

# Technology to develop a fast, clean, quiet supersonic transport for the next generation

Fast and quiet flight through the air. The wish is simple, but the hurdles are many. The biggest hurdle to the development of a new supersonic transport is the tradeoff between noiselessness and speed in vehicle design. Research on a new supersonic transport is steadily progressing. There have also been recent efforts afoot to establish environmental standards for air travel supersonic speeds.

## Mounting R&D on the supersonic transport

The Concorde, the world's only commercial supersonic transport (SST) ever developed, went out of operation in 2003. During its lifetime in service, the SST was a glamorous and convenient transport for transcontinental travelers. The flight time from London or Paris to New York was only three and a half hours. Yet even though the flights were mostly full, the Concorde was generally

evaluated as a commercial failure. The problems behind this failure were technical.

R&D on a new SST for the world is now active. What technologies will we need in order to create a new SST? And when can we actually expect to fly at supersonic speed in a new passenger aircraft?

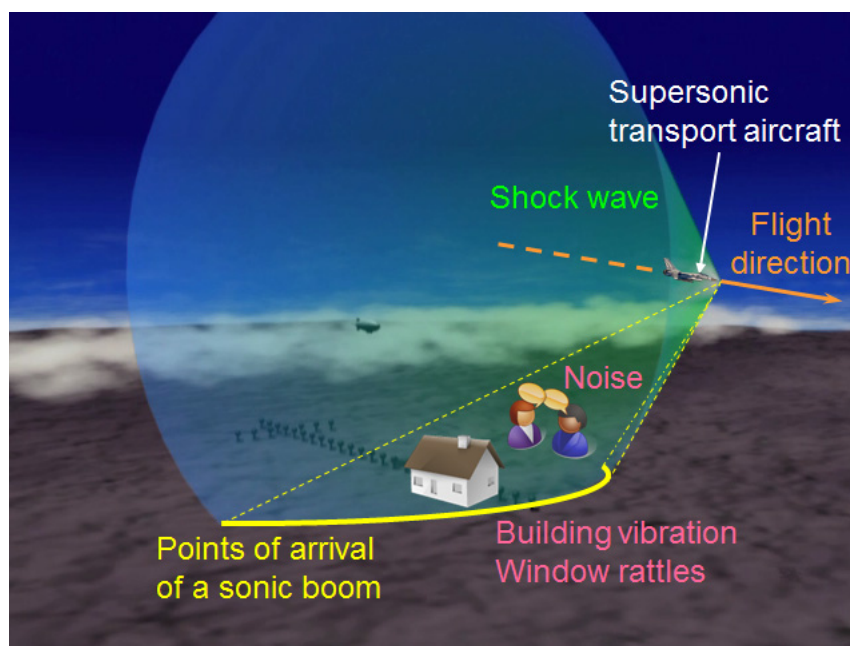


Fig.1 What is a sonic boom?

When an aircraft flies at supersonic speed (faster than the speed of sound), the interference between the airframe and surrounding air generates a shock wave accompanied by a sharp jump in pressure. This shock wave spreads conically from the airframe, the veritable tip of the cone. When the shock wave reaches the ground, it is perceived as a sonic boom. The sonic boom of the Concorde is just as intense as a blast of thunder close by.



### Quietness is the key factor

The reasons for the commercial failure of the Concorde give us hints for the development of the new SST. Two of the biggest reasons were poor fuel efficiency and the sonic boom unique to supersonic transports (Fig.1). The sonic boom was so unsettling to people on the ground, regulatory authorities prohibited flight of the Concorde over land and restricted takeoff and landing to only a few select airports. Worse, the limited passenger capacity (no more than 100 people) and high fuel consumption pushed fares up to very high levels.

A crucial feature for the new SST will be compatibility between environmental friendliness and economic efficiency. In practical terms, this means quietness, reduced emission of harmful substances, and fares affordable to people from all walks of life (Fig.2).

