JAXA’s Institute of Aeronautical Technology takes off
ECAT: Program for environment-conscious aircraft technology

FQUROH: Flight demonstrations of noise reduction technology
Measuring aircraft noise in a wind tunnel
aFJR: The Next-Generation Fan/Turbine System Technology Demonstration
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The JAXA Institute of Aeronautical Technology has launched
“Flight Path,” the organization’s public relations magazine.

In April 2013, JAXA integrated the Aviation Program Group with the division in the Aerospace Research and Development Directorate that was once responsible for fundamental research on everything from aviation to space. This combination formed the new Institute of Aeronautical Technology.

We would like to thank you for your dedicated readership of “Sora to Sora” and “Aviation Program News,” the PR brochures for the Aerospace Research and Development Directorate and the Aviation Program Group, respectively.

“Flight Path” will deliver all the latest news on JAXA’s aviation-related research and development efforts. We hope you enjoy the new publication!

CONTENTS

P.3 -11
Feature story
• JAXA’s Institute of Aeronautical Technology takes off
• ECAT: Program for environment-conscious aircraft technology

P.12 -17
Research and development
• FQUROH: Flight demonstrations of noise reduction technology
• Measuring aircraft noise in a wind tunnel
• aFJR: The Next-Generation Fan/Turbine System Technology Demonstration

P.18 -20
Basic research
• International standardization for advanced composite material testing methods
• Solving combustion instability problems
• "DAHWIN": a wind tunnel in the near future

P.21
External cooperation
• Promoting cooperation with global partners

P.22 -23
Flight Path Topics
• Flight demonstration of radiation monitoring UAS
• Combustion experiments at Mach 4
• The DAHWIN hybrid wind tunnel
• JAXA develops a motor coil for electric aircraft

Profile
Kazuhiro Nakahashi
Executive Director of the JAXA Institute of Aeronautical Technology

Although many people probably associate JAXA with space development projects like the HAYABUSA asteroid explorer and the International Space Station (ISS), the organization’s research and development efforts go beyond the realm of space.

The aircraft technology field, for example, is another area where JAXA is active on a global scale. With aircraft serving as a vital component of the social infrastructure and playing important roles in people’s economic activities and social lives, growing demand in the aircraft industry has sparked intense development competition around the world.

Having led Japanese research in aviation technology, JAXA created its Institute of Aeronautical Technology in April 2013 to forge stronger bonds with society and contribute to further development in Japan’s aviation industry.

We sat down with Kazuhiro Nakahashi, the Executive Director of the JAXA Institute of Aeronautical Technology, to get his thoughts on the new venture.
The new Institute of Aeronautical Technology: Fortifying further growth in the Japanese aviation industry

How has JAXA’s aviation technology research contributed to Japan’s aviation industry?

In the late 1970s, JAXA collaborated with industry, academia, and government to develop the F7F10—

a Japanese-made aircraft engine that would later power the ‘Asuka’ experimental quiet STOL aircraft—developed by JAXA, which made its maiden flight in 1985. The technology behind the F7F10 continues to thrive to this day, providing the basis for the V2500 turbofan engines used for the current A220 series of Airbus aircraft. With a track record of over 7,000,000 miles, the V2500 is now the third-best-selling engine of all time. Japanese manufacturers have accounted for 21% of international joint development on the V2500, making the engine a major source of profit for the Japanese corporations involved.

JAXA has also done substantial research on carbon-fiber-reinforced plastics (CFRP). By creating a model of the ‘Asuka’ tail wing section, we designed using CFRP. The results of our research have been incorporated into passenger aircraft, spurning the adoption of composites in many cutting-edge passenger planes.

Our research output has also played an important role in MRJ development. From reducing structural weight to simultaneously optimizing aerodynamic and structural performance, JAXA's aviation technology helps give MRJ the technological advantage to achieve outstanding levels of fuel efficiency.

JAXA has been involved in aviation technology research for many years. What does the creation of the Institute of Aeronautical Technology mean for those efforts, and what role does JAXA play in relation to the Japanese aviation industry?

The aviation industry is an advanced technology-intensive industry that epitomizes the very best in manufacturing—a high-value-added industry that fuels the spillover of sophisticated technologies to other industries. As booming economic growth in Asia, the Middle East, and Central and South America opens the doors for massive increases in aircraft demand across the globe, the aviation industry will be poised to drive future growth in Japan—provided that it can use its technological capabilities and sharpen its competitive edge to capture that demand.

As a public institution, we would like to forge deeper collaborative partnerships with the industrial sector to realize the positive development of our aviation industry. By further strengthening industry-academia-government collaboration and focusing on systematic research, we also hope to contribute to propelling the Japanese aviation industry forward by enabling companies to apply our research in an accurate, timely manner.

At the same time, we will continue to provide JAXA research tools to a wide range of universities and companies in order to help develop the next generation of young engineers responsible for carrying the aviation industry into the future.

This fiscal year marks the beginning of JAXA’s third Mid-Term Plan, which will run for five years, and the launch of the Institute of Aeronautical Technology’s research and development program, with which aims to take a more active approach to meet the social needs of industry, government, and other sectors. To coincide with these new programs, JAXA has integrated the division in the Aerospace Research and Development Directorate that was responsible for fundamental research on everything from aviation to space and the Aviation Program Group, which traditionally focused on more aviation industry-oriented, society-minded aviation research, into the Institute of Aeronautical Technology. This new organizational structure allows JAXA to manage all aviation research—from fundamental study to applied research—in an integrated manner, not only making its research and development activities more dynamic but also showcasing JAXA research and its output more easily.

What are some of the specific activities that you plan to focus on?

