JAXA Aeronautics Magazine

FLIGHT PATH

Shaping Dreams for Future Skies

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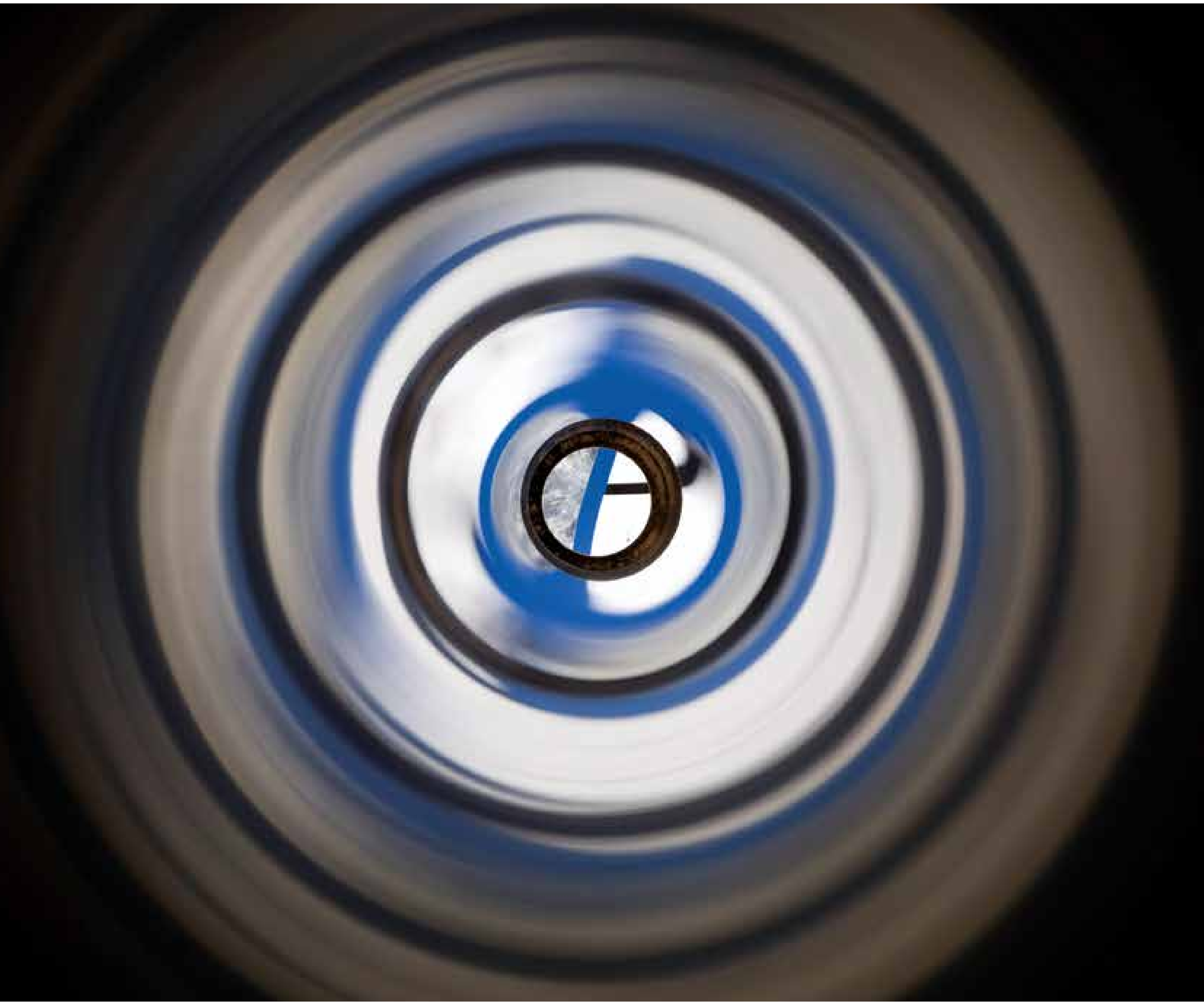

Feature Stories

At the stage of delivering tangible results that benefit society

Challenge of the Next Generation Aeronautical Innovation Hub Center

The aFJR (Advanced Fan Jet Research) project

Taking aircraft engine development in a new direction

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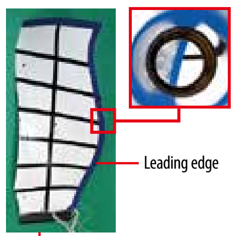
Cover Image: Inside the cylindrical launch tube of an impact resistance test device.
A gelatin ball, injected at a high speed, advances through the launch tube and hits the target at the exit of the launch tube. In the very center of the image is the test target, the leading edge (painted blue) of a CFRP fan blade prototype.



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Feature Story

Bringing together diverse human resources and technologies from a broad variety of fields, JAXA's Next Generation Aeronautical Innovation Hub Center transcends the boundaries of industry, academia, and government to fuel advances in aviation. Launched in FY2015, the Aeronautical Innovation Hub Center facilitates open innovation and is now starting to produce tangible results from its research activities. This article introduces the scope and progress of the research activities at the Aeronautical Innovation Hub Center through an interview with Shigeya Watanabe, Director of the Next Generation Aeronautical Innovation Hub Center.

