JAXA Aeronautics Magazine

FLIGHT PATH

Shaping Dreams for Future Skies

Aeronautical Technology Directorate

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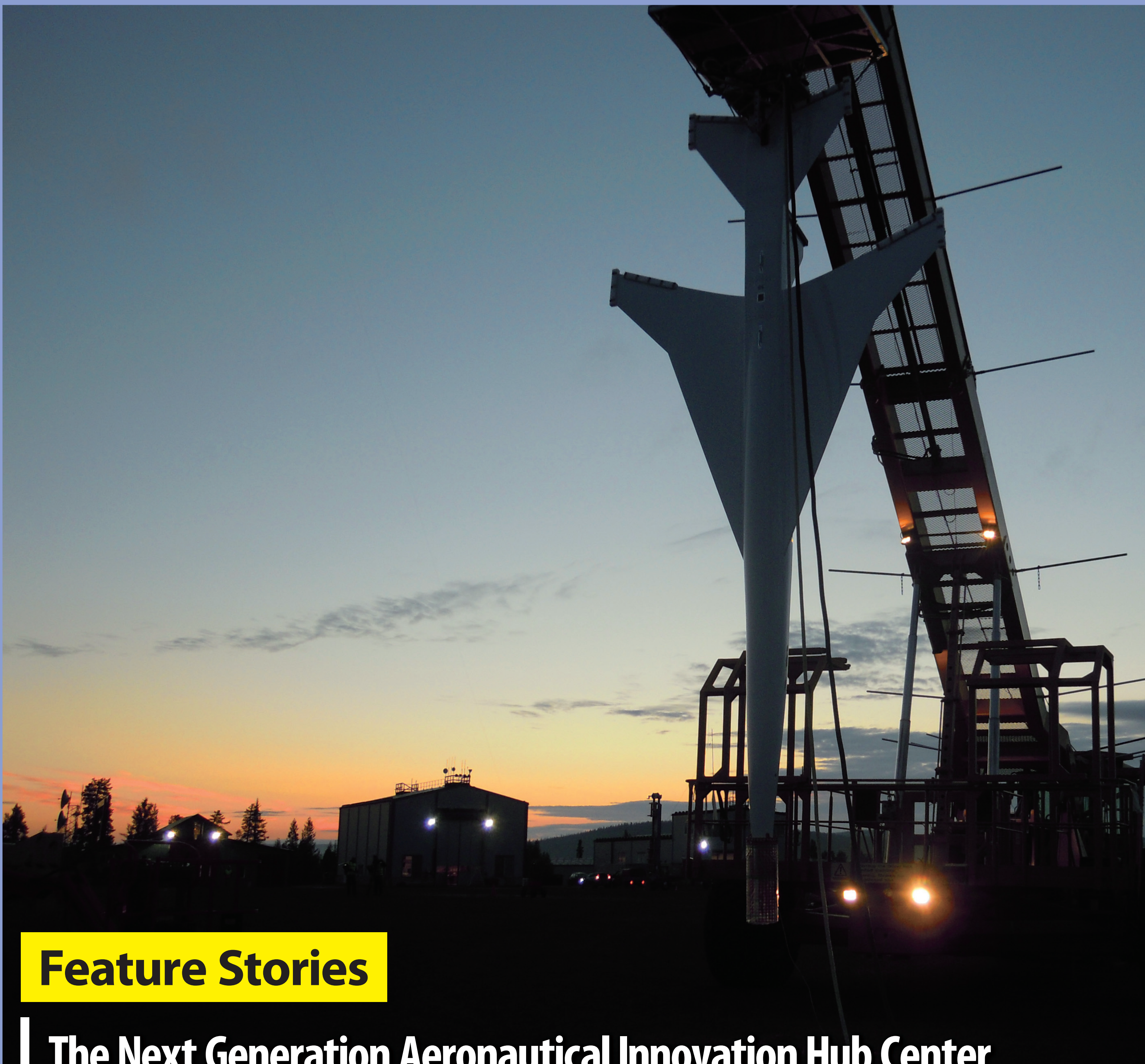

Feature Stories

- The Next Generation Aeronautical Innovation Hub Center
- JAXA's contributions to the Japanese aviation industry

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This issue looks at how JAXA research contributes to the Japanese aviation industry.

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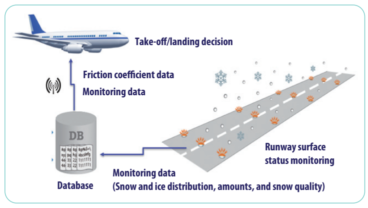
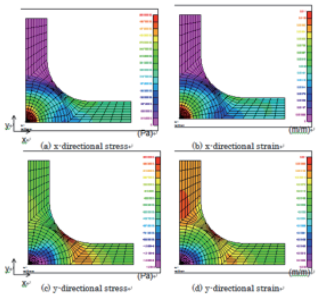
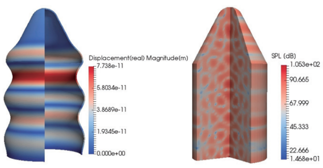
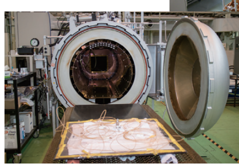








On the cover

The D-SEND#2 experimental aircraft getting ready for launch at the Esrange Space Center in Sweden

Facilitating collaboration with a wide variety of stakeholders in diverse field

The Next Generation Aeronautical Innovation Hub Center

— The latest initiatives in aviation safety technology —

In April 2015, JAXA established the "Next Generation Aeronautical Innovation Hub Center" as part of the Aeronautical Technology Directorate in hopes of forging an "all-Japan" base for aviation research and development. This feature covers two stories on the Innovation Hub Center: Fumikazu Itoh, Director of the Next Generation Aeronautical Innovation Hub Center, introduces what JAXA is trying to achieve through the newly created Innovation Hub Center, including the future framework of industry-academic-government collaboration. Atsushi Kanda, Associate Senior Researcher, explains the Innovation Hub Center's work on aviation safety technology.

—— Could you tell us a bit about how the Next Generation Aeronautical Innovation Hub Center came to be?

Itoh: In June 2014, the Cabinet Office released the "Comprehensive Strategy on Science, Technology and Innovation 2014." The document lays out the goal of accelerating innovation in Japan by "building a framework for cooperation for international industry-academia-government joint research centering on research and development agencies" and "introducing and utilizing a system for facilitating the mobility of human resources." The Ministry of Education, Culture, Sports, Science and Technology also released its "Strategic Vision for Researching and Developing Next-Generation Aircraft" in August 2014, encouraging organizations to produce "innovative, high-impact results" and "boost Japan's share of the global aircraft industry." JAXA, which became the National Research and Development Agency in April 2015, responded by launching the Space Exploration Innovation Hub Center (based at the Sagamihara Campus) and the Next Generation Aeronautical Innovation Hub Center (based at the Chofu Aerospace Center). The Innovation Hub Center operates under an open research and development framework that brings together human resources and insight from a wide variety of different areas, not just the aerospace field.

—— How will the Next Generation Aeronautical Innovation Hub Center make an impact?

Itoh: First of all, it'll enhance JAXA's research and development structure by creating a multi-field, multi-industry group that transcends the boundaries between industry, academia, and government. The Hub Center will also be instrumental in producing results that can benefit industry and society as a whole. JAXA's recent research and development initiatives have been focusing heavily on social needs. Moving forward, I think we'll need to concentrate even harder on speeding up the process of reaching the social implementation level. The three core goals of the Aeronautical Innovation Hub Center are pursuing initiatives that can benefit industry and society, driving open innovation, and delivering high-impact results—objectives that will not only help us make the Japanese aviation industry more competitive but also transform air transportation, thereby creating social value.

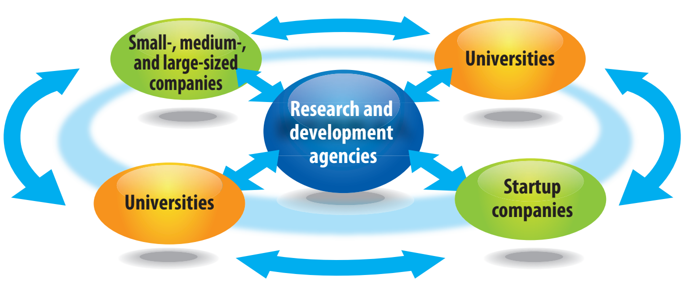
—— What kind of research and development is the Next Generation Aeronautical Innovation Hub Center working on?

Itoh: The JAXA Aeronautical Technology Directorate builds its research and development activities on a three-pillared program setup—environment, safety, and sky frontier—and bolsters those programs with research on foundational and basic technologies. While researchers continue working on their next candidate projects in each program area, we've decided to focus our work at the new Next Generation Aeronautical Innovation Hub Center on two safety-related components of our efforts to develop aircraft accident prevention technology: "protection technology for weather disturbances" and "human error prevention technology." According to a 2013 report by the International Air Transport Association (IATA), low visibility conditions, turbulence, and other weather-related phenomena account for 45% of the primary factors behind fatal aircraft accidents. When secondary causes like pilot error and faulty maintenance come into the picture and combine with primary factors, accidents happen. There are situations where weather plays a secondary role, too. That means that, in many cases, weather conditions are either a primary or a secondary cause. If we can start minimizing the effects of weather, then, we'll be able to prevent quite a few accidents from occurring. Aircraft operators have told us that the unique meteorological conditions that characterize Japanese winters constitute one of the biggest threats to aircraft safety.

—— Could you explain what goes into "protection technology for weather disturbances?"

Itoh: Aircraft operating companies invest a significant amount of time and energy in working to prevent weather-induced accidents—they cancel, delay, and divert flights (by changing destinations and landing flights at different airports) for safety reasons. These kinds of safety-related measures not only inconvenience passengers but also force the companies to take on additional costs. Through our efforts to develop protection technology for weather disturbances, we're trying to create operational safety technologies that help operators provide passengers with stable levels of convenience.