The biggest of the various technical challenges is to lower the magnitude of the sonic boom, a thunderous and awe-inspiring "KA-BOOM." As long as the annoying boom persists, SSTs will never fly freely through the skies of the planet. Research conducted so far has revealed that the magnitude of a sonic boom can be reduced by

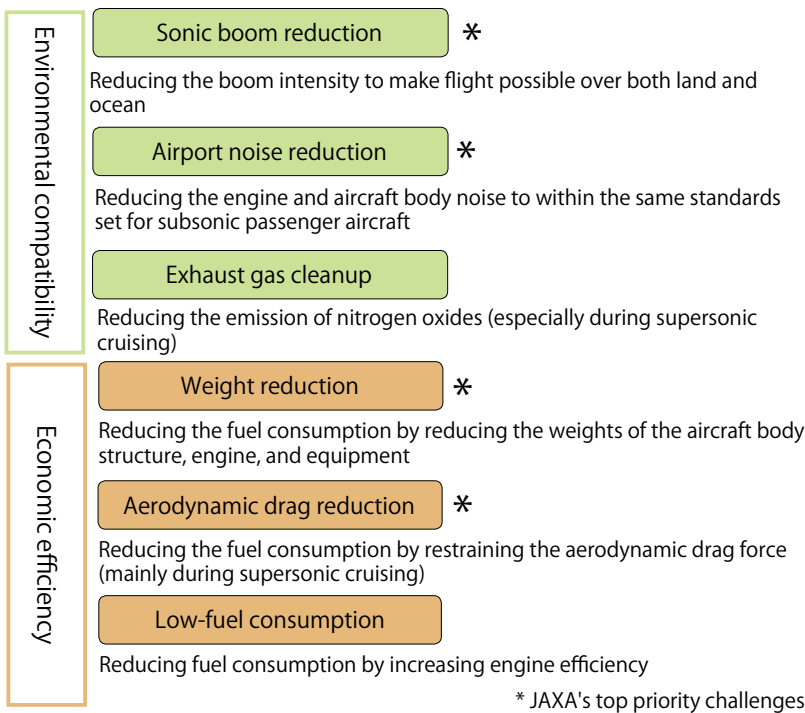


Fig.2 Technologies required for the realization of next-generation Supersonic Transport



Fig.3 Tohoku University, silent supersonic transport Offered by Tohoku University (Courtesy of Tohoku University)



Fig.4 JAXA's silent supersonic transport

Q Is the technology of an SST different from that of a supersonic fighter jet?

Though both of these aircraft fly at supersonic speed, the fighter jet and SST require different technologies. A fighter jet only needs to fly at supersonic speed for a very short time, but during its flight it must have extremely high maneuverability. Thus, the requirements of low fuel consumption, airframe efficiency, and

low noise are less important. An SST, meanwhile, must fly at supersonic speed for several hours. This makes it very important to improve the efficiency of the engine, reduce the weight of the airframe, and enhance the aerodynamic efficiency.

A

strategically designing the shape of the airframe. Research institutes have already proposed new airframes based on various ideas (Fig.3). JAXA may be able to halve the magnitude of the sonic boom by applying several of its original ideas to a small airframe (Fig.4).

### JAXA's research plan

JAXA's Supersonic Transport Team has been working on technical research necessary to develop a supersonic transport since 1997. The priority subject in Phase 1 was to enhance economic efficiency. The team developed a design technology to reduce drag, then confirmed the success of the technology in a demonstration flight of an aircraft fabricated based on the design, in Australia in 2005 (Fig.5).

Now that JAXA has reached Phase 2, the team has added environmental compatibility to its list of technological goals. Step by step, the team is reducing the magnitude of sonic booms as a priority target (Fig.6).

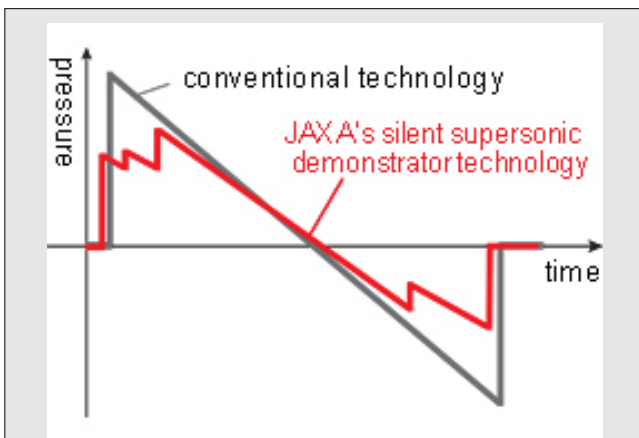
In flight experiments with the Silent Supersonic Technology Demonstrator scheduled for the mid 2010s,



Fig.5 Small supersonic technology demonstrator NEXST-1

JAXA plans to demonstrate a concept for halving the magnitude of sonic booms, as well as a new computerized design technology (Fig.7) to search for airframe shapes with reduced drag and reduced noise in flight.