In order to make contributions to the development of a safe, more prosperous society, the Institute of Aeronautical Technology focuses on research and development aimed at environment-conscious technology and safety technology in the aviation field. We will also continue our research on future technologies designed to benefit generations 20 and 30 years down the road—an area that industry often struggles to tackle.

Creating safe, environment-conscious aircraft

What does research on environmentally friendly aviation technology entail?

Air transportation is expected to grow by a factor of 2.6 over the next 20 years. This high rate of expansion has raised concerns about the increase in environmental impact from aircraft emissions of greenhouse gases like nitrogen oxide (NOx) and carbon dioxide (CO2), as well as noise levels around airports.

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Research and Development Directorate that was launched to make this vision a reality, with JAXA collaborating with CARATS on the DREAMS project.

To cope with increased air traffic levels around airports, the DREAMS project is currently researching technologies to efficiently avoid wake turbulence and shorten flight intervals to improve airport capacities and reduce traffic delays, as well as to optimize flight paths to reduce aircraft noise around airports during the landing phase. We are also conducting research on technology that facilitates optimal mission management and collision avoidance systems to improve efficiency during disaster relief activities. We aim to make practical proposals to international standardization agencies or transfer these technologies to industry by 2035.

What kinds of research are you doing on aircraft accidents?

According to the White Paper on Land, Infrastructure, Transport, and Tourism in Japan, approximately 50% of all aircraft accidents that occurred in Japan from 1999 to 2009 were caused by turbulence. JAXA has world-class laser radar (LIDAR) technology, having conducted R&D on on-board high-output turbulence detection system.

The Institute of Aeronautical Technology hopes to further develop this technology to make a weather safety avionics system that detects clear air turbulence before it has a chance to cause problems and automatically controls the aircraft based on turbulence information. With this undertaking, JAXA hopes to make significant improvements to the safety of air travel.
controllers from assigning planes in a timely manner. To fill the need for an effective system, JAXA has contributed to disaster monitoring and response activities.

In the aftermath of the Great East Japan Earthquake, many aircraft were dispatched to the disaster area for rescue and relief activities, but the lack of an integrated aircraft mission management and operational system made it difficult to keep the refueling process moving smoothly and prevented observe radiation levels of large areas from the sky.

We were frustrated that we didn’t have the vehicles for aerial vehicle research, the vehicles weren’t ready for use. The supersonic aircraft used in second-phase testing (D-SEND#2) were not yet ready. To fill the need for an effective system, JAXA are working on developing a system that can be used in disaster response activities.

Exploring the future possibilities of aviation transportation

We need to push ahead with research on future-oriented technologies that the private sector might not be able to engage in on its own—and we’re not just talking about supersonic and hypersonic aircraft technologies. These future technologies need to be tested and verified, after all, and if we don’t engage in research and validation of these technologies now, we won’t be ready when the actual need arises. That’s where JAXA and other public research institutions from around the world come in, engaging in long-term research.

Supersonic flight still has to deal with the problems of sonic booms—the loud “boom” that can be heard on the ground when an aircraft flying at the speed of sound produces shockwaves. The Concorde, retired from service in 2003, was banned from traveling at supersonic speeds over land because of the sonic boom issue. If we manage to get around that problem, airlines might be able to fly supersonic passenger aircraft once again. As we speak, JAXA and other organizations around the world are trying to figure out what extent sonic booms need to be reduced to allow for proper supersonic aircraft operations over land. At JAXA, in our D-SEND (Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom) project, we are working to validate our low boom aircraft configuration, and the second-phase tests of this project, D-SEND2, was conducted in Sweden in late August. In addition to these efforts, we are also contributing to the creation of noise standards for supersonic civil transport at ICAO by offering our technical expertise.

JAXA naturally does a lot of work on space development. Can the technology created through research at the Institute of Aeronautical Technology make an impact on space development, too? Technologically speaking, rockets, probes, and aircraft actually face a lot of the same challenges. They all have to have structures that are as lightweight as possible. They also require high levels of reliability. They have a lot in common when it comes to composite and computational simulation technology, as well. JAXA’s “KOUNDORYU” H-7 Transfer Vehicle (HTV), an unmanned resupply spacecraft for the space station, is built for one-time use. Therefore, we’re working on “HTV-II”—retrievable HTV—that can come back to earth after completing its missions. We know that the technologies and capabilities at the Institute of Aeronautical Technology, such as wind tunnels, will contribute to our HTV research. Our composite technologies are also used in some rocket components. Since fundamental research plays a very important role in R&D for both aircraft and space missions, we will need to work closely with relevant directorates within JAXA while playing a role as a specialized technology organization at the same time.

Also, looking at the operational side of things, we are seeing growing links between satellites and aircraft in remote sensing, for example. I believe the linkage between aviation and space will continue to grow stronger.

How do you think the Digital Analog Hybrid Wind Tunnel (DAHWT), which went into operation this fiscal year, will be used? With computational fluid dynamics (CFD), we can use computers to change the shape of the aircraft to determine aerodynamically ideal configurations. But since these calculations are computer-based simulations, the results could be different from actual airflow conditions.

Wind tunnel experiments, on the other hand, use real-life airflow that allows us to accurately grasp air behavior, but it takes a lot of time and money to construct the necessary models. The Digital Analog Hybrid Wind Tunnel (DAHWT), therefore, aims to strike the best possible balance between computer simulations (CFD) and wind tunnel experimentation, enabling us to accelerate R&D operations and produce dramatic improvements in precision at the same time. DAHWT makes it possible to do what would normally take a month under the conventional setup in a matter of just a few hours. It also lets us look at the experimental data and the result of simulation analyses from remote settings practically in real time.

When flying aircraft under flight test conditions, we can encounter unexpected behaviors and defects. Even in these situations, DAHWT gives us the ability to optimize aircraft configuration and perform wind tunnel experiments simultaneously, thereby making it possible to apply our findings to aircraft design quickly.