To safeguard against the effects of weather disturbances, we're directing our research along three main lines: prediction, detection, and protection. Recently, we've seen a lot of progress in "prediction" capabilities—higher-performance weather observation equipment and improved prediction technologies



Building a framework for cooperation for international industry-academia-government joint research, centering on research and development agencies:
Based on the "Cabinet Office: Comprehensive Strategy on Science, Technology and Innovation 2014 (Executive Summary) (June 24, 2014)"

will enable users to make high-precision predictions for aviation purposes. "Detection" is all about performing inspections and maintenance. Making sure an aircraft is safe to fly is a time- and labor-intensive process, which means that there's a need for technologies that deliver high-precision results at optimal levels of work efficiency. For the "protection" element, we're working on core protection technologies that keep snow from adhering to aircraft, materials that can withstand lightning strikes, and other essential protection technologies.

—— What are researchers concentrating on, specifically?

Itoh: Snow, ice, lightning, and volcanic ash are several weather conditions that can cause problems for aircraft in Japan—and detecting and safeguarding against these sorts of conditions is crucial to proper safety. One way that we're working to improve the detection of snow and ice, for example, is by developing methods of monitoring the accumulation of snow on runways. Snow buildup can cause major issues in snowy areas like Hokkaido and the Tohoku and Hokuriku regions, where operators often end up having to cancel or divert flights due to potentially dangerous runway conditions. Detecting snow and ice on runways is thus a key target for our research.

Another problematic phenomenon is airframe icing, which has a sizable impact on operational safety. The sensor technologies that we're developing will make it much easier for operators to take care of their icing checks. In terms of protection technology, we're researching anti-icing coatings for airframes, engines, and other components. We're following the same kind of prediction, detection, and protection framework for our research on lightning and volcanic ash, as well.

—— You talked about the "speed" of research and development. Could you tell us about how the idea of "speed" plays into your efforts?

Itoh: Our technologies for detecting snow and ice on runways could help operators in a variety of ways: they'd provide companies with high-accuracy landing distances, which would cut down on cancellations and diversions, and offer valuable information for making take-off and landing decisions, thereby minimizing the likelihood of overrun accidents. It'd also be easier for operators to schedule snow removal procedures and figure out how much anti-icing coating to apply to aircraft prior to take-off. That's what makes our snow and ice detection technologies so important—they make operations safer in so many different ways. Operators want to get access to the technologies as quickly as possible. The problem, though, is how long the research and development takes. First, we have to understand the principles of detecting snow and ice. The next steps involve making sensor prototypes and doing experiments in a laboratory setting. Once the indoor testing phase is complete, it's time to test the sensors outdoors and solve any problems that might be standing in the way of practical implementation. Finally, there's the process of doing demonstrations on actual runways. It's a time-consuming, step-by-step process. It'd be better if we could start pushing some of those different steps along in parallel after we've gotten a solid idea of the basic principles.

—— The JAXA Aeronautical Technology Directorate has focused on "exit-oriented" research and development. What's the main priority for the Innovation Hub Center?

Itoh: No matter how heavily you focus on needs-oriented research, researchers can only do so much when it comes to actual implementation in society. What makes the Innovation Hub Center different, though, is that we've had companies on board since the very beginning—and those corporate connections have the ability to translate the technologies we've developed into concrete solutions. To make a technology feasible for practical use, you not only have to understand the needs you're trying to address but also have to break the needs down into high-priority technologies by taking inventory from the exit side of the process. That's exactly what the Innovation Hub Center is trying to do.

—— How are you approaching the effort to develop human error prevention technology?

Itoh: Like I said before, accidents always have a primary factor and secondary factors. Accidents occur when given factors come together at the same time—and it's almost always a combination of weather and human error. If you can keep either one of those types of factors from coming into play, you can avoid a lot of accidents. In that sense, preventing human error is a huge part of the puzzle.

Operators work hard to minimize human error, but it's tough for them to eliminate those kinds of mistakes. Some companies put extra personnel on flights to check pilots' maneuvers for set periods of time, but that's essentially a spot-check measure—and an expensive one, at that. JAXA thinks that there might be more efficient ways of controlling human error, so our approach to human error prevention starts with figuring out which flight data parameters are most indicative of possible pilot error. Operators are providing us with actual flight data to analyze.

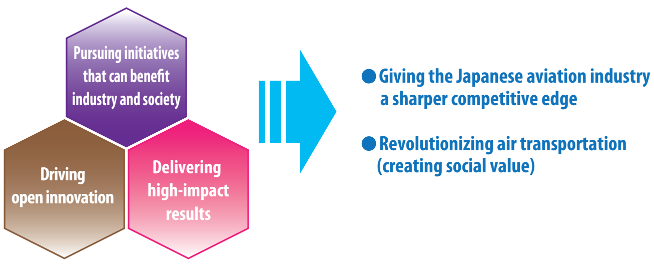
—— You're doing quite a bit of research on protection for weather disturbances and human error prevention. How are operators responding?

Itoh: I think they're really excited about what the technologies could do. Those expectations put a lot of pressure on us, too—we have to deliver the right technologies for ensuring proper safety.

—— What are some of the key features of the Innovation Hub Center?

Itoh: The Innovation Hub Center unites universities, research institutions, and companies in common goals. Our research on snow and ice sensors is a great example of how our different partners work together: the universities develop numerical models for basic research purposes, JAXA comes up with monitoring methods, conducts experiments, and manages the overall effort, and our corporate partners design and create the prototypes.

If we coordinate those individual activities and keep them moving in the same direction, we can do basic research and



Goals for the Next Generation Aeronautical Innovation Hub Center

	Current projects (outcomes expected)	Future project candidates (outcomes plus innovation expected)
Environment	•Ultra-high bypass ratio engine(aFJR) •Airframe noise reduction (FQUROH)	•Improved airframe efficiency (Eco-Wing) •Core engine/noise reduction (GreenEngine)
Safety	•Air traffic management system (DREAMS) •Turbulence-induced aircraft accident prevention (SafeAvio)	**•Protection technology for weather disturbances** **•Human error prevention technology**
Sky Frontier	•Sonic boom reduction for supersonic airplane (D-SEND) •Electric propulsion system (FEATHER)	•Silent supersonic transport technology
	Cross-field fundamental research activities	
Fundamental research	•Advanced Fundamental technology •Facility maintenance •Operations and servicing	•Applied fundamental technology

Major research themes at the Next Generation Aeronautical Innovation Hub Center

Creating a cooperative framework with a wide variety of stakeholders in diverse technological fields to share visions and promote mutually beneficial collaborative research

experiments at the same time. Right now, we're planning to conduct field demonstrations by the end of FY2016. Using actual runways for the tests would be too much of a challenge, so we're looking at doing the demonstrations on regular roads. When we start doing those road tests, I think airline operators will take notice and show a stronger interest in trying the technologies out on runways—and then we'll be able to reach the implementation stage even faster.

—— And that's how having a far-reaching, integrated framework for collaboration helps.

Itoh: JAXA has done a great deal of joint research with universities and companies, but most of the collaborations have either been with individual universities or individual companies—there weren't many opportunities to sit down and talk things out with everyone involved. At the Innovation Hub Center, we unite our partner research institutions, airline operators, manufacturers, and universities in a shared vision to forge a mutual, inter-connected collaborative environment. Having everyone share the vision of our effort to develop protection technology for weather disturbances, for example, might lead to even better ideas or new chances for cooperative relationships, creating an added dimension that wouldn't be possible under a one-on-one joint research arrangement.

—— What kinds of steps is the Innovation Hub Center taking to facilitate research and deliver beneficial results?

Itoh: To build a team of capable human resources, you need to have a flexible compensation system. A cross-appointment system is another big help, too, because it allows individual members to divide their time effectively: university professors can spend half of their time at their universities and the other half at JAXA, for example. The Innovation Hub Center has those structures in place. We've also taken steps on the intellectual property front. If a researcher on a temporary assignment from a company develops an invention at JAXA, the company receives preferential benefits. Those are two examples of how we're tailoring our personnel and intellectual property systems to make it as easy as possible for member institutions to get involved in the Innovation Hub Center.

—— Will JAXA be able to do successful research and development within that kind of new framework?

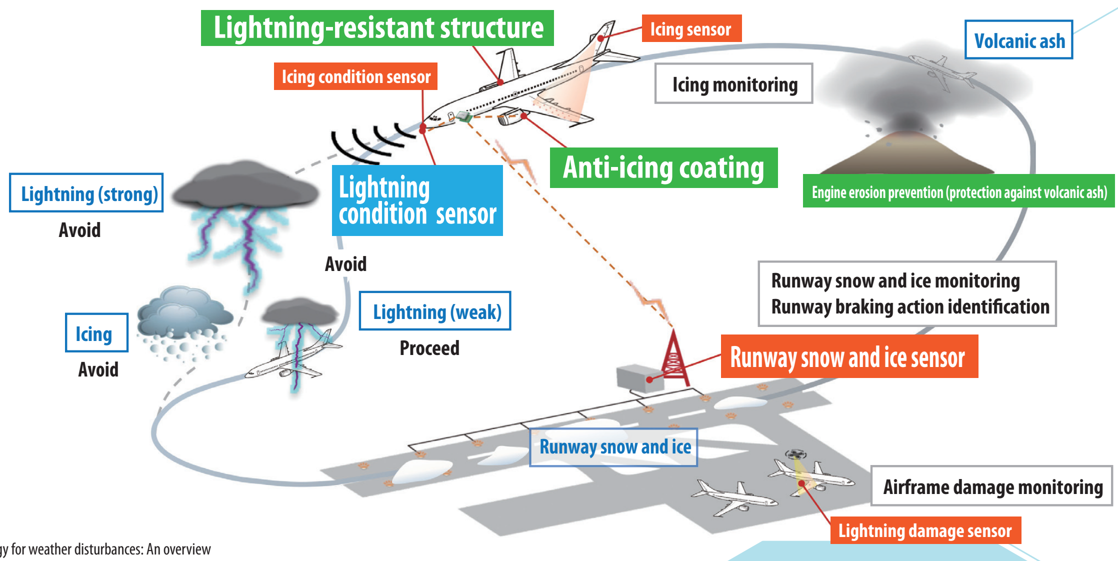
Itoh: Definitely. Our researchers are really open to everything. We got our management staff together into teams to iron out the frameworks, and we're always communicating closely with researchers in the field. I would never be able to change the way we go about our research by myself—it needs to be a group effort. We've already started taking those steps.