### A boom regulation value is to be considered



In a supersonic flight, a succession of tiny pressure waves generated from the airframe consolidate into larger waves until they reach the ground. We can reduce the volume of a sonic boom by making these tiny waves interfere with each other in a way that prevents their consolidation. In conventional technology, a change in pressure (sonic boom) felt on the ground has a black N (letter) type waveform. The noise of a sonic boom can be reduced by blunting this sharp waveform and decreasing the pressure difference. With help from its original demonstrator technology, our researchers at JAXA aim to use reduce the magnitude of the sonic boom from a thunderclap level to a sound comparable to a knock on a door.

Fig.6 Sonic boom waveform on the ground



The shape of an environmentally friendly airframe is quite distinct from that of an economical airframe. The end of the airframe should be preferably be round to reduce the sonic boom, yet also sharp to obtain a low-drag, fuel efficient airframe. Because the airframe shapes suitable for each type of performance are contrary to each other, the technologies to develop the two shapes are incompatible. JAXA is developing software to design and analyze optimum shapes which meet both requirements. Our researchers can verify its CFD-based design technology by developing a demonstrator aircraft and conducting flight experiments.

Fig.7 Silent supersonic demonstrator aircraft



How low does a sonic boom have to be, to become tolerable to people on the ground? As of now, no clear standard for the sonic boom has yet been established.

JAXA research on the sonic boom can be of help in the setting of such a standard. In 2007, we built a simulator to faithfully reproduce sonic booms in an experimental setting (Fig.8). With this simulator, we have been examining how test subjects feel when they hear sonic booms. The aim of this test is to determine the relationship between sensitivity to sound and physical indicators.

In May 2008, JAXA embarked on a joint research project with NASA (National Aeronautics and Space Administration) to clarify how a sonic boom is generated and how it travels in the air.

As of this writing, the U.S. has a plan to commission an 8- to 12-seater supersonic jet aircraft for business passengers by as early as 2014. In response to this plan, the ICAO (International Civil Aviation Organization) is now preparing to establish a set of environmental standards, including regulation values for the sonic boom. At JAXA we hope to contribute to the ICAO's efforts through research of our own.



Fig.8 Sonic boom simulator

### International joint development in view

The Concorde was the result of joint efforts by the United Kingdom and France. If plans go forward for the development of the Concorde's successor, a new aircraft capable of transporting large numbers of people at supersonic speed, it will also be an international effort. By demonstrating our technologies to other countries in the world, we aim to take the lead in joint development.

## When do you think we will actually be able to fly in a new supersonic transport?

A very fast supersonic transport is sort of a dream we all long for, but it also has features that can be perceived as negative, both economically and environmentally. The worst of these features are a heavy fuel consumption, a heavy discharge of exhaust fumes, and tremendous noise.

In researching the new supersonic transport, we are searching for strategies to overcome the problems which could hinder the acceptance of the aircraft worldwide. If we achieve

satisfactory results, you can count on witnessing the debut of an SST acceptable to people very soon. Yet the technologies are too daunting to reasonably expect a large SST anytime in the near future. JAXA is working towards technological demonstration at the level of a small 30- to 50-seater SST. But before that, an even smaller supersonic business jet plane may appear on the scene.

It feels like we are finally at the point where we can reach our dream.



Takeshi Ohnuki  
Head  
Supersonic Transport Team

If you ask us when we can expect to see our dream come true, the answer will be different for every person. That being said, I'm certain that we're moving closer with every step.