The Digital Analog Hybrid Wind Tunnel (DAHWT)
Developing domestically produced aircraft to invigorate the aviation industry and train skilled human resources

We're closing in on the MRJ’s maiden flight, the first passenger aircraft designed and produced in Japan since the YS-11.

At a value of over 1 trillion yen, the Japanese aircraft industry currently represents just 0.3% of the country’s total GDP. However, the industry is a knowledge-intensive one that demands sophisticated manufacturing technology, requires enormous amount of parts and components, and involves a broad range of other industries. Therefore, we think the MRJ will help invigorate Japanese industry across the board.

The development of domestically produced aircraft like the MRJ also figures to serve as a compelling goal for students and young engineers in aviation-related academic disciplines. By taking the lead in development, Japan will have to work on research and development for a massive array of technologies. In addition to manufacturing components as suppliers according to specifications established by overseas OEMs, Japan will also need to assume responsibility for operational performance after delivering the MRJ to airlines. Given the scope of these efforts, I think that Japan-led development efforts will really motivate young engineers and students to do profoundly challenging, worthwhile work.

We also hope that the MRJ succeeds and Japanese aircraft development efforts pick up momentum going forward.

What do you think is needed to develop human resources for the aviation field of the future?

I think we need to provide younger people with a robust vision for the aircraft industry. More often than not, things like aviation and space tend to inspire people to dream big dreams. That’s fine in itself, but those visions can lack concrete definitions. We need to take another step forward to show people a more realistic image of the industry, emphasizing the practical necessity of aviation and the real, tangible appeal of cutting-edge technologies.

Universities are the driving force behind educating human resources, with JAXA providing the necessary technologies and equipment. Few universities have the ability to furnish large-scale testing facilities, so we think we can play a helpful role in supporting student research. JAXA has already launched an “Aviation Education Support Forum” in collaboration with the Japan Society for Aeronautical and Space Sciences, for example. The project provides universities with JAXA’s CFD research results as research tools to be used at classrooms, gives students opportunities to experience real-life testing equipment, and brings Japanese students together with students and researchers from around the world through an international network of public aeronautical institutions. We will continue to do our best to contribute to the development of future human resources in the aviation field.

Working with companies is another important ingredient in developing human resources. For example, a manufacturer employee that spent two years at JAXA studying wind tunnel-based measurement technology went back to his employer and became a leader in aircraft development. Young JAXA researchers have also been involved in aircraft development at a manufacturer and brought their experience back to JAXA, incorporating their findings into their research activities.

We’d be severely limiting ourselves if we were to adopt a closed-door policy and focus solely on projects within the confines of the Institute of Aeronautical Technology. That’s why we need to promote lively interaction with companies and universities to train the human resources responsible for the future of Japan’s aircraft industry. Therefore, we are actively seeking out technology-related ideas from the business and academic spheres to promote joint research projects.

How does the Institute of Aeronautical Technology work with organizations abroad?

JAXA is a member of a global organization called the International Forum for Aviation Research (IFAR). Created in 2010, it is the world’s only public aviation research establishment network and currently has 24 participating institutions from around the world. The mission of IFAR is to promote collaboration among the world’s aviation research institutions and formulate frameworks shared by participating institutions for research on noise, emissions, high-efficiency operations, safety, and other environmental issues. JAXA played host in 2012 to the first-ever IFAR summit (annual meeting) held in Asia and is now acting as the Vice Chair of IFAR and working in close partnership with the Chair organization, NASA, to ensure the growth of this unique and valuable venue for multilateral cooperation in aviation research.

JAXA is also engaged in a wide range of joint research with public aeronautics research organizations around the world, such as NASA (the United States), DLR (Germany), ONERA (France), KARI (S. Korea), as well as private companies like Boeing and Airbus, and universities to promote strategic collaboration of mutual benefit.

Through this strategic international collaboration in pre-competitive research that complements the respective strengths of the parties involved, we hope to enhance Japan’s aviation technology and bolster its presence on the global stage.

The future of JAXA Institute of Aeronautical Technology

What does the JAXA Institute of Aeronautical Technology aim to be?

We want to embody our slogan, “Shaping Dreams for Future Skies,” to provide the state-of-the-art aviation technology that will make the skies of tomorrow cleaner, safer, and more comfortable for everyone. As Japan’s central R&D institution for aviation, we will do our very best in supporting the Japanese aviation industry so that it can rise to even greater heights in the world arena.
− Could you tell us about the current state of environmental technology in the aviation industry?

As environmental restrictions on cars got stiffer over the years, we saw incredible evolution in environment-related automobile technologies. With air traffic volume expected to grow by a factor of approximately 2.6 over the next 20 years, the environmental impact of aviation has become a global issue, and the International Civil Aviation Organization (ICAO), the UN’s regulatory body that sets standards and regulations concerning aviation, is introducing increasingly stricter standards on aircraft noise and exhaust gases. Airlines thus need aircraft that meet these requirements, which means that the manufacturers that supply aircraft need to ensure that their aircraft satisfy the applicable environmental standards. In hopes of enhancing the global competitiveness of the Japanese aviation industry, the JAXA Institute of Aeronautical Technology has positioned its new “Environment-Conscious Aircraft Technology Program” (ECAT) at the center of its research and development activities. We spoke with Dr. Akira Murakami, Advisor and Chief Engineer of the Institute of Aeronautical Technology, about what ECAT is designed to accomplish.

− What kinds of environmental technologies is the Institute of Aeronautical Technology researching at the moment?