—— JAXA has a foundational research system and a wide variety of test facilities, including wind tunnels. Do you think research and development benefits from those types of assets?

Itoh: Of course. The Innovation Hub Center is based at the Chofu Aerospace Center, which boasts the largest wind tunnel assets in Japan, including low-speed wind tunnels, hypersonic wind tunnels, and virtually every other type of wind tunnel at our disposal. I think our infrastructure can handle just about any aeronautical research and development activity out there. Computer simulations are another of our strong suits thanks to the tremendous computational fluid dynamics (CFD) capabilities we've developed. The Next Generation Aeronautical Innovation Hub Center provides an outstanding environment for collaborative research and development.

—— What are your hopes for the new Next Generation Aeronautical Innovation Hub Center as it takes its first steps?

Itoh: I want to hear that our technologies have made a positive impact on industry and society. I think the Next Generation Aeronautical Innovation Hub Center is a kind of special "sandbox" for the Aeronautical Technology Directorate—we get to take so many different approaches to research and development. I just want to see one of our initiatives produce a real, beneficial outcome. It doesn't have to be a home run—small ball will do. As soon as someone recognizes that our innovations are working, we'll get into a good rhythm and start churning out more and more research and development. It's my responsibility to accelerate that process, and I'm excited about getting things going.

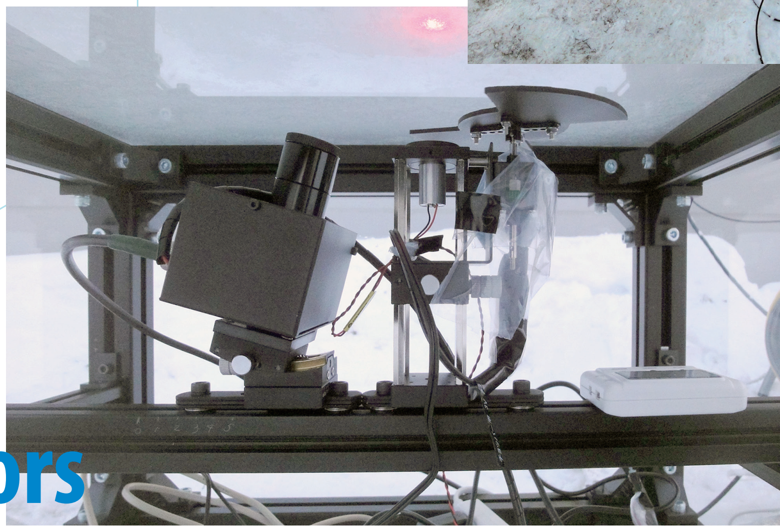


Protection technology for weather disturbances: An overview

A field experiment in naturally accumulated snow

One of the biggest headaches for airports in the winter is runway snow, which can cause overrun accidents during landings, cancellations, diversions (destination changes), and so on. JAXA's snow and ice monitoring sensors detect snowy conditions in real time, providing a technology that could make aircraft safer and operations more efficient in the future.

Snow and ice monitoring sensors



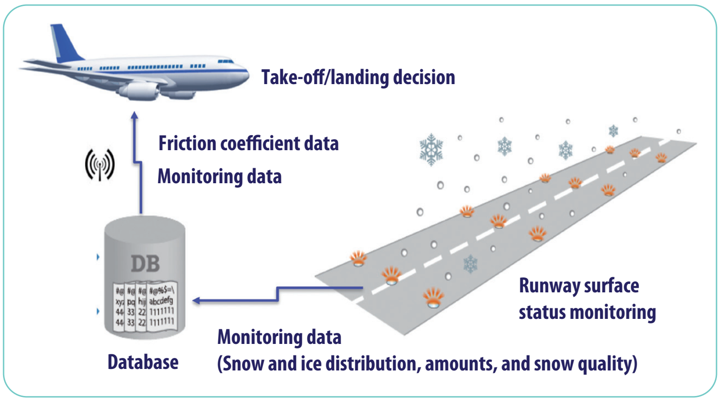
Researchers detected changes in the thickness and quality of the snow and ice on the surface based on the propagation and intensity of the light scattering off the snow.

Accumulated snow: A detriment to aircraft operating efficiency in Japan

The Next Generation Aeronautical Innovation Hub Center researches and develops technologies for safe aircraft operations. One of the Innovation Hub Center's current projects involves developing snow and ice monitoring sensors capable of measuring snow and ice conditions on runways.

Atsushi Kanda, an Associate Senior Researcher on the Innovation Hub Center's Aviation Safety Technology Research Team, says that "requests from airlines" were what got the project started. Of all the weather observation technologies that airlines need, snow and ice monitoring sensors represent one of the top priorities—and much of that pressing demand stems from the unique set of weather conditions that characterize Japanese winters.

When an aircraft attempts to land on a runway covered with accumulated snow, the reduced friction on the runway surface results in longer landing distances. Japanese snow is wetter than snow in most other countries, making runways even slipperier, and the numerous mountainous regions stretching across the Japanese landscape make it nearly impossible for airports in the country to have long runways—most are only around 2,000 to 3,000 meters long. In addition to causing overrun accidents and stuck aircraft, combinations of wet snow conditions and unique topographical conditions also prompt airlines to divert and cancel flights in hopes of preventing possible complications. Flights bound for New Chitose Airport in Hokkaido, for example, are particularly susceptible: the numbers show that every year, airlines have to divert dozens and cancel hundreds of flights heading for the airport—and those figures are for domestic flights alone. In order to keep cancellations, diversions, and overruns to a minimum and make aircraft operations as efficient as possible, operators need access to viable snow and ice monitoring sensors.



An overview of the runway snow and ice monitoring system

How monitoring sensors use light to detect snow and ice

JAXA's snow and ice monitoring sensor technology operates on a relatively simple principle. While illuminating snow or ice with a light source (a laser, etc.), the sensor measures the intensity and distribution of the scattered light to determine the thickness and quality of the target substance. Light snow accumulation lets light through easily and thus produces minimal scattered light, while heavy snow cover generates more scatter—which also varies according to the size of the snow grains. This new technology represents an important breakthrough, and JAXA has already applied for a patent on the technology. The world has never seen a technology that uses light to evaluate snow and ice conditions.

As it currently stands, airports measure the slipperiness of snow-covered runways by having special vehicles drive on the runway surface and then calculating the frictional resistance values of the vehicles' tires. The process is far from ideal, obviously, as airports need to close down during the measurement process for safety reasons, replace the test tires when they start to wear down, and make substantial financial investments just to purchase and operate the measurement vehicles. Although there are ultrasonic sensors for detecting the depth of snow on regular roads, these types of devices would never be feasible in an airport setting: they only measure depth, and airports would need to place ultrasonic generator equipment on actual runways.

JAXA's new technology provides a solution. Embedded into the runway at set intervals, JAXA's snow and ice sensors emit light through their glass upper surfaces to detect snow and ice on the surface and monitor the thickness of any accumulated snow on a constant basis.

The monitoring data is used to estimate the corresponding force of friction, which is then transmitted along with other data to the approaching aircraft. Ultimately, the technology thus aims to provide pilots with valuable information that can help them make decisions on whether or not to land.

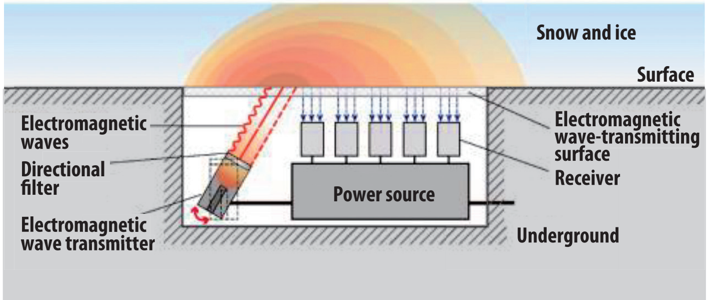
When JAXA's snow and ice monitoring sensors reach a feasible level, airports will be able to assess runway conditions in real time without having to shut down operations. The cost benefits will be significant, too: unlike approaches that rely on tire-runway contact to determine resistance values, JAXA's new technology performs non-contact measurements—and thus has very few components that will need replacement due to wear and tear. Once an airport installs the devices, the operational costs will be nominal.

Field experimentation paves the way for practical implementation in the near future

However, the new technology has some hurdles to clear before it can start making a difference in the real world. Kanda says that the sensors are still at the "laboratory experimentation level." The initiative to research and develop the snow and ice monitoring sensors is a far-reaching collaborative effort, with scientists from the Kitami Institute of Technology and Sentencia Corporation (an optical instrument manufacturer) joining JAXA researchers in the experimentation process. The project is also drawing on input from the Japanese Society of Snow and Ice and other academic organizations in non-aviation fields that JAXA has rarely made connections with.

The Kitami Institute of Technology has forged tight bonds with JAXA, having been a part of joint research projects ever since research and development on the snow and ice monitoring sensors began.