Shigeya Watanabe
Director
Next Generation Aeronautical Innovation Hub Center

Challenge of the Next Generation Aeronautical Innovation Hub Center

At the stage of delivering tangible results that benefit society

WEATHER-Eye: Preventing aircraft accidents caused by weather phenomena

—— Last year saw the launch of the WEATHER-Eye Consortium, in which members work together to develop feasible technologies for preventing aircraft accidents and delays attributed to weather—namely WEATHER-Eye (Weather-Endurance Aircraft Technology to Hold, Evade and Recover by Eye). How does that line of research fit into the Aeronautical Innovation Hub Center's strategy?

Research and development activities at the Aeronautical Innovation Hub Center are managed under three basic policies: addressing themes that can benefit society and industry; driving "open innovation" to create innovation through integrated R&D with cross-sectoral and multidisciplinary collaborations; and delivering high-impact results, eventually giving back to society through those outcomes.

The WEATHER-Eye Consortium perfectly fits with those policies. The aeronautical Innovation Hub Center's open innovation framework helps incorporate a wider breadth of knowledge from areas outside aeronautics, which brings about new ideas for better solutions in protecting aviation from weather disturbances. Plus, developed solutions make aircraft safer while safeguarding operational efficiency, which would make valuable contributions to society and industry.

—— Specifically, which weather phenomena does WEATHER-Eye Consortium deal with?

We're focusing on technologies for ice and snow, lightning, and volcanic ash. As for snow and ice, two research initiatives are underway. The first one is the "snow and ice monitoring sensor technology." Snowy runways can cause overrun accidents, diversions, and flight cancellation. JAXA has been developing sensor technologies* that enable the detection of runway snow and ice conditions in real time through a partnership with a sensor manufacturer and Kitami Institute of Technology. We are going to assess the performance of the technology in outdoor settings this winter by embedding the sensor systems in the ground at Kitami Institute of Technology in Hokkaido, Japan.

—— What about the scenario after the evaluation of performance?

Once the ground evaluation has demonstrated the feasibility and effectiveness of the sensor technology, we'll start receiving more detailed and specific demands from the prospective users: airlines, airports, and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), for example. Users' voices will help us improve technology to make further steps forward toward launching demonstrations on public roads in FY2018 and, eventually, on actual runways. Being able to work toward a common goal with users means a lot. Although it might create some added pressure, having users on board in the consortium allows us to gather valuable feedback and keep our innovations on course for society-wide implementation.

—— Airlines must be excited about this technology, which would help them greatly.

They definitely are—and we're determined to deliver what they're looking for. Another driver is the planned changes to the international regulations on the runway surface condition assessment, measurement, and reporting, which are going to go into effect in November 2020. In the conventional approach, the friction coefficient of a target runway is measured and then provided to passenger aircraft pilots, but the figures don't always match the actual runway surface conditions when the pilots make their landings. That's why there's a need to classify runway surface conditions from a more comprehensive standpoint, one that includes snow and ice type, depth, ambient temperature, and other key indicators instead of just the friction coefficient. The key is choosing the right types of information to base that classification on. Our sensor system can provide those types of data, which would help the MLIT set Japan-specific grading according to the new international regulation.

Accelerating R&D

—— What's the other part of the research on snow and ice?

The other piece is an "airframe anti/de-icing technology." Icing degrades the overall performances of aircraft, triggering causes of accidents. JAXA has been studying a hybrid ice protection system that combines an ice-phobic coating and an electro-thermal heater. The initial phase of the research was carried out under the EU-Japan framework project named JEDI-ACE (Japanese-European De-Icing Aircraft Collaborative Exploration). Hoping to turn

* A snow and ice monitoring sensor, which enables real-time monitoring of runway surface conditions such as snow accumulation and slipperiness; see FLIGHT PATH No. 11/12 for details.

that technology into a viable Japanese product, the second phase of the research on the hybrid icing-protection system is underway at the WEATHER-Eye Consortium.

—— How's the progress on the hybrid ice protection system?

We've been working with Fuji Heavy Industries Ltd. to develop ice-phobic coatings. Currently, we're examining several types of the coatings that we've come up with respectively—the JAXA coating and the Fuji Heavy Industries coating—by applying them on to the airframe of JAXA's Hisho research aircraft. To monitor and check if the coatings experience any deterioration due to sunlight exposure or the low-temperature and low-pressure environments that characterize real flight conditions, the experiment will continue throughout FY2018. Meanwhile, by the end of March 2017, we're going to perform experiments on a small-scale hybrid system using the icing wind tunnel at the Kanagawa Institute of Technology. Our plan for the year 2017 also includes a performance evaluation of a prototype system using a larger icing wind tunnel in the United States that can simulate conditions close to in-flight atmospheric icing. As we continue gathering sets of data to examine the feasibility of the technology, I'm confident that we'll be securely on our way toward a social contribution. I'm excited about the prospects.

—— That sounds like a fast-track effort.

The "snow and ice monitoring sensors technology" and "airframe anti/de-icing technology" are two of the fastest-moving parts of the WEATHER-Eye Consortium. We'll have to do a lot more to deliver practical results to users ahead of international competitors.

The importance of understanding needs

—— What about lightning?

Our lightning-related efforts include two types of approaches. One is the "tactical lightning avoidance technology," which makes it possible to detect lightning hazard area in advance, and the other is the "anti-lightning technology," which mitigates the damage to airframes when they experience lightning strikes.