Looking at the environmental performance of small-scale aircraft (with a capacity of 100-150 passengers), we think that we’ll be able to make a lot of improvements in that area; ten years from now, for example, aircraft will be at least 30% more fuel efficient than they are now. JAXA will not be directly responsible for the actual manufacturing of these aircraft, but in ECAT we will take advantage of our strengths and mainly focus on conducting R&D for advanced technologies airframe noise and resistance reduction, composite structures, ultra-high bypass engine technologies that can live up to demands for higher efficiency, less noise, and reduced emissions.
Environment-Conscious Aircraft Technology Program

As turbines reach extremely high temperatures that sometimes exceed the levels carbon fiber reinforced plastics (CFRP) can withstand, heat-resistant ceramic matrix composites (CMC) are gathering attention as a possible solution. There are still plenty of issues with CMC, though, so CMC-related work at engine manufacturers around the world is still in the developmental stages.

To contribute to this development, JAXA Institute of Aeronautical Technology has launched the “Next-Generation Fan/Turbine System Technology Demonstration Mission” (aFJR) to validate fans and low-pressure turbines that will be compatible with the ultra-high bypass engines of the future.

− Why are you concentrating on low-pressure systems?

High-pressure systems are an appealing area, indeed. They require frequent part replacement, which makes them quite profitable, and there is a lot of room for improvements in environmental performance. The big problem is the market—manufacturers in Europe and the United States have a firm hold on the competition, making it hard for Japanese companies to get into the mix.

− What is the goal of aFJR?

The core goal is to reduce total engine weight by around 10% by boosting the fan aerodynamic efficiency of existing engines by at least one point and using composites to make fans and low-pressure turbines lighter.

To do that, we are working to develop and demonstrate composite technologies for the laminar flow fan aerodynamic designs of fan modules, shock-resistant FRP blade design manufacturing, lightweight metal disks, and lightweight, sound-absorbing liners. For low-pressure turbines, we are also developing lightweight, low-pressure turbines that incorporate CMC.

These efforts will help us develop and demonstrate the kinds of high-efficiency, lightweight technologies that will give Japanese companies an edge over foreign manufacturers, compete more effectively in international joint-development projects on next-generation jet engines, and thereby secure larger shares of the design and manufacturing responsibilities in collaborative efforts.

− Is the ultimate goal to make entire engines completely in Japan?

The JAXA Institute of Aeronautical Technology has started research and development on “green engine technologies” for high-pressure systems and core engine technologies. As part of this initiative, we want to enhance the lean-premixed combustors and other advanced technologies that we have been working on and eventually establish them in a feasible system package. For our first step, however, we are planning on driving the aFJR effort, which focuses on low-pressure systems—an area where we already have experience and are confident about securing a larger market share.

Today, jet engines are developed through international collaboration, so we rarely see instances where a single manufacturer makes an entire engine by itself. Currently, Japanese engine manufacturers account for about 6% of the global share, and we would like to see it go up to about 10% by expanding their roles in international joint-development projects.

Somewhere down the road, I’m confident that Japanese manufacturers will be able to break into the private-sector engine market with domestically produced engines.

− What kinds of research are you doing on noise issues?

As for engine noise, noise levels have decreased by substantial margins thanks to the introduction of high bypass ratio engines. Now that engines are quieter, people are paying closer attention to noise generated by airframe during takeoff and landing at airports. JAXA has launched the “FQUROH” (meaning owl in Japanese) mission, which aims to demonstrate noise reduction technology. The core objectives of the FQUROH mission are to develop noise reduction technology for high-lift devices such as flaps and slats as well as landing gear, which generate significant noise, and to perform flight tests for technology validation.

− What other objectives does ECAT have?

We are advancing our work on composite materials and aerodynamic design in our Eco-Wing Technology R&D initiative, a project that focuses on reducing aircraft weight and improving lift-to-drag ratio. Through this effort, we hope to cut aircraft structural weight by 20% and boost cruising lift-to-drag ratio by 7% over the next 10 years.

− Finally, how do you want to see ECAT contribute to society?

In order for society to make full use of the fruits of science and technology R&D, strong cooperative ties between industry, universities, and research institutions like JAXA are vital. As a driving force in research and development, JAXA wants to play a central role in pushing advanced technologies forward with a sense of urgency and uniting various parties in fruitful collaboration. Doing that will contribute to making the Japanese aircraft industry more competitive internationally, which will also solidify JAXA’s presence and value within Japan. It takes a considerable amount of time—often at least 10 to 20 years—for aircraft-related businesses to make good on their investments. Unlike companies in other industries, manufacturers in this sector cannot just put aircraft on the market, sit back, and watch the sales roll in. Releasing aircraft is just one point on a protracted path. To stand a chance in international competition, aircraft manufacturers have to keep developing the next versions of aircraft and have their sights set on several steps ahead. Although JAXA’s Mid-Term Plan outlines the desired results for a five-year period, the process of making these technologies commercially viable stretches well beyond that scope. We need to bolster our support structure and keep our eyes locked on the next innovations to be made. Two or three decades from now, I hope we have made it to the point where we can improve fuel consumption by over 50%, achieve noise reduction levels that rank among the best in the world, and boast unrivaled emission-reducing technologies.
FQUROH: Flight demonstration of airframe noise reduction technology

Why is noise reduction necessary?

When passenger jets started flying in the 1960s, the aircraft tended to be extremely noisy. As conventional turbojet engines were gradually replaced with high-bypass turbofan engines, however, the noise levels began to drop. A turbofan engine adds a fan to the front of the jet engine and generates most of its propulsion from the large amounts of jet thrust that the fan produces. By using fans that are larger in diameter, the latest turbofan engines can generate the same propulsion levels at lower jet velocities. As the noise of a jet engine is proportional to the eighth power of the jet velocity, slower speed means less noise. These developments have helped achieve substantial noise reductions compared to early-generation jet engines. Reducing overall airport noise levels by a considerable margin. Still, taking and landing approach zones are exposed to noise levels of around 90 dB. With an air traffic volume expected to keep increasing in the future, the abatement of airport noise impact on airport communities requires even quieter aircraft. Efforts to reduce aircraft noise levels will need to devote further attention to noise-reducing technologies from airframes. Noise reduction also has discounts for low-noise aircraft, noise reduction also has an impact on profits. Moreover, noise reduction technologies are important for aircraft industries from the perspective of their products’ international competitiveness.