# Research for prompt and efficient disaster-relief activities with helicopters

Operation and Safety Technology Team

When a large-scale natural disaster such as an earthquake strikes, helicopters fly in from all over the country to transfer the injured and sick, carry in relief supplies, collect information, and perform other vital tasks. As each type of helicopter carries different equipment and performs different functions, the emergency services coordinating them must assign the optimal type for each mission. There are restrictions, for example, on the types of helicopters that can be deployed for the transport of the sick, the injured, or disaster victims with certain symptoms. The hospitals, meanwhile, can only accommodate certain numbers of people, and also their landing pads have restrictions on the types of helicopters. Mission planners also must decide where to fuel and maintain the helicopters after the missions are accomplished. When many helicopters fly to one destination, they will face long waits for refueling, and for takeoff or landing.

When planners assign missions nowadays, they use

information on the above matters called in by telephone or transmitted by facsimile. For a disaster of a larger scale, the amount of information to be sent grows commensurately and therefore prompt action becomes a problem. JAXA is researching an operation management system (Fig.1) to support the optimum mission assignment to helicopters based on information shared in real time via data communication systems between helicopters and disaster-response headquarters on the ground. For this purpose, JAXA developed D-NET (disaster-relief aircraft information sharing network) standards to share information, and proposing the standards to agencies concerned. For further details, see section 3 of this report, "From Research Centers."

## Coordination with disaster information systems

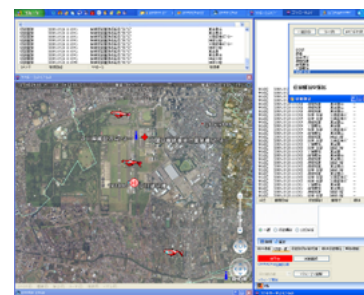
To perform prompt operation management, mission coordinators must share information not only on helicopter



Fig.1 Information sharing and operation management by D-NET

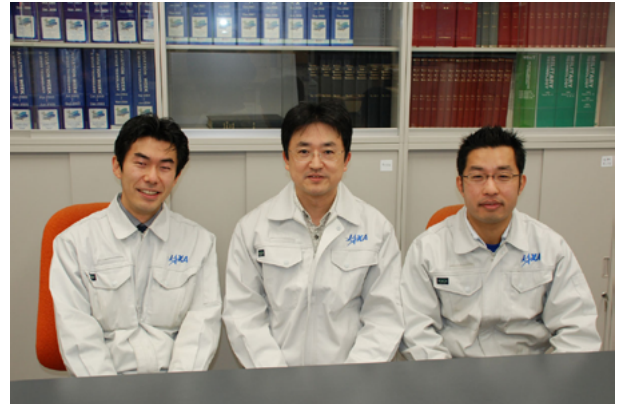


On-board display for pilots



Display for operation management on the ground

Disaster-Prevention/Operation Management Technology Section  
 (From left to right) Keiji Kobayashi, Yoshinori Okuno, Masahiko Sugiura



operation status, but also disaster conditions. D-NET is interconnected with a "Disaster-Mitigation-Information-Sharing Platform" under development in the "Special Project for Preventing and Mitigating Disasters Caused by Metropolitan Epicentral Earthquakes," a project promoted by the Ministry of Education, Culture, Sports, Science and Technology. Through this interconnection, JAXA has developed a function to perform operation management using information on the capacities of local hospitals and helicopter operation orders issued by local governments. Demonstration tests on this function were performed successfully in February 2009.

#### Responding to various communication systems

##### - Experiment on air to air communication via wireless LAN -

A data communication system between the ground and aircraft must be implemented to realize D-NET. A satellite communication system is expected, as helicopters fly over mountainous regions where terrestrial signals can hardly be received. As of this writing, an Iridium satellite which communicates with a small antenna of about 10 cm in diameter is deployed practically for this task. Technical hurdles have yet to be cleared before the communication speed can be improved and the high cost reduced.

A wireless LAN system of the type used by households is a ready solution for low-cost, high-speed communication. Yet the short area of coverage limits the application of LAN systems to the environs of an airport. Passenger airplanes, meanwhile, fly at high altitudes with long separations between them. For this reason, the radio waves sent by one airplane will not reach another airplane up in the sky. Helicopters, on the other hand, fly close to each other at low altitudes over disaster-stricken areas. Under these conditions, they may be able to communicate with each other via wireless LAN. JAXA conducted an IEEE 802.11b wireless LAN communication experiment using its own research helicopter and airplane (Fig.2).