For "tactical lightning avoidance technology," JAXA is collaborating with the Meteorological Research Institute (MRI) to gather lightning-specific meteorological data from MRI's weather radar and a lightning-monitoring systems.

The coastline along the Sea of Japan tends to experience "winter lightning," while the Pacific coast sees considerable amounts of lightning in the summer. To accumulate a sizable amount of data, a series of meteorological observations is underway at several places prone to those phenomena—at Shonai Airport (located on the Japan Sea side) in the winters of 2016 and 2017, and at some places in the Kanto region in the summers of 2016 and 2017.

In parallel, we are making collaborative efforts with the MRI in developing software that uses algorithms to detect lightning hazardous areas in advance to estimate which kinds of meteorological conditions are likely to trigger lightning strikes to airplanes. If we can develop a viable solution for forecasting lightning strikes, passenger aircraft will be able to avoid hazardous areas more easily.

——How about research on volcanic ash?

Japan is home to numerous volcanoes, and airlines are sensitive about volcanic eruptions because they can cause severe damage to aircraft and operations. Especially, engines can suffer severe damage if they ingest too much volcanic ash, and, needless to say, the simplest and most fundamental measure is to avoid volcanic clouds. There'd been very little research into volcanic ash at JAXA until we

The snow and ice monitoring sensor installed at Kitami Institute of Technology (Top: Construction in progress; Bottom: Installation site)

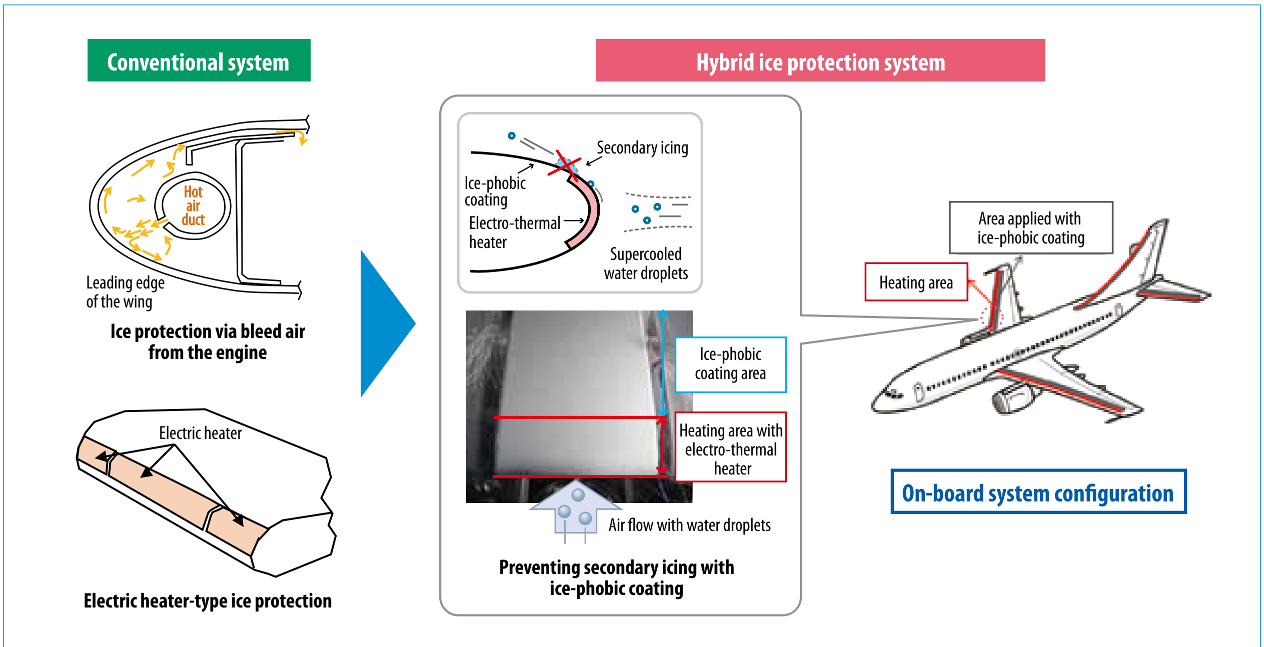
got into discussions about the WEATHER-Eye Consortium and started seeing how important the issue was. For our first step, we're now looking into simulation technology to help elucidate what might happen inside the engine when it ingests volcanic ash.

—— It sounds like user needs are the driving forces behind the research at the WEATHER-Eye Consortium.

That's the distinctive feature of the WEATHER-Eye Consortium. Users obviously won't be able to utilize technologies or products that aren't useful to them. That's why we're building our effort as much as possible around real and practical needs.

—— Do you think the WEATHER-Eye Consortium is going to make a big impact?

I believe so. I already see a positive effect of open innovation. We're charting a much straighter course toward



Applying a riblet coating to an actual-size aircraft mockup (joint research with Tokyo Metropolitan University; the red rectangle corresponds to the coating area)

social implementation than the path in a conventional R&D approach in JAXA.

Eco-Wing technology: Reducing the burden on the environment

—— What other research are you working on besides WEATHER-Eye?

We have the "Eco-Wing" initiative, which focuses on developing aviation technologies that reduce aircraft's environmental load by improving fuel efficiency, cutting down on CO_2 emissions, and reducing noise levels. I think it's the area where open innovation should play a major role in developing practical solutions.