The process of verifying the snow and ice monitoring sensor technology requires snow and ice, of course, but snow is a natural phenomenon—and even the coldest places go through periods without snow on the ground. For experimentation purposes, JAXA thus uses artificial snow and snow collected from actual snowfalls. To suppress changes in the snow during the experimentation process, researchers work in a Kitami Institute of Technology laboratory that maintains cryogenic temperatures of -20°C. The tests are physically demanding: despite the subzero temperatures, the meticulous nature of the operations involved prevent the researchers from wearing thick gloves. The project is now at the stage where workers can use numerical analysis simulations to figure out how light scatters in snow, making it possible to identify promising snow conditions in advance.



How a light scattering intensity measurement sensor works

"For FY2015, we're focusing our research on improving performance by adjusting wavelengths and light intensity," Kanda says. "After we've shown that the snow and ice sensors can function well in an indoor (laboratory) setting, we'll head into FY2016 with a goal of embedding the devices in roads to show how the technology works in an outdoor environment that's more like the conditions that they'll actually operate in." The natural environment has a substantial impact on outdoor field experiments, so researchers are anticipating even more challenging work moving forward. The effort will likely hinge on a stronger, more thorough collaborative arrangement with universities and manufacturers.

In addition to dealing with experimentation environment issues, researchers will also have to address technical matters. For one thing, the only way to elucidate the correlation between snow quantity and scattered light intensity is through actual outdoor demonstration testing. Researchers will have to perform repeated outdoor demonstrations and start accumulating correlation data linking snow and ice thickness with scattered light conditions in order to obtain accurate readings.

"We can detect changes in snow thickness, but we haven't gotten to the point where we can pinpoint thickness down to the millimeter," Kanda explains. "Although it's a pretty big technical challenge to overcome, I think we can formulate a plan and use our experiments in FY2016 to find an answer."

Around FY2017, Kanda wants to embed the snow and ice monitoring sensors in actual runways and conduct demonstration experiments to calculate the effects of vibration on sensors when an aircraft lands and examine the effects of tire contact on the glass covering the sensors. The plan is to submit the demonstration data to the relevant ministries and agencies, obtain a license, and secure a route for the technology to start making a difference in real-world applications.

By making it possible to detect the amount of snow on runways, snow and ice monitoring sensors will enable airlines to determine safe distances for take-offs and landings by deriving forces of friction based on past snow accumulation data. Airports that install the technology, meanwhile, will be able to attract more users thanks to safer, more efficient take-off and landing procedures.

The snow and ice monitoring sensors currently in research and development are runway-embedded devices, but future research could open the doors for the detection of snow and ice on airframes, too. If that possibility materializes, sensors mounted on airport equipment and the tails of aircraft will be able to illuminate aircraft to measure icing conditions. Talks are already underway to discuss potential applications in road management, as well, as JAXA works out arrangements for joint research with the Public Works Research Institute (PWRI). Understanding the conditions of the snow that accumulates on road surfaces will allow organizations to implement snow removal measures and road closures at the optimal times. The technology could also find applications in fields like railway services, where snow and ice have an influence on safety and operations.

"I want to do the necessary demonstration experimentation and get our snow and ice monitoring sensors to a practically viable level as quickly as possible," says Kanda.

Atsushi Kanda
Associate Senior Researcher
Safety Technology Research Team
Next Generation Aeronautical Innovation Hub Center

An interview with Program Director of Aeronautical Technology Takeshi Ohnuki:

How JAXA's technologies benefit the Japanese aviation industry

Takeshi Ohnuki
Program Director of Aeronautical Technology

Research and development efforts at the JAXA Aeronautical Technology Directorate have been making significant contributions to the Japanese aviation industry. This article features a special interview with Program Director of Aeronautical Technology Takeshi Ohnuki. He explains how JAXA's technological advances have benefited—and will continue to benefit—Japanese aircraft manufacturers, with the introduction of some key R&D initiatives on technologies for engines, airframes, and supersonic transport.

In front of a model of the "Hisho" jet research aircraft

The multiplier effect of collaboration

—— How has JAXA worked with the Japanese aviation industry in the past?

JAXA's contributions to the Japanese aviation industry have come from a wide variety of research fields, ranging from composite materials and computational fluid dynamics (CFD) to engine technology. If you go back a little further to when the JAXA Aeronautical Technology Directorate was the National Aerospace Laboratory of Japan (NAL), you'll find that we've been carefully placing stepping-stones of pioneering technologies for manufacturers. NAL engineers used composite material technologies, for example, to build a tail for the Asuka*1 STOL experimental aircraft at 1/2 scale, and the developed composite structure successfully passed strength tests. Although composite materials were not used when building the actual Asuka aircraft in full-scale, the research showed the world that manufacturers could use composite materials for aircraft production.

Asuka also featured an FJR710 engine, which organizations from all across Japan teamed up to build in the early 1970s. When manufacturers abroad saw the FJR710 and got a definitive look at Japan's technological prowess, Japan earned a spot on the international joint development project for the V2500—the engine that powers several aircraft, including members of the Airbus fleet. The research that came out of the FJR710 development effort is now part of the aFJR project*2, underscoring its lasting impact.

We've been spearheading research and development in the CFD field ever since the NAL days. The initiatives weren't about us teaming up with companies in manufacturing and industry, though: JAXA (NAL) took the lead in securing the necessary technologies and then transferred the resources to the private sector. We also worked with industry members, the Ministry of Economy, Trade and Industry (then the Ministry of International Trade and Industry), and other organizations on an airframe to succeed the YS-11—Japan's first domestic passenger aircraft. That aircraft ended up never seeing the light of day, but it's just another example of how JAXA technologies have been at the center of efforts to make Japanese aircraft manufacturers more competitive in the global arena.

JAXA came about through a merger of three organizations*3 in 2003, which was also when we started a joint research project with Mitsubishi Heavy Industries, Ltd.—an initiative that laid a lot of the groundwork for the MRJ.

—— Are you involved in any other joint research projects?

When we started collaborating with Mitsubishi Heavy

*1 A short take-off and landing (STOL) experimental aircraft developed based on the C-1 transport aircraft; equipped with four FJR710 engines, the aircraft completed 97 flight tests from 1985 to 1989.
*2 The Advanced Fan Jet Research project, which aims to develop lighter, higher-efficiency fans and low-pressure turbines for use in jet engines; see FLIGHT PATH No. 1/2 for details.
*3 The Japan Aerospace Exploration Agency (JAXA) was established in 2003 via the merger of three organizations: the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA).

Industries, Ltd., we also got involved in joint research on small-sized engines with IHI Corporation. Since 2013, JAXA's been expanding its scope to cover research and development on "market-oriented" (exit-oriented) technologies—resources that have a direct impact on people's lives—instead of concentrating solely on cutting-edge technologies, science, and basic technologies. Our new focus on more practical technologies has brought us into discussions with a broader range of manufacturers, sparking more collaborative partnerships. The FQUROH*4, aFJR, and SafeAvio*5 projects are just a few of the joint research initiatives we're currently working on with members of the manufacturing community.

—— Going back to what you were talking about before, how do technologies like composite materials and CFD make their way into the industrial market?

For composite materials, JAXA has been carrying out joint research with material manufacturers to see if certain materials have the functionality to satisfy the given performance requirements. Manufacturers have then taken those technologies, developed them into feasible solutions, and brought them to market. Our work on CFD has followed the same process, essentially: we've teamed up with manufacturers in heavy industry to create component technologies, which industry has then brought up to a practical level. After JAXA gets things going with research initiatives, private-sector players take the baton and start pushing toward commercial viability.

JAXA technologies play pivotal roles in the MRJ

—— What was the joint research initiative with Mitsubishi Heavy Industries, Ltd. all about?

The first step began in the conceptual design phase: talking about what kind of aircraft the MRJ was going to be and how it'd be different from the competition. From 2002 to 2012, we collaborated with Mitsubishi Heavy Industries on research in aerodynamics, noise reduction technology, structural materials, flight test technology, and other areas. Doing studies with people from the actual aircraft development field was an eye-opening experience for us at JAXA.

Now that the joint research project is complete, we've signed an official partnership agreement with Mitsubishi Heavy Industries to provide support through joint research and development. If the MRJ ever has a problem that needs fixing, JAXA will contribute to helping the MRJ development team find a solution.

—— Could you tell us a bit more about what went into the collaboration?

For the aerodynamic side of things, we used CFD to optimize the airframe design. The noise reduction research we did for the MRJ collaboration has continued to evolve—it's a key piece of JAXA's ongoing FQUROH project, in fact. On the structural material side, we did joint research to find ways of ensuring that the airframe would be as safe as possible. One of the things we looked at was flutter*6, an extremely dangerous phenomenon that occurs when certain structural and aerodynamic conditions converge. To help combat flutter, we developed an analysis tool for estimating flutter tolerance, a tool for assessing the strength-related safety of the airframe during emergency landings, and more.

Composite materials are used for the tail of the MRJ. To give the MRJ team a solid foundation for incorporating composite materials, we helped formulate ideas on how to use methods like strength testing on actual-size vertical tail wings, coupon testing*7, and panel testing*8. We also assisted in demonstrating the safety of the tail.

Flight tests help aircraft to demonstrate its airworthiness and are crucial to obtaining type certification. When the MRJ made its maiden flight on November 11, 2015, JAXA's jet research aircraft "Hisho" took to the skies to check the weather conditions in the test airspace before the MRJ took off—since the MRJ hadn't obtained its type certification yet, Hisho made sure that the weather conditions were fit for flight. Hisho has continued to assess weather conditions for the ongoing battery of MRJ flight tests; I've heard that they've even

The Asuka STOL experimental aircraft

*4 The Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations project, which aims to establish technologies for reducing airframe noise and measuring noise sources on aircraft; see FLIGHT PATH No. 1/2 for details.
*5 The R&D of onboard safety avionics technology to prevent turbulence-induced aircraft accidents project, which aims to establish technologies for detecting clear-air turbulence in front of an aircraft in flight and suppressing the lurching of the aircraft; see FLIGHT PATH No. 3/4 for details.
*6 A phenomenon caused by a combination of inertia, elasticity, and aerodynamic force that result from the vibration of wings or other structural components; see FLIGHT PATH No. 7/8 for details.
*7 A type of plate-based impact testing that applies an impact to an unprocessed material to measure the energy absorption rate and other conditions
*8 A type of testing that applies an impact to a processed part or a subcomponent with multiple parts to assess the destruction state and other conditions

canceled MRJ tests based on Hisho's weather readings. Moving forward, we're planning to focus our research on investigative elements like measuring main wing deformation and locating noise sources. We're also talking about other ways we might be able to get involved.