According to the results shown in Fig.3, two aircraft flying at a distance of 9 km from each other exchanged information at a communication speed 200 times higher than that achievable via an Iridium satellite. At this communication speed, a digital camera image consisting of several million pixels of data on a disaster-stricken area can be transmitted in ten-odd seconds. Under normal conditions, two or more helicopters will fly



Fig.2 Helicopter and airplane used for the communications experiment

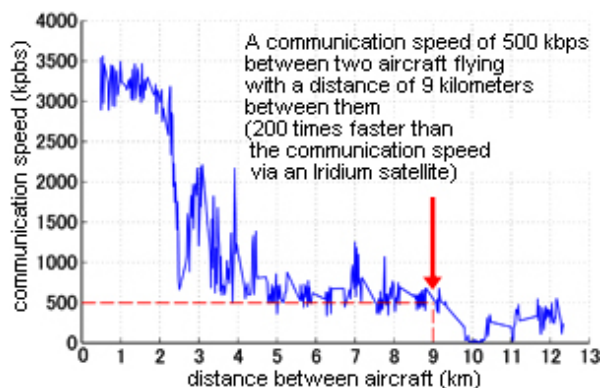


Fig.3 Results of the communications experiment between aircraft via wireless LAN

over a disaster-stricken area within a 9-kilometer radius. By constructing a communications network in which helicopters serve as relay stations, a helicopter can send data to the disaster-response headquarters on the ground 9 kilometers or more away.

With the constant advance of communications technology, next-generation standards with improved performance for both Iridium satellites and wireless LAN are in the pipeline. D-NET will be applied to these diverse communications systems.

#### Future goal

- Practical deployment of the operation management system-  
 JAXA's on-board avionics and prototype operation management system for ground use will be in trial operation for evaluation at disaster-prevention agencies since fiscal 2009. As more findings accrue, JAXA will feed them back into its process to develop a practical system by fiscal 2010.

(Yoshinori Okuno)

# Wind-tunnel water-dropping test using a fire-fighting amphibian

From the research field

Civil Transport Team / Wind-Tunnel Technology Center



Fig.1 Fire fighting by using an amphibian (Conceptual diagram: Offered by ShinMaywa Industries, Ltd.)

## What is a fire-fighting flying amphibian?

When it is difficult to extinguish a large-scale earthquake fire or a forest fire or to check their spread at a close range from the ground, spraying water from the air is helpful. It is expected that aerial firefighting using flying amphibians is more effective because a flying amphibian can carry a

large amount of water and easily take water from a lake or river by landing on the water and gliding. JAXA, ShinMaywa Industries, Ltd., and Japan Aircraft Development Corporation have been conducting joint technical research to develop a fire-fighting amphibian, as shown in Fig.1. Conceptual Diagram.

## To efficiently drop water

When water is dropped from the air, a large lump of water splits up into fine particles and flies in all directions. The size of this water particle, the scattering range, and the amount of water that reaches the ground determine whether fire fighting is a success or not. These factors are greatly affected by the flying speed and altitude of an aircraft. Consequently, it is essential to determine the relationship between scattering of water and flight conditions and establish analysis and evaluation techniques for effective fire fighting.