Here, let me introduce two research activities under the Eco-Wing initiative. The first one is our "Flight Investigation of skiN friction-reducing Eco-coating (FINE)." Reducing air-induced skin friction on aircraft surfaces boosts fuel efficiency, and researchers have found that there are several effective ways to do that: You can coat the surface of an airframe with a "riblet" pattern of ultra-fine streamwise grooves, for example, or cover the airframe with a sheet of such grooves. JAXA has studied the riblet height and angle, investigated optimal riblet configurations, and even applied for a patent. The big issue for realizing the riblet is that knowing the ideal riblet configuration doesn't do much good if you can't actually apply it on an airframe—a step that requires the help of a specialist in coating methods. That's where the open-innovation approach of the Aeronautical Innovation Hub Center comes in, making it easier to get over that barrier and create real, practical solutions for society at large. We want to give manufacturers and users tangible results as fast as we can, so our plan for 2017 and 2018 is to use the eco-coating on "Hisho" and get some flight data on the drag reductions.

The other research that can really benefit from open innovation is our "High performance Optical fiber sensor flight Tests for AirpLane Wing (HOTALW)," which centers on technology for measuring aircraft wing deformation. We just completed our first HOTALW flight test in November 2016, actually. Aircraft wings have to be designed under a delicate balancing methodology: A wing naturally bends due to aerodynamic force, but erring on the side of caution and making the wing too strong can lead to increased weight and inefficient fuel usage. To design the optimal wing, then, manufacturers need to have a good grasp of how much the wing deforms. That knowledge makes it possible to develop thin, light wings capable of adapting to situations where sudden gusts of wind create increases in aerodynamic load. For our research, we use optical fibers on the wing surface to determine the distribution of the deformation that the wing experiences—and that process, once again, involves drawing on assistance from outside the aviation sector. Our open-innovation approach has enabled us to work with a sensor manufacturer that boasts expertise in what we're looking for, thereby facilitating the overall effort.

Technologies for aircraft component certification: A crucial area for the Japanese aircraft industry

——Another point we'd like to hear your thoughts on is your research for securing aircraft component certification, an area where the Aeronautical Innovation Hub Center seems to start devoting a lot of energy.

Japanese aircraft component manufacturers boast a wealth of sophisticated technologies, but getting their products into actual aircraft entails obtaining official certification—a step requiring an environment for certification that few small- and medium-sized individual manufacturers have access to. For component manufacturers, that's a huge roadblock. To help companies clear that hurdle, we're going to keep developing software libraries and other resources for companies to use on a shared, common basis. The challenges of the certification process go beyond technological resources, too: It's hard to navigate all the complicated procedures without a solid base of experience. By working together with component manufacturers, pooling together valuable experience, and sharing that insight with members of the component manufacturer community in Japan, JAXA can lower the threshold to successful certification.

——And that's JAXA's responsibility.

Yes—and it's something that the Aeronautical Innovation Hub Center allows us to do. The certification process hadn't been a part of JAXA's research agenda until the Aeronautical Innovation Hub Center took shape. Considering what the center should do, I knew that certification could be a great area to venture into. To boost overall sales and keep performance climbing, the Japanese aircraft industry needs component manufacturers to expand their businesses.

Forward-looking technologies in long-term R&D

—— What other kinds of research efforts are you hoping to see at the Aeronautical Innovation Hub Center?

I want to keep tackling technologies with a focus on the long-term future. Emission-free aircraft technology, for example, is something we might be able to do years and years down the road. Imagine the breakthrough that we could achieve if we succeeded in making aircraft completely electric and capable of running on renewable energy—we'd have access to amazing, emission-free air transportation. For these kinds of forward-looking initiatives with the potential for significant social impact, we're going to rely heavily on open innovation with players from other fields to get the cutting-edge technologies we're looking for. Future-oriented technologies like emission-free aircraft are exactly what we envisioned when we made delivering "high-impact" results one of our three policies.

—— What are your hopes and goals for the future?

It's important for the Next Generation Aeronautical Innovation Hub Center to produce a steady stream of tangible output, in particular, from FY2016 onward. As we start producing tangible results, I'm sure we'll start seeing new needs emerge. Likewise, as we bring in new technologies from other fields, we'll be able to do things we've never been able to do. We at the Aeronautical Innovation Hub Center can really make a real difference if we keep those types of activities growing—and producing results that benefit the world. That's the kind of positive, virtuous cycle we're aiming for.

http://www.aero.jaxa.jp/eng/about/hub/index.html

Airlines

All Nippon Airways Co., Ltd.
JAL Engineering Co., Ltd.
Japan Airlines Co., Ltd.

Manufacturers

Fuji Heavy Industries Ltd.
Nihon Tokushu Toryo Co., Ltd.
Sentencia Corporation

Universities

Kanagawa Institute of Technology
Kansai University
Kitami Institute of Technology
Nagoya University National Composites Center
Osaka University
Tokyo University of Agriculture and Technology
Tokyo University of Science
University of Tokyo
Yamagata University

Public research institutions

Civil Engineering Research Institute for Cold Region(CERI)
Japan Aerospace Exploration Agency(JAXA)
Meteorological Research Institute(MRI)

18 member organizations of the WEATHER-Eye Consortium
(6 companies, 3 research institutions, and 9 universities)

Improving air safety with open innovation approach

The WEATHER-Eye Consortium

By incorporating diverse knowledge and insights across disciplines and sectors, the WEATHER-Eye Consortium aims at developing integrated and practical solutions to protect aircraft from weather issues such as snow, ice, lightning, and volcanic ash.