Using the fruits of research initiatives that began in earnest around 2004, JAXA has now launched its “FQUROH” (Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations) mission to verify developed noise reduction technologies by implementing them in actual aircraft and evaluating the results through a series of flight tests.

JAXA’s noise reduction technologies

JAXA has focused its research on reducing the amount of aerodynamic noise from the airframe, a large amount of which comes from the flap on the trailing edges of the main wings, the slat on the leading edge, and landing gears. The flap extends downward from the trailing edge during landing, increasing the size of the main wing camber and expanding the total wing area to generate sufficient lift as the aircraft flies slowly. The same principles apply to the slat: it protrudes downward out of the leading edge of the main wing in accordance with the extension of the flap. This creates space between the slat and the leading edge of the main wing from this space, air flows over the surface of the main wing to prevent the separation of smooth airflow and delay stalling. Lift is generated by the airflow passing smoothly over the surface of the main wing. “Stalling” refers to the condition where this smooth airflow comes off (flow separation) the surface of the main wing, preventing the aircraft from maintaining the lift required to keep the aircraft aloft against the force of gravity. Although high-lift devices like flaps and slats delay stalling by boinghting lift and preventing major flow separation on the wing surface, local flow separations that occur inside the slat and on the flap edge form turbulent vortices and pressure fluctuations. Those are the causes behind the saxon aerodynamic noise we hear during flight.

The most effective way of abating the noise is to control and restrict the local flow-separations that occur vortex becomes an extremely turbulent airflow and leads to lift fluctuation around the flap edge. That’s what causes the noise. By suppressing the amount of vortex turbulence and changing the location where the vortex occurs on the flap edge, we can suppress pressure fluctuation and, consequently, reduce the amount of associated noise.

JAXA wind tunnel experimentation has demonstrated that the method can achieve a 2 to 3 dB reduction in noise. The next source of noise is the inside of the slat, where airflow separates and creates turbulent vortices. By modifying the configuration of the inside of the lower surface to eliminate the vortices, JAXA has successfully reduced noise by about 10 dB. However, this approach, in practice, prevents slat from being stowed in the main wing. That’s why JAXA is now looking into reducing noise by setting the cusp at the bottom of the slat for application in actual aircraft. Most slat noise comes from near the top of the slat trailing edge (the side near the leading edge of the main wing), but the turbulent flow on the trailing edge of the slat, which cause the noise originates at the slat cusp. If JAXA narrows this portion to prevent large vortices into smaller pieces, it will be possible to decrease the large-scale turbulent flow that generates substantial noise inside the slat.

The landing gear is another key area to look at. Most landing gear noise originates from fluctuating flow around the main structural elements such as the tires and support structure called the “side brace.” The region between the tires is full of various parts—wheels, brakes, shock absorbing structures, hydraulic piping, and electric cables—arranged in an elaborate configuration. When airflow gets into this area, it creates noise. The idea that JAXA is exploring involves putting perforated flaps (cover) over this region to both reduce noise and allow cooling flow to reach the brakes. Wind tunnel experiments have shown that these flaps can cut noise by approximately 2 to 3 dB.

How much of an effect will these technologies have once they are installed in actual aircraft? That’s what FQUROH’s flight demonstration is designed to find out.
The FJR710, Japan’s first high-bypass jet engine (1), formed the basis of the JAXA Institute of Aeronautical Technology’s engine research with its AFRJ mission aims to make a positive impact on the Japanese aviation industry. Here, we take a closer look at the next-generation jet engine that aFJR is determined to create.

Having impressed British engine manufacturer Rolls-Royce with its performance in demonstration tests, the FJR70 left its technological mark on the V2500 series—the global best-seller that provides the engines for Airbus A320 aircraft and has over 7,000 total orders to its name. Japanese companies provide the fans for the engine’s low-pressure system components, giving Japan a 23% share of the total manufacturing effort.

The jet engine aFJR is after

The environmental standards on the noise, NOx (nitrogen oxide), and other negative products generated by aircraft continue to get increasingly stringent year after year. Due to sharp increases in general instability in fuel prices, the market is also stringy year after year. Thanks to their central roles in developing technologies that, for example, use different materials for the liner of the honeycomb structure inside the fan nacelle, which serves to cut down on noise.

Technology for creating ultra-high bypass engines

What sort of component technologies go into creating an ultra-high bypass engine with a bypass ratio of over 13, then? A higher bypass ratio requires a bigger fan, which in turn creates a heavier engine. Bigger means heavier, heavier means worse fuel efficiency. That is why creating lighter engines is the most pressing issue at the moment.

Manufacturers have thus started using carbon fiber reinforced plastics (CFRP) to help make large-scale engine lighter. aFJR’s goal is to reduce overall engine weight further by redesigning the CFRP structure and making the materials hollow—something that no one has ever done before. The organization will also tweak the configuration of the fan blade, applying its ‘laminar flow fan aerodynamic design technology’ to move the point where the laminar airflow on the surface turns into turbulence further back and thereby reduce resistance.

For the disk in the center of the fan, aFJR will develop new processing technologies that will make it possible to reduce the weight of the traditional metal materials without sacrificing any strength.