As shown in Fig.2, we placed the fuselage of a model flying



Fig.2 Water releasing test in a wind tunnel

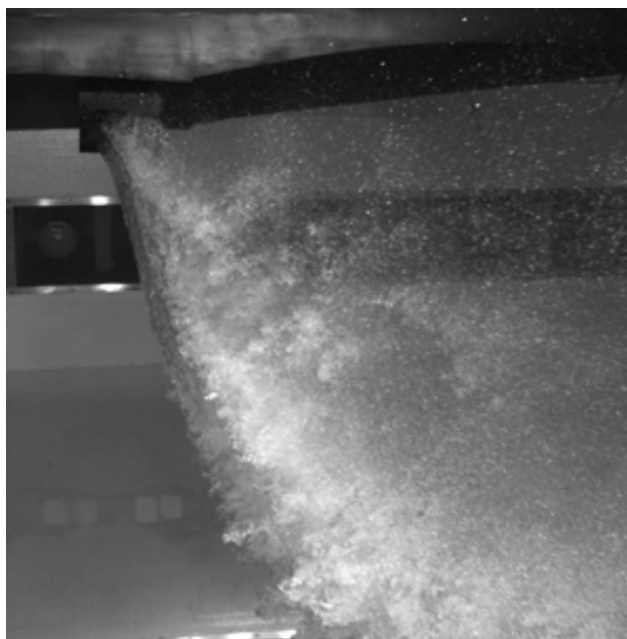


Fig.3 Image captured by a high-speed camera





Members of the water-dropping research for a fire-fighting amphibian  
(The author is the fourth person from the right of the top photo.)



Fig.4 PIV

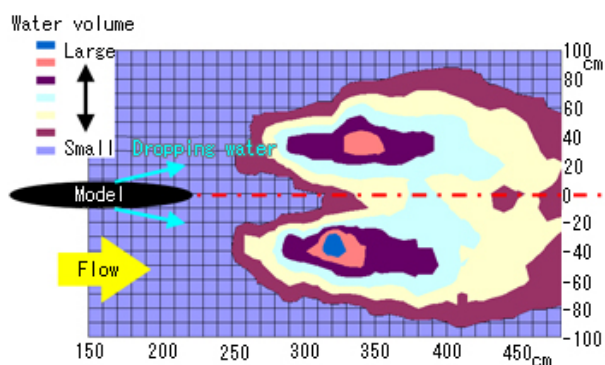


Fig.5 Dropping water density distribution

amphibian in a 6.5 m x 5.5 m low-speed wind tunnel to measure the distribution of water dropped from the model, to observe the water lump splitting condition with a high-speed camera, and measure the distribution of water drop speeds by applying PIV (Particle Image Velocimetry), with respect to various wind velocities and flight altitudes. Using the water drop data obtained from the experiment, we will search for an effective aerial fire fighting method through the verification of the numerical analysis evaluation technique.

#### Behavior of sprayed water

We studied the behavior of water dropped from the model in the air current of the wind tunnel with a high-speed camera. Fig.3 shows that a large lump of water was split up into particles by the wind current and also reveals that as it went downstream, it changed into fine mists. We can also see that the behavior of water depends on the wind velocity and the scale of the model. Water takes the form of particle or mist, depending on the magnitude of surface tension acting on a water drop, as well as the gravity and wind velocity. As discussed above, we have obtained very interesting results as a physical phenomenon.

Furthermore, in order to obtain detailed specific numerical data on water dropping, we attempted to measure the water drop speed distribution. We applied PIV technology that has been developed by JAXA as a technology to measure the air

current in a wind tunnel. In this measurement, we radiated continuous light laser in the form of sheet as shown in Fig.4 and captured the image of a water drop with a high-speed camera. Then, we found out the same water drop from two continuous frames of the image and determined the speed from the amount of travel. Thus, we were able to obtain data on the speed of water drops in accordance with the change in place and time.

Also, we evaluated how water dropped into the wind tunnel scatters by measuring the precipitation with a measuring cylinder and an increase in the weight of water absorbed by a water-absorbing sheet. As shown in Fig.5, water released right and left dropped as it was scattered and flew in all directions with water distributed around a certain point. This figure shows how water reaching the ground is distributed. It serves as valuable basic data to properly predict and control this water dropping distribution.

\*

As discussed above, we made it possible to determine in detail the whole picture of the behavior of water when it was released, by taking the picture of the entire phenomenon with a high-speed camera and obtaining numerical data on falling water drops by PIV and the whole data on dispersion after the fall. The data obtained from these tests will be helpful to determine how to drop water from an amphibian to extinguish a fire more efficiently.

(Takeshi Ito)





Interview  
People who fly dreams  
Vol.11

# To engineer a truly quiet jet engine, we have to know the source of the noise.

The first step to defeat an opponent is to investigate the opponent's background.