Protecting aircraft from special weather conditions

JAXA promotes open innovation, encouraging the flexible use of knowledge from outside the aeronautics field to tackle research themes at the Next Generation Aeronautical Innovation Hub Center. An example of JAXA's strategic approach to open innovation is the WEATHER-Eye technology.

Aircraft accidents often involve weather-related factors, including sudden airflow changes like wind shear and microbursts. Meteorological conditions have a substantial impact on aircraft operating efficiency, as well: Airframe icing can result in delayed takeoffs, while runway snow can cause cancellations and diversions. Lightning strikes also cause more damage to composite airframes than conventional metallic airframes, requiring longer repair times to fix. Minimizing and avoiding the effects of weather would thus not only enhance aircraft safety but also improve overall aircraft operational efficiency.

To enable an integral and open approach in developing the WEATHER-Eye technology, the WEATHER-Eye Consortium was launched on January 15, 2016, upon the agreement of 18 member organizations.

Creating a shared vision to work toward a common goal

The WEATHER-Eye Consortium brings together a wide variety of knowledge and ideas across fields and sectors, including airlines, manufacturers, weather-related organizations, and civil engineering institutions. To share the same vision for the future, the Consortium has compiled a list of problems that occur under special weather conditions, evaluated the corresponding risks, and used the results to lay out key themes (see the Table below). The members have also formulated a road map for short-term (3- to 5-year), medium-term (10-year) and long-term (roughly 20-year) goals, moving from technological development in the near future to technological demonstration and, ultimately, social implementation. Through the process, the members have also reaffirmed that efforts to develop the WEATHER-Eye technology will be instrumental in helping Japan's aircraft-related industries sharpen their competitive edges.

The WEATHER-Eye Open Forum

The Consortium presented its future vision at the "1st WEATHER-Eye Open Forum: Protecting aviation from special weather conditions (snow, ice, lightning, and volcanic ash)," held at the University of Tokyo's Takeda Hall on September 27, 2016.

Comprising of two parts, the Open Forum aimed to help identifying new partners for aiding in the problem-solving process and locating latent and more diverse user needs.

The first part introduced the WEATHER-Eye Consortium's vision and addressed the expectations of user representatives from the public and private sectors. Norio Okada from the Japan Civil Aviation Bureau explored the possible benefits from the regulatory side, speaking on behalf of Japan's civil aviation authority, while Masami Ichikawa from the Japan Airlines Co., Ltd. addressed weather-related technologies from a pilot's perspective. The second part included a series of presentations that introduced ongoing research efforts to develop solutions corresponding to various weather-related factors (see below).

The Open Forum successfully drew even wider attention from various fields, including information, communications, architecture, engineering, and electricity. The ideas exchanged at the Open Forum will be incorporated into the discussion at the WEATHER-Eye Consortium to create even better outcomes that benefit both industry and society at large.

The WEATHER-Eye Open Forum: lectures and presentations

- **Preventing overrun accidents caused by snow accumulation**
  Hirokazu Ohmae (Sentencia Corporation)
- **Ensuring safety through icing-prevention measures**
  Takeshi Yoshida (Fuji Heavy Industries Ltd. Aerospace Company)
- **Preventing accidents caused by turbulence**
  Naoki Matayoshi (JAXA Aeronautical Technology Directorate)
- **Mitigating the risks of lightning strikes**
  Ken'ichi Kusunoki (Meteorological Research Institute of the Japan Meteorological Agency)
- **Safeguarding against airframe damage caused by lightning strikes**
  Tomohiro Yokozeki (The University of Tokyo School of Engineering)
- **Protecting engines from ingesting debris (ice crystals, volcanic ash, and more)**
  Shigeru Tachibana (JAXA Aeronautical Technology Directorate)

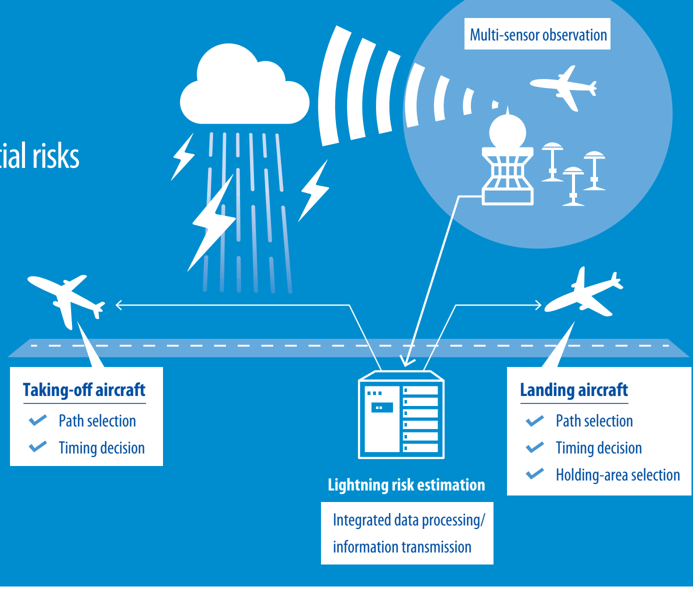
Key themes for the WEATHER-Eye Consortium

Phenomenon	Resulting problems
Runway snow/ice	Flight cancellations and overrun accidents, etc.
Airframe icing	Loss of lift and increased fuel consumption, etc.
Turbulence	Reduced flight control, etc.
Low-level wind shear	Reduced flight control, etc.
Lightning strikes	Structural damage, etc.
Ice crystal ingestion	Sensor malfunctions and loss of thrust, etc.
Supercooled water droplet ingestion	Internal damage and loss of thrust, etc.
Fog	Flight delays and cancellations, etc.
Cosmic rays	Disabled equipment, etc.