Another way to make engines lighter is by developing technologies that, for example, use different materials for the liner of the honeycomb structure inside the fan nacelle, which serves to cut down on noise.

aFJR is also working on using ceramic matrix composites (CMC) for the low-pressure turbine blades. Lighter and more resistant to heat than metal, CMC has a temperature limit of approximately 1,200°C—or around 100°C higher than that of the conventional metals. Although that may not seem like a big difference on paper, introducing CMC makes it possible to achieve reductions in weight while still maintaining the necessary heat resistance performance.

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The project is so designed to develop aFJR's next-generation engine technology to improve safety and reliability attributes of aircraft engines. Unique to aircraft engines.

Cultivating human resources for the aviation industry of the future

“The development of next-generation engines is expected to begin sometime around 2021,” says mission leader Toshio Nishizaka, who is also a group leader. “No matter what, we need to have the right base technologies in place before development starts.” By that time, the domestically produced MRJ passenger aircraft will likely be in service, prompting overseas manufacturers to introduce their own new models into the market. Japan will need to be able to withstand that pressure and weather the competitive storm.

“Aircraft projects are long-term efforts,” Nishizaka continues. “Cultivating capable human resources is going to be a crucial piece of ensuring that we continue to thrive in the market. I hope to see more and more young people get interested and involved in the aviation field.”

The JAXA Institute of Aeronautical Technology is ready to be a powerful driving force for the future of Japanese aviation, infusing the industry with the boundless energy of youth.

The FJR710, Japan’s first high-bypass jet engine (1), formed the basis of the JAXA Institute of Aeronautical Technology’s engine research with its AFRJ mission aims to make a positive impact on the Japanese aviation industry. Here, we take a closer look at the next-generation jet engine that aFJR is determined to create.
Advanced noise source measurement technology

Measuring aircraft noise in a wind tunnel

To reduce aircraft noise, we need to determine exactly where on the aircraft the noise comes from. Flight tests to measure noise from actual aircraft represent one important step in pinpointing the sources of noise, but wind tunnel testing not only makes the measurement process less expensive but also lets researchers perform their experiments repeatedly. However, the electric motor-driven fans at the general wind tunnel facility used by JAXA and the majority of research institutions produce a substantial amount of noise, which severely complicates noise measurements. To get around this problem, most research organizations do their measurements in special low-noise wind tunnels with anechoic measurement areas. JAXA, on the other hand, is developing technology that will enable advanced noise source measurement in general wind tunnel environments.

What is noise source identification technology in a wind tunnel all about?

Although useful, noise measurement in a traditional wind tunnel poses a significant challenge. Wind tunnels were originally built for the purpose of generating high-speed airflows that would allow researchers to measure the force pressure, flow field, and other aerodynamic characteristics of the model inside the tunnel. Therefore, they lack noise-suppressing features and thus produce a considerable amount of operating noise. A loud wind tunnel can mask the sound coming from the model, making it hard to detect the target noise.

Why are wind tunnels so noisy? The answer lies in the devices that the tunnels require and the configuration of the tunnels themselves. To generate high-speed wind, a wind tunnel uses a giant fan powered by an electric motor. The noise from these devices reflects off the wind tunnel walls, generally made of metal and concrete, and travels the length of the tunnel. Generally, sound tends to decay as the corresponding propagation distance grows. In a closed circuit type wind tunnel, however, sound continues to bounce off the walls and maintains an essentially constant level.

JAXA has developed measurement technology that can identify noise sources under noisy conditions, pinpointed where sounds come from, and evaluated the effects of noise reduction technology (Figure 1). The organization has also performed noise measurements using low-noise wind tunnels provided by outside institutions. However, JAXA is planning to add a low noise feature to the 2 m by 2 m low-speed wind tunnel by covering the interior surface of wind tunnel to prevent the fan noise from reflecting off the walls.

When measuring noise in a wind tunnel, researchers generally remove the walls of the test section to keep the test noise produced by the model itself from reflecting throughout the tunnel interior. They then place the microphones outside the airflow for measurement purposes. Although this method does limit the noise generated by reflection, it leaves a portion of the wind tunnel open, this can interfere with airflow quality by creating turbulence in the air in the vicinity of the model or causing gallows, thereby making it more difficult to assess the noise coming from the model.

JAXA thus developed an anechoic test section that uses high-acoustic-transmission sheets as wall surfaces, allowing researchers to conduct measurements with the wind tunnel open. To minimize the effects of sound reflections, the wall surfaces are replaced with Kevlar sheets, and the sound from the model is picked up through the sheets by a microphone array in an adjoining anechoic chamber (Figure 2). By shooting out wind but allowing sound to pass through, Kevlar sheets make it possible to capture sound without disrupting the airflow.

How can microphones be used to identify noise sources?

Researchers usually use a radial array of around 100 microphones to pinpoint the sources of noise coming from a model inside a wind tunnel. Arrays currently in development are about 1.5 m in diameter and have thirteen radial arms, seven microphones on each arm, and five other microphones in other locations. The sound from a single source reaches the different microphones in the array at slightly different times; a microphone closer to the source, for example, will pick up the sound a split second before a microphone further away. Using these small time difference values, researchers can back calculate the propagation time to determine where the sound is coming from (Figure 3). The microphones are omnidirectional, but you can also create a directional setup by arranging them in certain ways.

From a purely technology standpoint, that is how most noise source identification systems work. When it comes to actual usage inside wind tunnels, however, you have to deal with the potentially problematic effects of strong winds. JAXA’s system minimizes that impact. Noise source resolution varies according to frequency and processing methods, but the JAXA array has a resolution (1) of around 30 cm at 1 kHz.

Using this noise source identification technology, we performed noise measurements on a 40% scale model of the landing gear for a regional jet with a seating capacity of around 100. The results showed that a significant amount of noise (2 kHz) was coming from the structure between the landing gear wheels (Figure 4). As the model was less than half the size of the real-life landing gear, we used the reciprocal of the scale value to determine that the amount of noise coming from the actual landing gear was equivalent to 800 Hz (1 Hz).