Joint research efforts drive two separate projects

—— Has noise reduction always been a big part of JAXA's joint research efforts?

The International Civil Aviation Organization (ICAO), which defines international aviation standards, was clearly moving toward stricter noise regulations, so we knew that we'd have to keep the overall noise to levels that would satisfy the rigorous standards on the horizon. Given that minimizing noise would bring down airport landing fees and reduce the sizes of noise control areas around airports, we could see that noise reduction technology would be a big potential asset for airlines and the country as a whole, too. That was an important impetus for our research.

—— And that's what led to the FQUROH project. How is that initiative going?

Our plan for FY2016 is to conduct demonstration tests with Hisho, so we're busy designing on-board noise reduction devices to put on the flaps and landing gear for testing. Eventually, we want to do demonstration experimentation with noise reduction devices on the MRJ, as well. If we can demonstrate the effectiveness of the technology and apply it to the MRJ, that functionality alone will be a great selling point to work into the airframe marketing approach—not just for the MRJ, but for lots of other aircraft, too.

Despite all the research on noise reduction technology going on around the world, no one has done a successful flight demonstration of the technology. If we can use Hisho to show how the technology functions, we'll be able to give Japan a leg up on the global competition.

—— Are you going to be doing demonstration tests for the aFJR project, too?

The aFJR project may have finished its technological development phase, but we still need to test the component technologies on the ground before we can put any of the new technologies on an actual jet engine. Ideally, we'd procure a test engine, install the aFJR technologies, and perform demonstrations, but the project period doesn't extend that far into the future. The aFJR project team is currently working on joint research with engine manufacturers, which will acquire the results via technology transfer once the project is complete—and have new assets to use strategically in international joint development and other settings.

—— Are you working on projects in the composite material field, too?

We don't have any big projects in the composite material field, unfortunately, but we're looking to using composite materials for Eco-Wing—our research into technologies for developing efficient main wings. We still have a lot of technical wrinkles to iron out, so Eco-Wing will have to move through the component technology research phase before it becomes a full-fledged project.

The FJR710 jet engine, developed as Japan's first-ever turbo fan engine

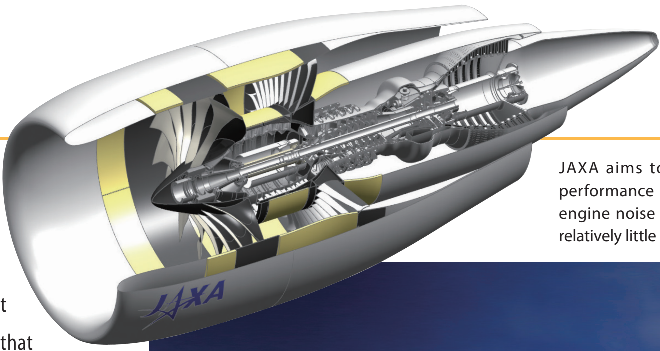
Japan's position in the aviation industry of tomorrow

—— International competition in the aviation industry is obviously going to be heated. How will Japan fit into that competitive context?

With the success of the MRJ flight, Japan has taken a big step forward as an integrator. Boosting Japan's participation rates in international joint development is one priority, of course, but the real key for the country is developing the capabilities to put aircraft in flight as an integrator. I think we need to keep our focus on creating the next domestically produced passenger aircraft—always looking ahead—through an "all-Japan" framework. To do that, we'll need to figure out how to give Japanese aircraft some separation from the competition. Operating from a far-sighted perspective, JAXA has to keep researching and developing distinctive, globally competitive technologies.

—— The supersonic transport development project is another future-focused initiative.

We started researching supersonic transport (SST) at NAL in 1997, back before the merger that created JAXA. Supersonic flight makes travel times much shorter, giving passengers an immensely convenient mode of



JAXA aims to provide an additional boost to environmental performance by developing and demonstrating core engines and engine noise reduction technologies, two areas where Japan has relatively little leadership experience.

transportation. When we first launched our studies, the Concorde supersonic jet was still in operation—but it was clear that there were plenty of problems to address. We decided to tackle the Concorde's environmental issues and cost-related problems from a technical angle, one by one.

Our first advance came in 2005, when our flight experimentation on the NEXST-1 (a small supersonic aircraft) in Australia established technology that brought about drastic air drag reductions. In 2015, we went to Sweden and conducted second-phase tests for our simplified evaluation of non-symmetrically distributed sonic booms (D-SEND#2)—and successfully demonstrated our sonic boom reduction technology. Thanks to these two breakthroughs, we've got a good enough idea to clear the technical hurdles in the SST field. In FY2016 and onward, we would like to start designing the concept for the overall system. One amazing technology isn't enough to put an aircraft in the sky—it's all about putting everything together into an integrated whole. After we're finished with the conceptual design, we're hoping to organize a new project to fly an actual experimental SST aircraft.

—— The testing for NEXST-1 and D-SEND went on for extended periods of time.

We learned a lot from those tests, I think. Both of the regimens involved creating and flying actual aircraft—a valuable experience in and of itself, of course. But each of the missteps we experienced on the NEXST-1 project and the D-SEND project proved to be extremely productive and informative. When you get down to building an actual aircraft and putting it in the air, you run into problems you'd never even thought about. I'm glad that our younger researchers got the chance to understand just how hard it is to create an entire system and fly it. Avoiding mistakes altogether would obviously be ideal, but the process of figuring out what went wrong, formulating solutions, and giving the test another shot is the kind of rewarding experience that doesn't come along all too often.

—— What kind of impact would SST have on the Japanese aviation industry?

A conceptualization of JAXA's small quiet supersonic passenger aircraft

SST development would be too expensive for a single country to pull off alone, so I think it'll be an international joint development initiative. If it does turn out to be a multinational effort and JAXA has a substantial collection of the data it's currently collecting, Japan would be able to make an immediate impact and play an influential role in the international effort. SST is a future market, one that major aircraft manufacturers have yet to make any entry into. That's why getting involved from the outset will be crucial for Japan.

—— Is SST a big target for JAXA?

Definitely. JAXA's mission is to provide Japanese manufacturers with technologies that they can use to gain a competitive edge in the international arena. It's our responsibility, I believe, to research and develop cutting-edge, future-oriented technologies like SST.

—— How would you like to support equipment manufacturers, airline operators, and other players in the industry?

We've been making collaborative efforts with manufacturers to develop technologies that improve operational safety and efficiency. With the SafeAvio project, for example, we are developing onboard safety avionics technologies that use Doppler LIDAR to detect clear air turbulence in front of aircraft and make use of the turbulence information to suppress the sudden motion of aircraft. Research into protection technologies against weather disturbances such as snow, ice, lightning and volcanic ash is also underway. With the "Next Generation Aeronautical Innovation Hub Center," which was launched in April 2015, we promote open research framework with all-Japan approach. This new R&D framework will enable us to work with diverse partners —airlines, universities, and manufacturers (including those from outside aviation industry and with whom we've never worked)—to create new technologies. With all these efforts, we will not only support Japanese aviation industry to enhance its competitive edge in the global market but also provide innovative solutions to global challenges such as environmental issues.

Supersonic transport research: Current trends and future prospects

It may have been burning low for a while, but the spark of supersonic transport research is back as demands for supersonic business jets grow. This article looks at JAXA's R&D initiatives to date and its vision for the next step to enable the next-generation of supersonic passenger aircraft.

Yoshikazu Makino
Leader of the Silent Supersonic Aircraft Systems Research
Aircraft Systems Research Team
Next Generation Aeronautical Innovation Hub Center

Supersonic transport research: Some background

In 1947, a manned, American-made jet called the "X-1" became the first aircraft to break the sound barrier and open up the doors to supersonic flight. With experts predicting that supersonic aircraft would eventually be global standard in the 21st century, the United States, Russia, and a host of other countries went head to head in a rush to develop supersonic transport (SST) aircraft—a frantic race that the United Kingdom and France eventually won in 1969, when their co-developed Concorde made its maiden flight. The Concorde proved to have its share of flaws, however: in addition to demonstrating bad mileage that made operations uneconomical, the aircraft also had a negative impact on the environment such as NOx and CO_2 emissions and sonic boom noise generated by supersonic flight-originated shockwaves. When authorities banned the Concorde from flying over land at speeds exceeding Mach 1 due to the unhealthy effects that hearing a sonic boom could have on people, the only routes that the Concorde could fly were a limited selection of oceanic airways. With the demise of the Concorde went much of the excitement surrounding SST research and development.

The United States canceled its SST research and development program in 1971, but the launch of the High-Speed Research (HSR) project in 1986 re-ignited discussions about the possibilities of creating a feasible form of SST. The flame eventually dimmed again, however: the HSR project came to a close in FY1999, as aircraft manufacturers pulled out of the effort before it could meet its goal of creating a large-scale aircraft with a capacity of around 300 passengers. Still, the US National Aeronautics and Space Administration (NASA) and Defense Advanced Research Projects Agency (DARPA) pressed on with their SST research. In 2003, the two organizations used a Northrop F-5E Tiger II fighter with a modified front tip to create a Shaped Sonic Boom Demonstration (SSBD) demonstrator and conduct demonstration experiments on low sonic boom technologies.