Attended by 184 participants from a diverse mix of fields, the WEATHER-Eye Open Forum stimulated lively discussions among presenters and participants.

Technology for detecting lightning-hazard areas and estimating potential risks

Tactical lightning avoidance technology



JAXA's research on tactical lightning avoidance technology focuses primarily on feasibility studies of an airport-based support system that provides taking-off or landing aircraft with lightning avoidance information. Eiichi Yoshikawa, researcher at the Next Generation Aeronautical Innovation Hub Center, provides an overview and discusses the challenges of the tactical lightning avoidance technology, which forms a part of the WEATHER-Eye initiative.

How lightning affects aircraft operations

Everyone knows what lightning looks and feels like: a flash of light bolts through the sky as a rumble of thunder rattles the air. A bolt of lightning is more than just a visual and aural jolt, however—the energy of a lightning strike is also powerful enough to split a tree in two. Lightning is an electrical discharge phenomenon that occurs because of an electric potential difference. When ice particles in a cloud (hail and crystals) collide, those particles are electrically charged, and the cloud takes on positive and negative charges. When the charge amount exceeds a certain threshold, a lightning discharge occurs. Although most people probably assume that a bolt of lightning always extends downward from a cloud until it reaches the ground, most lightning occurs entirely inside clouds—and some can even strike airplanes.

An aircraft in the en-route phase can easily adjust its flight path to keep sufficient distance from thunder clouds and avoid lightning strikes. Even if the aircraft suffers a lightning strike, the event almost never causes a fatal accident because aircraft are designed and built with strict certifications for lightning endurance—but the phenomenon can be more challenging to deal with in other phases. "It's harder to avoid thunderstorms during takeoff and landing phases, first of all," Yoshikawa explains. "Even though a lightning strike may never be the direct cause of an accident, the resulting damage still creates the need for repairs that can hamper aircraft operations."

Until very recently, research on the relationships between lightning and aircraft attracted minimal attention among the global community. Not only did observation equipment lack the high-resolution capabilities to gather detailed readings of thunderclouds, but the fact that lightning never directly triggered a significant incident in civil aviation relegated the phenomenon to a relatively low profile in research circles. However, the circumstances have been changing along with the increase in the use of composite materials in aircraft. A lightning strike can have a powerful impact on composite materials, making the repair process much more time-consuming for a composite material-based aircraft than it is for a standard metallic unit. To ensure efficient operations, aircraft need to avoid lightning strikes wherever possible.

Collaboration beyond aeronautics

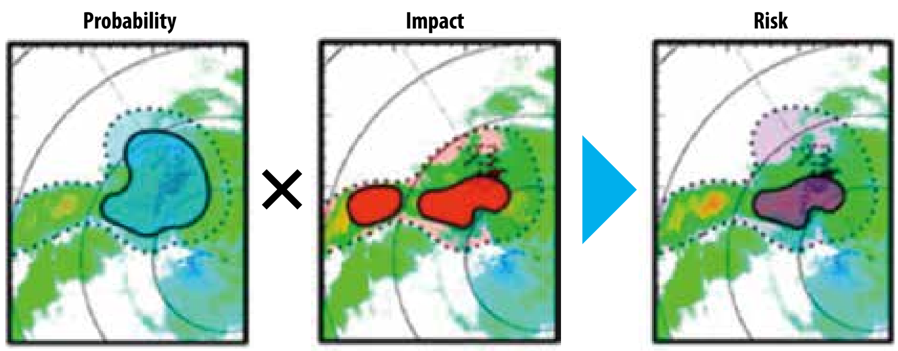
JAXA has been addressing aviation weather information technology. Although lighting has not been part of past research initiatives such as the DREAMS Project, which ran through FY2015, JAXA has long been gathering input on aircraft lightning strikes from relevant parties such as airlines, manufacturers, universities, other research institutes, the Ministry of Land, Infrastructure, Transport and Tourism Civil Aviation Bureau, the Japan Meteorological Agency, and other sources. To turn that base of knowledge into a tangible technology, JAXA has decided to launch a research initiative named "tactical lightning avoidance technology" beginning in FY2017. With this initiative, we are going to develop an airport-based support system that detects lightning-hazard areas and estimates potential risks.