With just a few calculations, tests on scale models thus make it possible to identify the characteristics of noise coming from actual, full-size equipment: the sources and approximate wavelengths of the sounds. That means that we can figure out which locations, levels, and frequency bands of noise sources need to be targeted in order to minimize noise most effectively.

Human ears have an audio-frequency range of 20 Hz to 20 kHz. Noise source identification on the lowest end of the range requires a microphone array with a larger diameter (1 Hz), which would make the array simply too big for wind tunnel equipment to hold. Given these limitations, there is currently no way to measure noise at these low frequencies in wind tunnels.

However, research on ultrasonic sound—sound that exceeds the audio-frequency range—is booming at JAXA. As scaled models are used in wind tunnel testing, the surrounding flow conditions differ from those around actual aircraft. If the model is one-tenth the size of the actual aircraft, for example, you would divide the frequency of the sound coming from the model by 10 to find the frequency of the sound coming from the full-size device (2). When researchers try to assess noise of up to 10 kHz—the standard range for aircraft noise regulations—they need noise source identification technology capable of measuring ultrasonic sound, which sits above the audio-frequency range. Having already confirmed that its technology enables measurements of up to 60 kHz, JAXA is now working on research that will boost measurement precision to even higher levels.

Linking noise sources and fluid phenomena

JAXA’s 2 m by 2 m low-speed wind tunnel was originally built to investigate aerodynamic characteristics. If the tunnel successfully makes it possible to perform noise measurement with higher quantitative accuracy, researchers will be able to conduct noise measurement and assess aerodynamic characteristics at the same time. By simultaneously observing changes in aerodynamic characteristics, aeroacoustic characteristics, and noise source distribution over time, investigations into noise attributes will reflect actual conditions much more faithfully. JAXA is also working to develop its entire image processing technology to prevent noise interference from obscuring sound sources.

What lies ahead, then? JAXA is also developing measurement technologies for unsteady velocities and pressure fluctuations. “Wind Tunnel Technology Center researcher Hiroki Ura says, “Right now, researchers are analyzing the measurement results from these technologies and the results of noise source identification projects separately. We’ll be able to get a better idea of the mechanisms behind noise generation if we can establish a direct link between noise sources and fluid phenomena and develop analysis technology accordingly. I’m looking forward to making noise reduction more accurate.”
Supporting the world’s aeronautical technology through advanced composite materials testing standards

Working toward international standardization for advanced composite material testing methods

Over half of the structural weight of the Boeing 787, an aircraft that JAXA put into service before any other carrier, is made of carbon fiber reinforced plastic (CFRP). Light, strong, and durable, CFRP generates dramatic improvements in aircraft fuel efficiency and represents a vital element in enhancing aircraft performance. However, new materials have to clear certain hurdles. An aluminum alloy database has already been prepared for public use by the development of aircraft design rules due to the long history that metal materials have as structural elements. However, one of the problems with CFRP is the lack of a sufficient public database related to testing methods.

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From the aircraft research and development field.

2000s, the digital/analog hybrid wind tunnel—research and development of aircraft is in progress. From 1997, the Japan Aerospace Exploration Agency (JAXA) had been engaged in bilateral research projects uniting Japan and Europe. This has intensified competition in aircraft, and others that Japan has entered the market to compete with countries like Russia, China, and other countries that have large-scale and high-capacity research and development capabilities. Japan also has to continue working with other countries to develop a solid foothold in the global arena. The Japanese government has set ambitious goals, such as realizing the Japanese aviation industry by 2030. JAXA, the JAXA Institute of Aeronautical Technology, is pursuing this goal by focusing on the following activities. To achieve this, JAXA plans to closely work with the Chair organization NASA, and contribute to IFAR so that it can achieve its full potential in global research collaboration and training the next generation of leading researchers in aviation research.

IFAR

The IFAR (International Forum for Aviation Research) is the world’s only public aviation research establishment network founded in 1997 with 8 Member countries, NASA is a dedicated program providing an avenue for collaborative research among the world’s leading aviation research institutions and formulating guidelines towards international policies for the purpose of participating researchers for research on science, education, high-efficiency operations, safety, and other environmental issues.

DAHWIN

A wind tunnel is a facility that artificially creates wind tunnel data are collected. In the wind tunnel, a 5:1 scale model of an aircraft under development is kept at an angle of attack of 0° and a Mach number of 0.8. The status of the tunnel can be checked on the screens in the room. Numerical results computed by a supercomputer are also displayed on screens nearby. Based on these results, real-time wind tunnel data corrections can be applied. The aircraft designer checking the data via the internet is sending an instruction: “Let’s try changing the angle of attack to 2°.” Then the model angle of attack is rapidly changed. As the model position is changed, corresponding numerical data are immediately displayed on the screens.

This is a view of the aircraft design field in the not-so-distant future. Completed in 2012, DAHWIN became one of the new wind tunnel systems that realize the near future as the model position is changed, corresponding numerical data are immediately displayed on the screens.

Future of DAHWIN—From shape determination to real-flight predictions

In the numerical analysis, complicated flow physics are modeled and solved. However, the results show different trends depending on the choice of the model. Furthermore, in wind tunnel tests, the wing of the model is deformed and these effects are usually not taken into account. Therefore, an approach was developed where wind tunnel data are fed back into the numerical tool and computations are conducted again using these data. This step improves the precision with which wind tunnel data and computational data can be compared.

The system is presently constructed for use in the JAXA 2 m × 2 m Transonic Wind Tunnel and will be routinely operated from the spring of 2013. DAHWIN has already been applied to a number of test campaigns, including the low-shear boom design concept validation of a supersonic transportation system (O-SEND project, fig. 1) and the recoverable H-II transfer vehicle (HTV-4). DAHWIN will be extended to other JAXA industrial facilities, including low-speed and supersonic wind tunnels, in the near future.