JAXA's experience in the field

The SSBD demonstration experiments showed that it was possible to reduce the sonic booms that supersonic

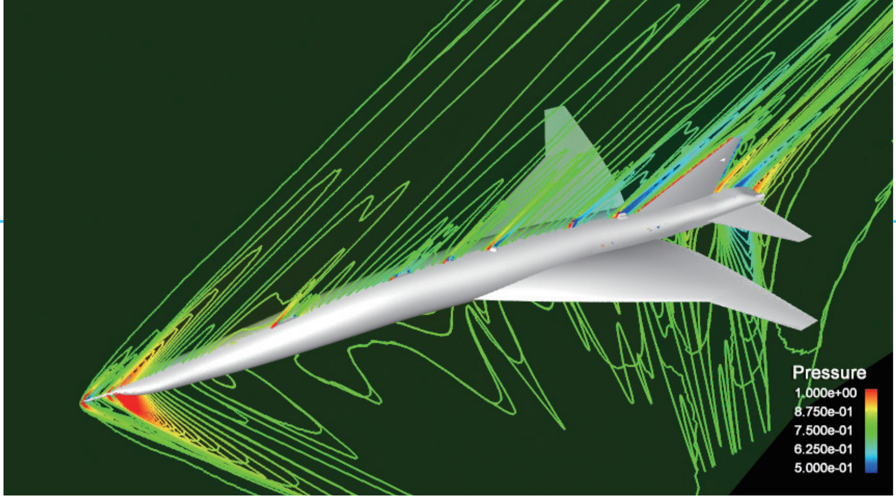
The scaled supersonic experimental airplane NEXST-1 on display at the Chofu Aerospace Center Exhibit Hall; it was used for actual fight test

●Area-ruled fuselage
Volume-dependent wave drag caused by shockwaves is reduced by narrowing the fuselage at the wing section

●Cranked arrow wing
A wing planform with a large sweepback angle is designed to reduce both the wave drag and lift-induced drag

●Warped wing
The airfoil camber and spanwise twist of the wing are optimized to minimize drag

●Natural laminar flow wing
Makes the airflow passing over the wing surface as smooth as possible to reduce friction drag



CFD analysis of D-SEND

aircraft produced in flight. Eager to capitalize on these new findings, a handful of American startups set out to develop a supersonic business jet—one type of SST. In Europe, meanwhile, Dassault (France) and other manufacturers launched the HISAC (High-Speed Aircraft) supersonic research program to research and develop a supersonic business jet that would minimize sonic booms, reduce noise around airports, and achieve longer-range flight.

JAXA began its "Next-Generation Supersonic Transport Technology (NEXST)" program in 1997 to reduce aerodynamic drag in supersonic flight. Aircraft burn less fuel when they have less aerodynamic drag. In 2005, JAXA successfully completed the flight test at the Woomera Test Range in Australia, demonstrating the validity of JAXA's drag reduction concept by flying a developed "NEXST-1" vehicle, a scaled experimental aircraft, designed to reduce skin friction drag and other forms of aerodynamic drag. In 2015, JAXA successfully conducted the D-SEND#2 flight test at the Esrange Space Center in Sweden. The flight test proved the validity of JAXA's low sonic boom design concepts, demonstrating its effectiveness in tailoring both the front and aft shockwaves.

If SST were to take to the skies, the bans on overland supersonic flight in place around the world would place severe constraints on SST's reach in the market. To get regulators to change those rules, researchers and developers will have to find a way to bring SST-induced sonic booms down to a level that has a negligible effect on humans. Initiatives on that front are already underway at the SuperSonic Task Group of the International Civil Aviation Organization (ICAO), which is busy formulating sonic boom standards. Part of the effort since around 2005, JAXA has impressed the international research community of the SSTG with reports on the results of the D-SEND#2 project.

Noise issues are just some of the items on the ICAO agenda. SST aircraft fly at higher altitudes than normal passenger jets so that they can achieve high lift-to-drag ratios, operate more efficiently, and minimize air-induced frictional heating. ICAO is thus looking into the climatic effects of NOx emissions at the high altitudes where SST aircraft cruise.

How JAXA envisions the SST research and development of tomorrow

So far, JAXA has established drag reduction technologies for improving fuel consumption through the NEXST-1 flight demonstration and the sonic boom reduction technologies through the D-SEND#2 project. What's next? That would be to develop system integration technologies (integrated design technologies), which serve to fuse various individual technologies into a single airframe/propulsion system.

The NEXST-1 and D-SEND#2 projects showed everyone involved—JAXA and its research partners in the manufacturing world alike—the importance of flying actual aircraft for demonstration purposes. Although getting to the flight demonstration phase is obviously never an easy task, actual flights provide researchers with a vital asset that can play a pivotal role in the process of ironing out international standards. "As we refine the low drag technologies, low sonic boom technologies, and other component technologies we've developed, we're looking forward to trying the results out in real-world flight demonstrations," says Yoshikazu Makino, leader of the Silent Supersonic Aircraft Systems Research.

Why are integrated design technologies necessary?

Researchers have some hurdles to clear before they can establish viable integration technologies. One obstacle is the noise that aircraft produce during takeoff and landing. Supersonic aircraft excel at high-speed flight, naturally, but run into difficulties at the low speeds that takeoff and landing procedures require. The Concorde used afterburners*1 (with special permission) to reach the necessary speeds at takeoff, creating much more noise than a subsonic aircraft would ever make leaving the runway.

Minimizing takeoff noise generally involves making the fan at the front of the engine larger to increase the bypass ratio,*2 but a low-bypass ratio engine works more efficiently when cruising at supersonic speed. Given that a single engine is either high-bypass or low-bypass (not both), the process of making a supersonic aircraft quieter hinges either on varying the airflow duct during takeoff and cruising procedures to regulate airflow volume levels or on tweaking the configuration of the nozzle at the aft of the engine to reduce noise levels without altering the bypass ratio. Instead of trying to meet these conflicting component requirements with a single component technology, the key to SST development is to find solutions by looking at the entire aircraft as a whole—which is exactly what integrated design technology is about.

JAXA's role in SST development

JAXA will need to tackle research and development projects that would be hard for private-sector companies to do alone—the demonstration experiments for NEXST-1 and D-SEND#2 are two good examples of what that involves. The difficult part, however, is how to use the outcomes of the research and development projects: the drawn-out process of transferring new technologies to companies would make it hard for Japan to keep up with the rest of the world. "For our future research projects," Makino says, "we want to build a stronger structure for collaborating with the private sector. That'll be a vital piece to have in place when international joint-development projects in the SST arena start to take shape."

Provided that it has unique, distinctive technologies, Japan can be an influential force in future cross-border SST development. JAXA will continue working to establish powerful SST technologies, leading the way for Japanese manufacturers in the aviation industry.

*1 The name of a technique and a piece of equipment that injects fuel into jet engine exhaust to reburn the fuel and thus produce significant additional thrust; primarily used for military aircraft
*2 The ratio of the airflow passing through the fan to the airflow passing through the core engine; a higher bypass ratio helps limit noise levels but also reduces the aircraft's maximum speed.

Aeronautics in depth

This profile looks at how JAXA's "biaxial fatigue testing machine" measures the characteristics of different materials.

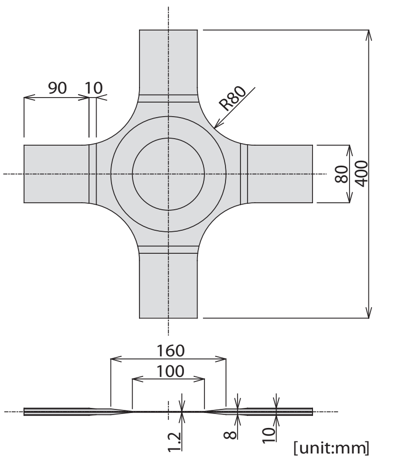


Figure 2 A sample test piece; the standard test piece is 400 mm x 400 mm in size and has a measurement area about 1 to 2 mm thick.

Biaxial fatigue testing machines: Principles and applications

The most common way to determine the fatigue, strength, and other properties of a given material is with a uniaxial fatigue testing machine, which holds a strip-shaped test piece in place on both sides and applies a load to the material in a single direction. However, the loads that the parts and components of an actual aircraft experience often come from two or even three directions at the same time. The properties of anisotropic composite materials also vary according to the direction of the load acting on them. In order to understand the properties of composite materials, researchers thus need more data and information than uniaxial fatigue testing machines can offer.

Whereas uniaxial fatigue testing machines apply load in a single direction, biaxial fatigue testing machines can apply load to a material in two perpendicular directions (see Figure 1). Test pieces for use with biaxial devices are cruciform, as subjecting the piece to loads at perpendicular angles creates the need for a total of four actuators in fixed locations (see Figure 2).

With a uniaxial fatigue testing machine, researchers can only test materials under uniaxial stress. A biaxial fatigue testing machine, however, enables researchers to evaluate material characteristics under biaxial stress conditions—a major asset in many cases. The problem is that the cruciform test pieces that biaxial fatigue testing machines require are hard to fabricate: they have to be designed using the finite element method* and other techniques to suit specific test purposes (see Figure 3).

When using a biaxial fatigue testing machine, researchers place the test piece inside the area bounded by the four actuators and use hydraulic grips to fix the piece in place. The actuators then apply tensile or compressive load to the test piece and measure the resulting strain, giving the researchers data they can use to evaluate the material's strength and fatigue characteristics. Biaxial testing machines are versatile, too: users can control each actuator independently and configure the devices to apply tensile load in two directions, compressive load from two directions, or even tensile load in one direction and compressive load in the other. The devices also make it possible to conduct repeated tensile and compressive load tests in an alternating pattern (see Table 1).

Determining how heating and cooling produce changes in characteristics

Many aircraft and spacecraft components are made with materials that need to withstand high temperatures, such as the materials inside engines, and materials capable of functioning under cryogenic conditions, like the materials that form liquid hydrogen tanks. JAXA's biaxial fatigue testing machine enables measurements of metal fatigue, plasticity points, and many other attributes, but its biggest benefit is its ability to replicate actual usage conditions by heating or cooling the target test pieces.