Clean Engine Team  
Hideshi Oinuma, Kenichiro Nagai

✈ Although that sound of jet is a symbol of high-speed transport we have developed and improved over hundred years, the tremendous noise, of course, is a nuisance. Today's engines make far less noise than the engines 30 years ago. Our group is working towards the development of even quieter engines to make our experiences with aircraft more pleasant in the years to come.

What are the noises we hear, and from where do they come?

✈ What do you research in the Noise Reduction Section?

Oinuma We research ways to reduce the noise generated from aircraft jet engines. Various types of engine noise are generated, such as the noise from the front fan and the jet noise caused by the high-speed exhaust from the rear. This fiscal year, our section is focusing on the jet noise.

Nagai Our research can be roughly divided into two themes: how to accurately measure noise and how to reduce noise. Let's take the example of a doctor's treatment of a patient. A doctor carries out various examinations such as X-rays and endoscopy studies to search for the cause of a disease. After the doctor makes his diagnosis, he gives the patient a suitable medical treatment, such as an injection or oral medication. Our team does something similar with noise. We begin by accurately measuring the source of the noise, then we think out some way to reduce the noise.

✈ How do you measure noise?

Nagai We employ a method called "noise source localization" to determine what the noise is, and where it comes from. First, we place an array of microphones and simultaneously acquire sound data for each microphone. By checking the differences in the

noise travel times to the different microphones, we can analyze where the noise actually comes from. In one experimental setup, we put tens of microphones on a runway and fly model planes over the microphones to measure the noise. Through this procedure, we can determine which noise comes from which part of the model plane, with photographic accuracy. But to do so we need to accurately acquire noise data and measure the speed and altitude of the model plane the moment it flies over the microphones. Even with the model airplanes in this experiment, the flying speeds are over 200 km/h. This creates a challenge, as it can be very difficult to capture the noise of an aircraft moving fast. Our team develops various measuring methods on our own and then mixes and matches these methods in our experiments.

Oinuma We are also developing a telemetry system with a microphone and camera for installation on an unmanned model vehicle called a rover. With this rover, we carry out outdoor operation tests on the jet engine. Specifically, we have the rover run around the engine by remote control via wireless LAN, to measure the noise. With this procedure, we can determine the differences in the noise transmitted to different places along the rover's path. The rover is also useful for monitoring engine trouble. A jet engine is far too dangerous for people to approach while it is actually running. Instead, we have the rover approach the engine to check problems and monitor the status of operation.

Nagai Based on noise data obtained by these methods, we can actually calculate the noise of an aircraft in flight and predict how the noise at takeoff and landing will impact the people living around the airport.

✈ What roles have you been assigned?  
Oinuma Roughly speaking, Dr. Nagai is in charge of software development and I am responsible for hardware. Sound level meters are commercially available. We use an off-the-shelf sound level meter to take the noise readings. Noise readings alone won't tell the cause of the noise. To find this, we think up new measuring methods and instruments.

✈ Could you explain your methods for reducing noise?

Oinuma The higher the exhaust velocity is, the louder the jet noise becomes. So we can reduce noise by decreasing the exhaust velocity. One of the available methods to realize this is to put a special device at the end of exhaust nozzle. Yet the high-speed exhaust is also thrust, so a decrease in the exhaust velocity causes a loss of thrust. How can we minimize the loss of thrust and at the same time achieve noise reduction? The balance between these opposing factors is critical. Our team repeatedly fabricates models and conducts tests to develop a device with an optimal balance.

