During the tests, you assumed control from the control room for the measuring sites set up at four locations, right? Were you worried up until it was confirmed that measurements have been taken?

Shindo Since we came well prepared, I thought that if a sonic boom could be produced, we would be able to measure it. I was in the control room and I monitored the measuring system the whole time after it was launched, so

that I could respond to any issues. As the measuring site team members had some work that could only be done after the decision to launch was made, they were in the field working at the measuring sites throughout the night from the previous day to prepare for the early morning drop test. So, I was also stuck in the control room all the time, except to have some meals.

✈ What were the biggest challenges?

Shindo Using a wireless LAN connection, we formed a network to remotely control and monitor the four measuring sites from the control room. As backup, we set up a secondary communication tool, using satellite phones. Since the control room was a maximum of 100 km away from the measuring sites, the wireless LAN communication was set up with multiple relay points. I also helped in setting up these relay points to make communication possible, and that was quite difficult work. With various problems occurring, things not going smoothly and the test start date imminent, I felt pressed for time.

✈ So, some things were unknown until they were attempted on site?

Shindo The first few days, I was instructed by the manufacturer in charge of the design, who accompanied us from Japan, but since they were not going to be there during the entire preparation period, we had to ensure that we would be able to do it ourselves. While in Japan, a few people, including myself, had practiced to be able to perform the assembly and communication. However, we couldn't predict some conditions, such as deep snow on site at the beginning which took us 40 minutes to progress 100 meters through.

✈ What other troubles did you encounter?

Shindo Since a balloon was used to suspend the test bodies, we waited a long time until the wind was such that the measurable area would not be missed. In addition, if there is not some level of humidity, the waveform does not reach the ground properly, so humidity is needed. If those conditions had not been met, the test could not have been performed. However, since we have experienced the complete testing procedure, facing many difficulties, I expect to feel slightly more comfortable with D-SEND#2.

✈ This seems to be a uniquely developed measurement system, in one word, what makes it so impressive?

Shindo Commercial measurement devices that measure sonic booms are available. However, those would not have been suitable. The unique thing about our system is that its construction meets our demands. It can be remotely controlled over an expansive allowable drop area, it can take measurements in the air, it is light, and it can even operate in low temperatures. Dare I say, what may be impressive is that not only it meets these constraints but it was developed with using ready-made goods.

✈ With the success of this test, can this measurement system be recommended?



Shigemi Shindo
 Test Planning Section
 In charge of developing a sonic boom measurement system



Measurement system blimp

Shindo It seems to be gaining the attention of researchers in other countries. A study by ICAO has begun to determine environmental standards, for example, regarding noise, so that supersonic civil transport aircraft can fly again. We plan to propose to them that measurements be taken in this way with this type of measurement equipment.

✈️ Could you hear the sonic boom from the control room?

Shindo I didn't hear it with the first drop test, but I faintly heard a sonic boom for the N-wave model in the second drop test, where the drop point was near the control room. The control room was about 20 km away at that time. I didn't hear sonic booms with the low-boom model.

A measurement professional

✈️ Until now, what research have you conducted?

Shindo When I joined NAL (National Aerospace Laboratory of Japan; one of the organizations preceding JAXA), at the time when construction on the gust wind tunnel began, I first started as the site foreman and, after it was completed, I was in charge of wind tunnel testing. Around the same time, a project focused on development of vertical takeoff and landing (VTOL) aircraft was implemented, and I helped with flight testing of the prototype equipped with the JR100 engine, developed for the VTOL. Next, I belonged to a division researching a motor and, for a while, I participated in conducting engine noise measurements. The FJR engine being developed at that time was installed on the short take-off/landing (STOL) experimental aircraft "Asuka", and I also helped on the midair test (test where the engine is installed on an airframe and flown for verification) in order for the engine to obtain Type Certification.

Then, I tackled "flow visualization" research. There is a method of cooling by blowing cooler air out from small holes in the turbine blade to form a layer over its surface so that the turbine of the engine doesn't become too hot. So, how to blow out the air for better cooling efficiency was being researched. I researched the method for visually understanding the condition of the air flow at that time. I tried various methods such as circulating water instead of air.

Afterward, NAL began research on launch vehicle, or "spaceplane". A spaceplane is an aircraft that is able to take off from earth to go into space and return to earth, with supersonic speeds decidedly a stepping stone. I was involved in the development of its engine, and I tackled research of the "schlieren" method, which visualizes how shock waves are formed within its intake (air inlet).

✈️ So, you participated in the research of supersonic aircraft technology? You must be a measurement professional.

Shindo Based on my experience, I suppose so. Experimental trials are my forte. What I find interesting is that my own imagination and creativity could be incorporated even into the various visualization tests. I think it is because I had understanding superiors.

✈️ You have had experience with a wide variety of projects.

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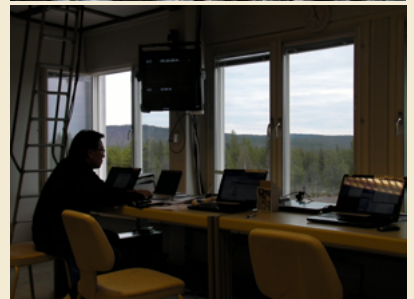
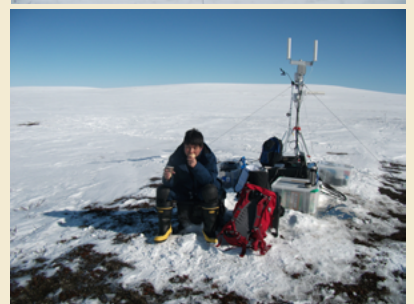
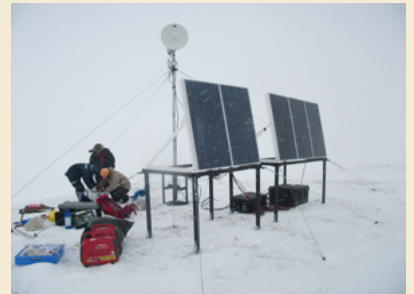
Shindo I was able to experience things that are not normally experienced. Once a project is implemented, it must succeed. It may be difficult, but that is the energy of the research institute.

✈️ What do you enjoy doing in your free time?

Shindo I have gone to the Disney Resort many times. My daughter is now a preparatory school student, but she likes their shows and goes there frequently. I am in charge of driving her there and holding a spot at the shows for her. Essentially, I am her chauffeur.

✈️ What are your future goals?

Shindo Since I have just one more year until I reach retirement age, nothing really special. (laughs) That may be a standard question for a younger person though. My biggest goal is to pass on what I have done so that D-SEND #2 will go safely and smoothly. Later on, I am thinking that I'd like to make good use of my past experiences. After I am 65 years old, I will have a normal retirement.



- 1) Test bodies; (Right) Low-boom model, (Left) N-wave model
- 2) Traveling by helicopter together with the cargo
- 3) Setting up a relay point. Work also had to be done in the snow.
- 4) Test team member at lunch
- 5) Shindo monitoring the measurement system from the control room
- 6) On-site office