The device generates heat with a laser heating mechanism, which emits a laser via a laser oscillator. As it bounces off two variable-angle mirrors, the laser beam can heat a rectangular area of the test piece to temperatures of over 2,000°C.

The cooling component is one of the testing machine's most distinctive features. Despite the need for biaxial fatigue testing in low-temperature environments, the considerable technical challenges of trying to test cruciform pieces at cryogenic temperatures—especially the issue of vacuum insulation—have made it hard for organizations to meet that demand. JAXA rose to the challenge, however, and successfully completed a cryogenic refrigerator-based cryogenic chamber by employing a rather unique approach to sealing the test environment: placing the sealing rubber directly on the test piece. With the new cryogenic chamber, researchers can now conduct load tests on pieces cooled to temperatures as low as 20 K. When testing composite materials under cryogenic conditions, meanwhile, researchers also use ultrasonic test equipment to check for damage and multipoint strain and incorporate temperature measurement systems to evaluate the distributions of strain and temperature. Now that JAXA has the ability to test materials in low-temperature environments, researchers are planning to start acquiring the requisite data for eventually replacing liquid hydrogen tanks and other metal parts exposed to low-temperature conditions with parts made of composite materials. JAXA also has its sights set on developing a cryogenic gas leak measurement system that would prove valuable in the event that propellant starts leaking out of a component like a liquid hydrogen tank.

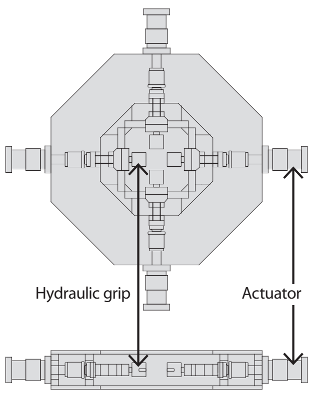


Figure 1 The structure of a biaxial fatigue testing machine

Table 1 Biaxial fatigue testing machine specifications

Maximum load	±245 kN
Maximum displacement	±50 mm
Frequency range	0–10 Hz
Control methods	Load displacement Electrical/hydraulic servo-type with arithmetic feedback control
Vibration waveforms	Sinusoidal, triangular, square, or any external input-based arbitrary waveform
Year completed	1987

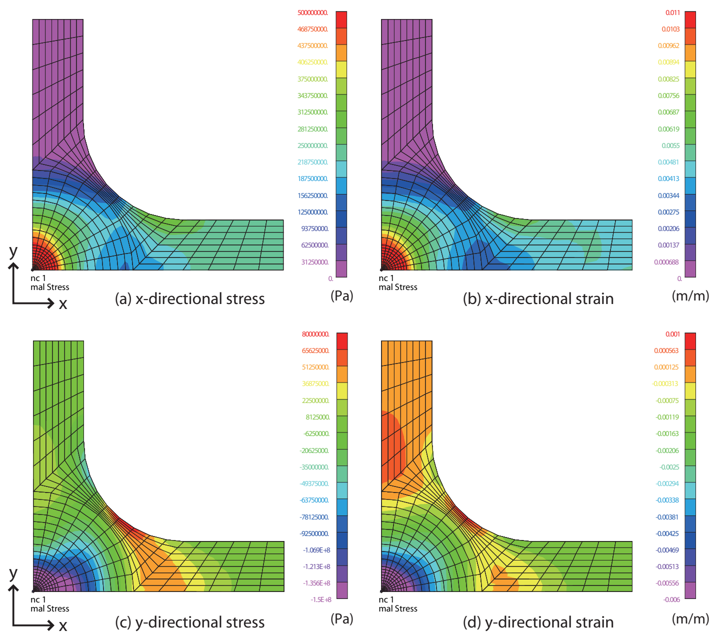


Figure 3 The stress (L) and strain (R) distributions for a cruciform test piece under a uniaxial load; the visualizations show that a load coming in one direction produces stress and strain in other directions.

* An analysis method that involves subdividing a target domain into small elements and analyzing each element to approximate values for the entire domain

Aeronautics in depth

Acoustic analysis (non-linear acoustic propagation and acoustic transmission/vibration)

This edition profiles numerical analysis technologies for evaluating acoustic properties.

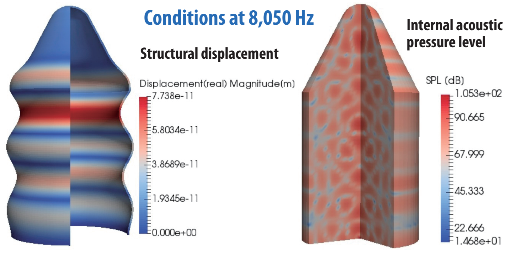


Figure 4: A WBM-based prediction of the acoustic environment in a rocket fairing model

Non-linear acoustic propagation and acoustic transmission/vibration

Sound, an air vibration (pressure fluctuation) that propagates as a wave (sound wave), comes in many forms: there are pleasant sounds and abrasive noises, for example, and even sounds capable of producing visible effects like vibrations and physical damage. Aircraft—especially in flight—can cause noise problems, creating the need for technologies that allow researchers to analyze the origins, propagation, transmission, vibration, and other characteristics of sound.

Despite the plethora of existing research on the sources and linear propagation of sound, the methods that scholars have developed for predicting the non-linear propagation, transmission, and vibration of sound are far from perfect. Sound usually decreases in amplitude as it propagates, but the shapes of the corresponding sine waves normally remain intact. In cases involving extremely high-volume sound, however, the shapes of the corresponding sine waves break down and transform into "sawtooth" configurations with sharp upward spikes (see Figure 1)—a phenomenon called "non-linear acoustic propagation." The roaring sound of a rocket launch and the sonic boom that occurs when an aircraft exceeds the speed of sound are two of examples of non-linear acoustic propagation. Acoustic transmission, meanwhile, refers to the phenomenon of sound passing through a given physical body—sounds that are audible through windows and walls, for instance (see Figure 2). During a rocket launch, the roar of the liftoff can penetrate through the fairing and initiate an acoustic vibration powerful enough to shake the artificial satellite inside—and, in the worst-case scenario, even damage the satellite. Tools for analyzing non-linear acoustic propagation, transmission, and vibration are thus some of the most important technologies in the aerospace field.

Analyzing non-linear acoustic propagation under atmospheric effects

The Thomas waveform parameter method (the "Thomas method") has been a leading method of analyzing sonic booms for several decades. Accounting for waveform distortion under the principles of geometrical acoustics[*1] and isentropic wave theory, the Thomas method uses information from cruising aircraft to predict the conditions of the resulting non-linear sound waves on the ground or in other locations considerable distances from the corresponding aircraft. As the method treats shockwaves as discontinuous planes, however, it leaves users without any way of determining the rise time of an existent waveform. Rise time, which varies according to the atmosphere that the waveform propagates through, has an enormous impact on how humans hear the corresponding sound, making it an integral variable in predicting sonic booms. JAXA's sonic boom research has used formulas like the extended Burgers equation, which takes the effects of atmospheric changes, thermal viscosity, and relaxation into consideration, and the HOWARD method, which also factors in the impact of atmospheric disturbances, to create an analysis program (see Figure 3) capable of predicting waveform rise times with high degrees of precision.

The sonic boom measurement data that the D-SEND#2[*2] team collected in 2015 exhibited a slightly different waveform from what the researchers were anticipating[*3], but the results concurred with the atmospheric disturbance-sensitive predictions almost perfectly—indicating that the waveform would not have been possible without the D-SEND#2 low sonic boom technology.

Using transmission and vibration analyses to make artificial satellite development more economical

To investigate the effects of acoustic vibration on an artificial satellite, researchers usually subject the satellite to direct sound waves in a "reverberation chamber." The problem with the reverberation chamber method, however, is that it neglects the effects of the fairing structure covering the satellite during the launch procedure. Without that protective feature figuring into the tests, the method—designed to err on the side of caution—exposes the satellite to excessive amounts of noise. When developers create an actual artificial satellite based on reverberation chamber tests, then, the end product turns out stronger than necessary—and it ends up costing more to minimize vibrations. Efforts to suppress the amount of transmitted sound running through the satellite can be problematic, too: if developers install additional sound-limiting equipment on the fairing or take steps to enhance the unit's overall rigidity, the fairing gets heavier.

Researchers have used several methods to analyze transmission and vibration: the statistical energy analysis (SEA)[*4] approach has provided a statistical perspective on high-frequency waves, while the finite element method (FEM)[*5] and boundary element method (BEM)[*6], deterministic methods, have been common tools for examining low-frequency waves. The weakness of these three methods, however, lies between the two ends of the frequency spectrum: they struggle to generate high-accuracy analyses of intermediate-frequency waves. JAXA thus built an analysis program applying the wave based method (WBM), which covers the intermediate-frequency range, to produce precise assessments of transmission and vibration effects in the fairing (see Figure 4). Supplementing the WBM with the FEM also enables researchers to examine how complex satellite configurations and noise-absorbing materials impact vibration, thereby making it possible to model conditions more realistically. If researchers could make accurate analyses of transmission and vibration properties through numerical calculations, they would be able to optimize the placement of noise-absorbing materials inside fairing structures and—by reducing the amount of sound in the fairing—make the artificial satellite development process less cost-intensive.