Furthermore, the system will be utilized to determine the optimal shape of aircraft and to predict real-flight performance by combining flight data with CFD/CFD data.

Eric B. Jones, Jr., current Chairman of IFAR, has said, “In particular, the IFAR Summit is designed to provide an opportunity for IFAR researchers to network with their colleagues from around the world.” As a newly elected Vice-Chair of IFAR, JAXA hopes to demonstrate its leadership working closely with the Chair organization NASA, and contribute to IFAR so that it can achieve its full potential in global research collaboration and training the next generation of leading researchers in aviation research.

DLR, ONERA, and other Japan-Europe collaboration

Since 2000, JAXA has been researching and developing an on-orbit DOF (degree of freedom) spacecraft for the detecting turbulence in flight and predicting accidents before they can occur. In 2010, JAXA, NASA, and Boeing collaborated in order to enhance performance, reliability, durability, and competitiveness based on actual design specifications and installation requirements. Through this ongoing collaborative partnership with Boeing, JAXA hopes that this technology will have a significant impact in the next few decades in making the world safer and cleaner to travel.

In its collaborative partnership with Airbus, JAXA has been working on joint research in composite materials since 2005. Researchers from the JAXA Advanced Composite Research Center had the opportunity to conduct research at Airbus Headquarters in Toulouse, France in 2011 and 2012, and an Airbus engineer spent a summer at JAXA working with JAXA composite researchers in 2012. An additional valuable experience the relationship has created.

Since 1997, JAXA has been involved in bilateral collaborative research with DLR in Germany and ONERA in France. In 2007, a joint research initiative was established by JAXA, DLR, and ONERA, since the three organizations have been accumulating fruitful collaborative researches under this valuable framework. Collaborative efforts also take place during annual bilateral meetings, where research academic leaders from the respective organizations discuss recent progress and strategic directions for future collaborations in all, the three countries’ partnership continues to form close, mutually beneficial bonds. Japan and the European Union (EU) also signed “The Bilateral Science and Technology Agreement” in November 2008, which entered into force in March 2011, paving the way for ongoing collaboration in aeronautical, transport projects and Japan-Europe.

Numerical analysis is conducted considering the model configuration with support systems (left) as well as without (right). These results are used to correct for the support interference in wind tunnel data.

In parallel with wind tunnel tests, numerical analyses are conducted by supercomputers, and the results are rapidly fixed with the wind tunnel data. Since the data can be visualized in real-time on Internet, designers can quickly check the data and maneuver the test schedule.
JAXA completes flight demonstration tests on its small unmanned aerial system for radiation monitoring

On March 7, JAXA conducted flight demonstration tests for its unmanned aircraft, equipped with radiation spectrometer technology developed by the Japan Atomic Energy Agency (JAEA), at Shikabe Airport in Hokkaido. The tests were carried out to confirm and fine-tune the flight function and capability of the small unmanned aircraft and validate the performance of the on-board radiation spectrometer technology.

The unmanned aircraft used for the March tests had a length of 2.7 m, a span of 4.2 m, a total height of 1.3 m, and a takeoff weight of 50 kg. Flying with a reciprocated engine and an auto-flight program system, the aircraft successfully met the intended basic functionality requirements. JAXA plans to improve the safety, reliability, and flight functionality of the aircraft to make unmanned aircraft-based radiation monitoring systems feasible for practical use.

Combustion experiments at Mach 4 prove successful for JAXA’s hypersonic jet

Combustion experiments were performed at the Nasu Rocket Testing Center on March 5 to evaluate the performance of JAXA’s hypersonic jet at Mach 4. As the turbine's engine was run under different conditions for its first test, it could yield the expected high-temperature operation at Mach 4 by using a hydrogen-air mixture. The heat exchanger also improves the efficiency of the engine, which makes the engine operable at a temperature of up to Mach 5. Driven by the aim of one day making its own hypersonic hybrid passenger aircraft, JAXA has already developed an engine for technological verification purposes and used it to conduct static firing experiments under takeoff conditions and flight functionality requirements.

After five years of development, the DAHWIN hybrid wind tunnel is now complete and in full-scale operation as of this April. DAHWIN combines a conventional wind tunnel (an “analog” wind tunnel), which simulates flight conditions at different Mach numbers, and a digital wind tunnel to create a “digital/analog hybrid wind tunnel” through analyzal data that can be used to improve design precision for aircraft and spacecraft, and shorten the development periods. Although analog wind tunnels ensure high levels of data reliability due to the use of real fluid, the model simulates a number of processes in time and space, making it possible to compute simulations in the time domain. Computer simulations also store the impact on the experimental data outcomes. Meanwhile, the effects of non-ideal effects in the experiments at specific conditions are monitored in the digital wind tunnel. It is advantageous to use computational fluid dynamics simulation for DAHWIN, thus facilitating the combination of conventional wind tunnel data with digital wind tunnel data to compute for the two tunnel type independent shortcomings, improve design precision for aircraft and spacecraft, and provide development periods.

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The DAHWIN hybrid wind tunnel goes into full-scale operation

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Hisho monitors an observation rocket experiment from high altitude

For their first day in August, 12 spacecraft operators worked in the Tanegashima Space Center to launch the 4th IFAR Satellite, a technology demonstration satellite. As the payload, Hisho, JAXA's experimental aircraft, was launched into orbit. During the flight, Hisho monitored the performance of the observation rocket experiment from high altitude.

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Hisho is equipped with a lithium light (photo-emitting technology) for the demonstration tests for the 4.5 and 7.5 t.f. (2017-2018) satellite development programs. Hisho will be launched into orbit in mid-2023 for extended flight testing as part of the IFAR project.

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