The tactical lightning avoidance technology is based on a three-party collaboration of JAXA, the Meteorological Research Institute (MRI), and the Electronic Navigation Research Institute (ENRI). The MRI offers high-level knowledge pertaining to atmospheric phenomena of all kinds, including lightning discharge. What JAXA brings to the table, meanwhile, is its expertise in evaluating how discharge phenomena affect airframes and flight. Completing the collaborative structure is ENRI, which is adept at assessing the effects of weather on aircraft operations. By gathering their resources, the three partners have what it takes to address the issue of aircraft lightning strikes from a comprehensive, integrated standpoint. JAXA is planning to expand the collaborative arrangement beyond the MRI and ENRI, as well, intending to get multiple universities on board as the project moves forward. For FY2017, the plan is to determine the feasibility of the target technologies. Although the research effort is just getting off the ground, the ultimate goal is clear: create a system that integrates a wide variety of meteorological data, displays lightning information on a map-based interface, and gives users a clear, intuitive picture of potential lightning hotspots without the need for any special technical knowledge.

Refining Japan's unique technology

In Japanese, lightning also goes by the name of inazuma, a kanji compound that contains the character for "rice plant" (ina). The word is said to be derived from the fact that lightning is most common during the period when rice plants are in bloom (summer to fall), but lightning can occur during other seasons. "Winter lightning," for example, is a relatively rare phenomenon that occurs in just two areas in the entire world: the Sea of Japan coastline and a portion of the Norwegian coastline. Bursting with energy 20 to 100 times more powerful than normal summer lightning, winter lightning is thus a much more potent threat to aircraft. That makes the ability to locate lightning-prone areas particularly important in locations where winter lightning occurs; as Yoshikawa explains, "JAXA's lightning detection system would definitely be a big help for airports along the Sea of Japan."

Although researchers abroad are also working on tactical weather support, most of the projects focus on detecting rain and clouds (for storms)—not the occurrence of lightning itself. Even if the aircraft avoids cumulonimbus clouds, it can still experience lightning strikes. Researchers are already aware that aircraft-initiated lightning is a frequent occurrence—and JAXA's efforts will have to take those types of conditions into careful consideration. The process of gathering massive volumes of data, analyzing the findings, and building a reliable system will obviously be a challenge. If we can clear those hurdles and develop feasible results, we will be able to showcase and cultivate the technology as a unique Japanese achievement.



A conceptualization of the lightning weather information interface; "impact" refers to the potential intensity of a lightning strike or potential damage to the aircraft.

JAXA's aFJR (Advanced Fan Jet Research) project is about to deliver tangible results for both the fan and low pressure turbine components as the team gears up with industry players for its final demonstration tests in FY2017. This article introduces a special talk on the latest project progress.

Special talk

Kuniyuki Imanari IHI Corporation × **Toshio Nishizawa** JAXA

Feature Story


Kuniyuki Imanari (IHI) (Left), stands with Toshio Nishizawa(JAXA) (Right) in front of the RJ500 engine

The aFJR (Advanced Fan Jet Research) project

Taking aircraft engine development in a new direction

Japan's high-bypass-ratio engine development began with the FJR710

—— Let's take a look back at how jet-engine development evolved up to the aFJR project. Was the FJR710 the first step?

Nishizawa: It was. The FJR710 was a project by METI, the Ministry of Economy, Trade and Industry (then MITI, the Ministry of International Trade and Industry), and it marked Japan's first foray into developing high-bypass-ratio engines. The government invested a substantial budget into the project, which produced an engine that we eventually installed on the "Asuka"*1 experimental STOL aircraft for flight tests. Through these initiatives, many engine-testing facilities were built at JAXA (then the NAL), and the engine industry really started to grow. The FJR710 paved the way for Japanese manufacturers to get involved in the international project to develop the V2500.

Imanari: The V2500 is nearing the end of its run, with a new engine model set to take its place, but it had an impressive, best-selling track record with sales of over 7,000 units.

Nishizawa: That's a pretty amazing number, isn't it? The V2500 hit the market in the late 1980s, which means that it took about 20 years to develop after the FJR710 project got going in 1971.

Imanari: That's generally how it goes in the aircraft engine world. You normally have to put 20 years of R&D into a project before it produces an actual engine. Technological development starts to hit full gear about 10 years into the project, with engine development only getting off the ground about 15 years after the launch of initial research. Basically, you need to have good, viable technology—something that people can see promise in—a decade in advance. To get to the point where you have advanced, globally competitive technologies a full 10 years before the final product takes shape, you have to get the research process started 20 years out. That gives you enough time to push things far enough forward and steer the project through any complications.

Nishizawa: I don't know how clearly the FJR710 team was envisioning the V2500 market when the project got started, but one thing's for sure: The timing was great.

Imanari: After the FJR710 performed extremely well during its test operations in the UK, Rolls-Royce came forward with an offer to work on the engine together. That laid the groundwork for the RJ500 project, which later expanded to include collaborators in five countries and become the V2500 development project. Once the V2500 was ready, Airbus signed on to install the engine. Japan was lucky to be part of that joint-development initiative—and without the FJR710, I don't think that luck would've ever come around.

—— So the team wasn't actually aiming to install the FJR710 on Asuka?

Nishizawa: Not as far as I know. The FJR710 was a MITI project, but Asuka was an initiative at the Science and Technology Agency—an NAL-led effort. The Asuka team probably had other engine options, I imagine, but they ended up installing the FJR710 and using it for flight demonstrations. That was a big step for Japanese engine development.