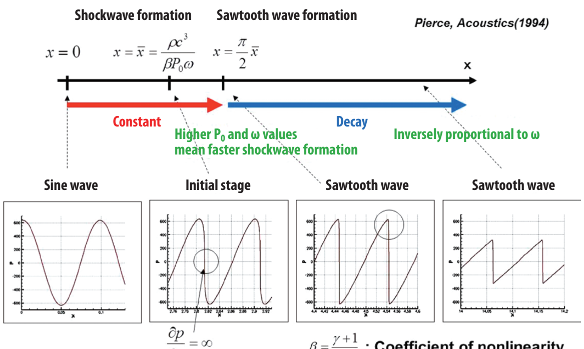


Figure 1: Sound wave deformation

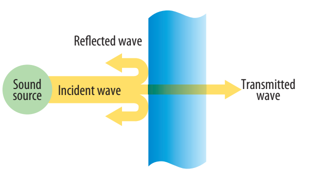


Figure 2: Acoustic transmission

$$\frac{\partial p}{\partial x} = \frac{\partial p^2}{2\,{}_0c_0^3\,\partial t'} - \frac{1}{2A}\frac{\partial A}{\partial x}p + \frac{1}{2\,{}_0c_0}\frac{\partial\left({}_0c_0\right)}{\partial x}p + l_{cl}\left(t'\right)p + l_{rel}\left(t'\right)p$$

Non-linear effect | Geometrical decay | Atmospheric change | Thermal viscosity | Relaxation

Figure 3: The extended Burgers equation, which factors in atmospheric effects

*1: A branch of acoustics that studies the propagation of sound energy in geometrical terms; although geometrical acoustics methods make it possible to visualize the path of a sound as it reflects off a wall surface, they do not take the wave characteristics of sound into account.

*2: Second-phase testing for JAXA's "Drop test for the Simplified Evaluation of Non-symmetrically Distributed sonic boom"; see FLIGHT PATH No. 9/10 for details.

*3: See page FLIGHT PATH No.9/10 for details.

*4: An analysis method that calculates the average vibrational energy in given spaces and frequency intervals in statistical terms

*5: A numerical analysis method that finds solutions by subdividing the space of an analysis target into small subdomains; although the FEM also works with complex configurations higher frequencies require smaller subdivisions.

*6: A numerical analysis method that finds solutions by subdividing the boundaries of analysis targets into small subdomains; the BEM is generally ideal for analyses of open domains, while the FEM is more effective in analyzing closed domains.

FLIGHT PATH Topics

Noise source localization tests on the "Hisho" jet research aircraft at Noto Airport

From September 28 to October 3, 2015, JAXA conducted noise source localization tests by having the "Hisho" jet research aircraft fly over a microphone array installed on the ground at Noto Airport as part of the FQUROH project.* In preparation for the project's scheduled flight demonstrations, the noise source localization tests aimed to evaluate the repeatability of analyzed noise source data, improve the accuracy of data analysis, and evaluate the improvement of measurement system hardware for resistance to severe climate conditions.

Although the tests were limited for the first three days due to a developed low-pressure system over the area, researchers still managed to conduct more than the 60 planned noise source localization measurements. The severe climate conditions also gave JAXA an opportunity to assess procedures and constraints for tests under unexpected weather changes.

The FQUROH project is developing airframe noise reduction technologies to reduce aerodynamic noise emanating from wing flaps and landing gear. Drawing on the results of the recent tests at Noto Airport, JAXA plans to perform preliminary flight demonstration tests in 2016 using "Hisho." The main objective of the flight demonstration is to establish all the testing methods and procedures to ensure verification of the applied noise reduction technologies. It will then be followed by the full-scale technical demonstration of developed noise reduction technologies in 2017.

* The Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations project; see FLIGHT PATH No. 1/2 for details.

"Hisho" makes a low-altitude pass over the measurement points (indicated by a red arrow) at Noto Airport

"Hisho" sets the stage for the MRJ's maiden flight

On November 11, 2015, Mitsubishi Aircraft Corporation and Mitsubishi Heavy Industries, Ltd. conducted the maiden flight of the first flight test aircraft for the Mitsubishi Regional Jet (MRJ) at the Nagoya Airfield. Aiding in the effort to make the maiden flight a success, JAXA's jet research aircraft "Hisho" performed a preliminary flight to observe the wind, cloud, and other meteorological conditions along the MRJ's scheduled flight route and airspace .

The MRJ (L) and the "Hisho" jet research aircraft (R) prepare for take-off at the Nagoya Airfield

Large spin tester goes into operation

JAXA installed a "large spin tester" for performing strength testing on rotational element parts and launched test operations in December 2015.

The spin tester is a useful tool in research and development on using new low-pressure turbine blade materials to reduce weight, which represents one focus of the aFJR (Advanced Fan Jet Research) project.* With a spin tester, researchers can assess fast-rotating turbine blade rotors via blade vibration tests (which determine blade vibration properties by applying vibration through external force), rotational stability tests of prototype rotating parts, burst tests, fatigue life tests, and more.

JAXA's new large spin tester can perform rotation tests on rotors measuring up to 1,600 mm in size and 400 kg in weight at up to 42,000 rotations per minute. The rotational speed is variable; for example, the spinter simulates rotational speed under the full range of actual flight conditions—from takeoff to cruising and landing.

The spin tester that JAXA used in the past was a small-sized device. With its new large spin tester, the organization will be able to test larger parts that more closely approximate the sizes of actual components.

* See FLIGHT PATH 1/2 for details.

The large spin tester prior to an evaluation; the preparation process involves taking the lid (L) off the cylindrical vacuum chamber (R) and mounting the rotor (circled in red).

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JAXA evaluates D-NET2* in a DMAT drill

On January 30, 2016, JAXA's D-NET2 research and development team participated in the 2015 Japan DMAT Kanto Block Disaster Drill, which was jointly organized by the Ministry of Health, Labour and Welfare's DMAT (Disaster Medical Assistance Team) Head Office , the Tokyo Metropolitan Government, and other participants.

Bad weather prevented JAXA from carrying out some of the flight experiments originally scheduled for the day, but the system's overall functionality was verified successfully. In particular, D-NET2 terminals were used at the Tachikawa Substitute Facility of the Government Headquarters for Disaster Countermeasures and two other facilities to determine whether the D-NET2 information integration system—which combines aircraft information, observation data from the "DAICHI-2" (ALOS-2), DMAT position information, and more—was an effective tool for disaster relief activities.

JAXA will continue the research and development of D-NET2 to help immediate post-disaster operations and offer valuable resources to rescue workers by deepening the connections between the aviation field and the space sector and aiming toward safer and more efficient disaster relief operations.

* D-NET2 (Integrated aircraft operation system for disaster Relief) ; see FLIGHT PATH No. 7/8 for details.

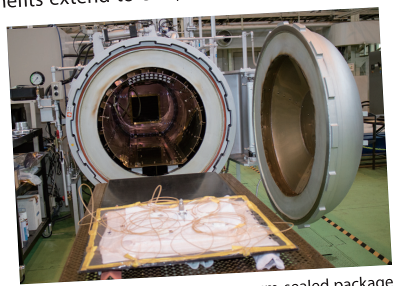
The Japan DMAT Kanto Block Disaster Drill, organized by the Ministry of Health, Labour and Welfare's DMAT (Disaster Medical Assistance Team) Head Office , the Tokyo Metropolitan Government, and other groups, was conducted on January 30, 2016. JAXA used three D-NET2 terminals at the Tokyo Metropolitan Government Office and two other locations to assess the system's effectiveness. (Pictured: Participants at the Substitute Facility of the Government Headquarters for Disaster Countermeasures)

High-temperature autoclave (composite curing oven) for experimental applications started full-scale operation

JAXA's high-temperature autoclave for experimental applications, installed in November 2015 as part of the Cabinet Office's "SIP* Structural Materials for Innovation" project, went into service in January 2016. An autoclave produces composite materials by applying pressure and heat to a carbon fiber impregnated with resin (a "prepreg"). Compared to the autoclave that JAXA installed in FY2014, a device that could produce up to 200°C at 10 atm, the new autoclave reaches temperatures of up to 460°C.

The new high-temperature autoclave not only makes it possible to create materials with even higher levels of heat resistance, thereby further extending the range of high-temperature environments that researchers can conduct experiments under, but also shortens the experimentation cycle (from the prepreg order to the completion of the experiment) from 3 months to as little as 2 to 3 weeks. The benefits extend to cost, as well, with the new technology cutting experiment-related expenses by around 75%.

* SIP (Cross-ministerial Strategic Innovation Promotion program): A cross-ministerial, interdisciplinary program created by the Cabinet Office's Council for Science, Technology and Innovation



After the prepreg is put in a vacuum-sealed package and the heat sensors are placed, the prepreg is cured while temperature readings are gathered at several points.

Flight demonstration of the small unmanned airplane for radiation monitoring system (UARMS) in Fukushima

JAXA and the Japan Atomic Energy Agency (JAEA) conducted flight tests of aerial radiation monitoring using the new version of the UARMS in Minamisōma, Fukushima Prefecture, on December 20, 2015.

The UARMS has been jointly developed by JAXA and JAEA since 2012.The new UARMS may seem to be the same as the previous prototype version because of its appearance, but many new features have been added into the system for longer endurance and safer, more precise monitoring missions.

The structure design was renewed to ensure a lighter, stronger airframe, and the fuel tank capacity was increased so that the aircraft could fly for up to six hours. JAXA also renewed the onboard system architecture by adding system redundancy, an in-flight failure detection algorithm, and automatic recovery and flight termination functions, including Return-To-Base mode, forced landing using automatic glide mode, emergency parachute, and spin descent applying full rudder.

The flight test results demonstrated not only the operational capability of the UARMS in evacuation zones but also the quick, precise aerial radiation mapping functions of the JAEA's radiation detection and analysis system.

After the UARMS R&D program, JAXA is going to transfer its technologies, such as the aircraft design data and operation and maintenance procedures, to JAEA so that they can apply the resources to their continuous monitoring missions and make improvements to the small UAV.

* See FLIGHT PATH No. 1/2 and No. 5/6 for details.

Preparing the small unmanned airplane for UARMS (Unmanned Airplane for Radiation Monitoring System) for takeoff on the runway