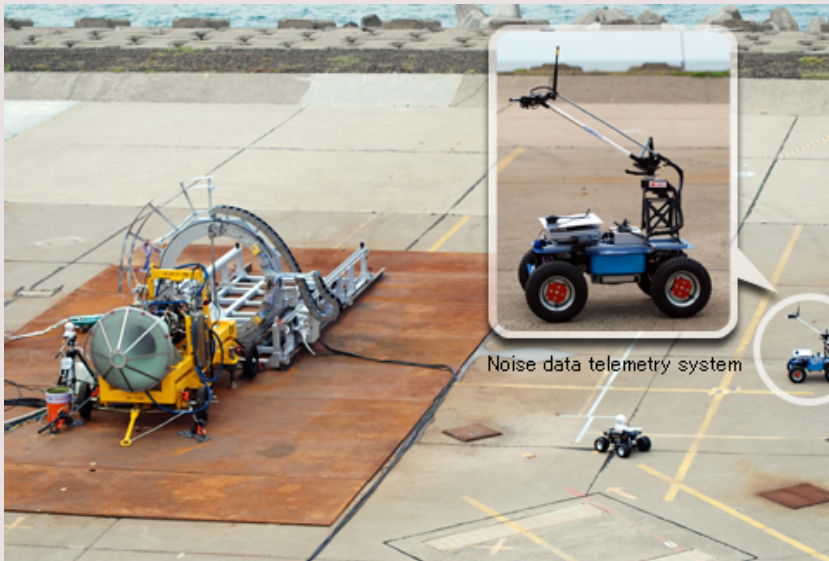
Sports-oriented type researcher

✈ What was your dream as a child?

Oinuma I used to say that I would be a



Kenichiro Nagai  
Noise Reduction Section  
Specialized in aerospace engineering in graduate school.



Jet engine operation test

motorman.

Nagai When I was in elementary school, I wanted to be a novelist. I liked reading books and used to read detective stories such as the Sherlock Holmes series. But I didn't seem to have a talent for the Japanese language. Loathing Classical Japanese and Chinese classical literature, I decided to major in science.

✈️ What convinced you to choose a career in JAXA?

Nagai In my last months of graduate school, I had my sights set on an opening at a manufacturing company. My plan was thwarted when the company chose someone else to fill the position, a younger woman in our laboratory. Then my professor recommended that I look into an opening at NAL (the



Hideshi Oinuma  
Noise Reduction Section  
Majored in mechatronics in junior college

National Aerospace Laboratory), one of the predecessor organizations of JAXA. Eager to continue my research on aircraft, I jumped at the chance.

Oinuma I decided to get a job in NAL because NAL had a branch office in Miyagi Prefecture, my home. My first position at the laboratory was as a facility manager. I also studied in a college at night. One of my superiors had recommended it, and it gave me the opportunity to fiddle with machines, a pastime I adore. Afterwards I was transferred to the research section and started researching.

✈️ We've heard you that both of you are members of JAXA sports teams.

Nagai I joined the soccer club. It gives me the chance to stretch my legs and practice over my lunch break.

Oinuma I'm in the volleyball club. Flatteringly, someone told me that I, as a tall person, would make a good volleyball player. So I started to play. I've been playing for long time, but I never improve. (Laughs)

✈️ Researchers are surprisingly active as athletes, aren't they?

Oinuma Yes. Sports help us get rid of stress. It's refreshing to tire myself out by playing a sport, but not to tire myself out by doing work. After exercising, I see things from a different perspective.

✈️ How do you spend your weekends?  
Nagai I'm an amateur soccer coach at

my son's elementary school. I take care of first graders. It's actually more like babysitting than teaching the sport. I constantly have to tell them to "Stop playing with sand!" and things like that. (Laughs)

Oinuma I spend my weekends lazily, watching movies on TV.

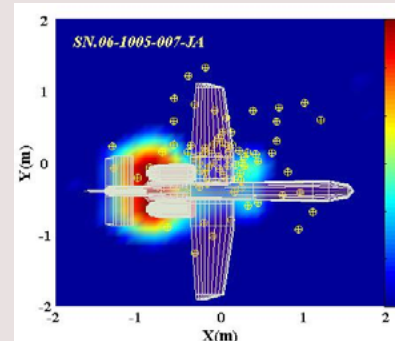
✈️ Could you tell us about your dream or goal?

Nagai I'm presently doing joint research on noise source localization equipment with a company. We expect to go commercial. This is a rare chance. When working in a laboratory, one has only slim hopes of actually seeing one's ideas take shape in the outside world.

Oinuma I hope that many of the things I've made so far get out into the world and serve useful purposes. We want our inventions to help reduce engine noise in commercial aircraft. We will be delighted if the measuring instrument manufacturers apply our inventions in various fields outside of aeronautics, as well. We are also developing technologies with other companies. Other sections at JAXA are using these technologies for their own research.



Noise source localization experiment with a model plane



Result of noise source localization (the area marked in red is possible noise source.)