The advent of supercomputer-based simulations

—— JAXA continued to press forward with research on the METI-led HYPR and ESPR engines projects for supersonic transport. Did the FJR710 development initiative have an impact on those efforts?

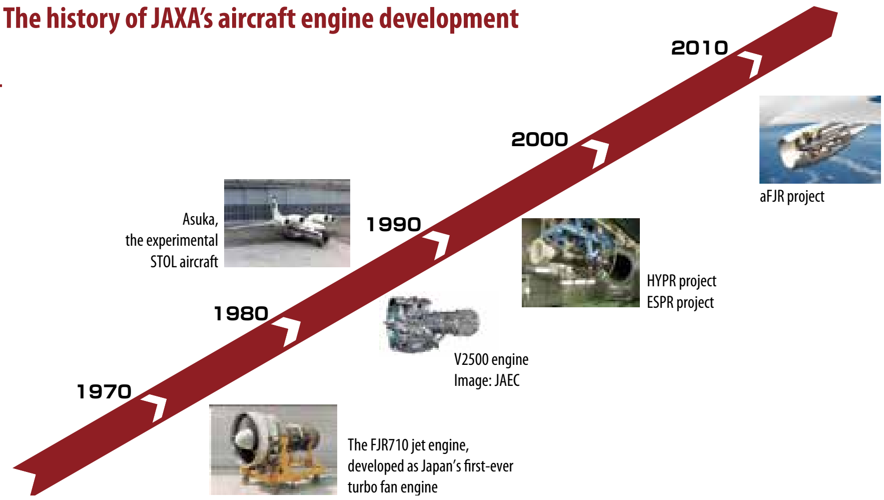
Nishizawa: The HYPR and ESPR engines look different from the FJR710 because of their different target speeds (Mach 5 and Mach 3, respectively), but they both utilize technologies that came out of the FJR710 project. When work began on the HYPR and ESPR, JAXA was just getting started with supercomputer-based engine simulation—something that didn't exist during the FJR710 initiative. I think the HYPR and ESPR came along right around the time when simulations were occupying bigger and bigger roles in what we were doing.

Imanari: Around the time of the HYPR project, we were actually working under joint-development arrangements with some foreign manufacturers. When they saw the

Kuniyuki Imanari
Deputy Division Director
Research & Engineering Division
Aero-Engine & Space Operations
IHI Corporation

*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.

The history of JAXA's aircraft engine development



calculations from the NAL supercomputer, which we were using at the time, they couldn't believe how fast we were coming up with our results. Those manufacturers were world-class firms, too—and even they couldn't keep up. Japan was a cut above the rest when it came to computational fluid dynamics (CFD).

Nishizawa: At the time, the NAL supercomputer was consistently at the top of the world benchmark rankings. That resource gave researchers what they needed to do some really challenging, high-level work.

Imanari: We're still using JAXA's CFD software for our design efforts. The low-pressure compressor for the successor to the V2500 engine was one example. In the new "geared turbofan" engine type, there's a reduction gear between the fan blades and the low-pressure compressor. To make sure that the gear in the engine moves smoothly, you have to supply and drain oil through the frame. The lubricant—hot oil—flows through the frame near the compressor's upstream sector. In designing the engine, we needed to figure out how the heat transfer from the frame to the mainstream would affect engine performance. That's where JAXA's technology came in, allowing us to simulate the conditions and do a quantitative assessment of the resulting impact. Without that capability, the process would've been much more challenging.

Nishizawa: Simulation technology is extremely valuable when you're dealing with special conditions that make element tests hard to do.

—— The eco-engine research project came along after that.

Imanari: The eco-engine was another METI project where manufacturers got to pursue their own ideas for different parts. For the combustor, though, there were three companies vying for the spot. We had to make a competitive proposal, and we decided to use JAXA facilities for our testing procedures. When I think back about the connections between IHI and JAXA during the eco-engine project, that's what I remember most.

Nishizawa: The project didn't produce an actual engine in the end, but it was instrumental in bringing existing technologies into the new millennium. The low-pressure system at the heart of the aFJR initiative, for example, wouldn't have been possible without the fan and simulation technologies that came out of the eco-engine project. That basis let us take the next step forward—and that's a pattern of progress that depends on programs for passing technologies along.

Today's R&D make tomorrow's aircraft engines possible

—— Why is JAXA working on the aFJR project now?

Nishizawa: We're targeting a small-sized aircraft for 150-passengers—a type that has a big share of today's aircraft market. We estimate that airlines are going to be switching over to new fleets between 2025 and 2030. For Japan to develop competitive technologies in the run-up to that transition, we figured that we'd have to launch the effort now. As we got talking with manufacturers, we identified some target technology areas: low-pressure system consisted of fans and low-pressure turbines. Our meetings with different players in the manufacturing industry helped us identify solid candidates and narrow the field down to a smaller group of research elements.

—— Does JAXA's approach fit with the market outlook from a manufacturer's point of view?

Imanari: It sounds about right to me, yes. Assuming that the transition is going to happen between 2025 and 2030, you'd need to give yourself 10 years for front loading—which would mean starting now. Low-pressure systems are IHI's biggest strong suit at the moment, so we started thinking about how to get a competitive edge in that arena. We eventually decided to focus on composite materials: carbon fiber-reinforced plastics (CFRP) for fans and ceramic matrix composites (CMC)*2 for low-pressure turbines. Another component that we wanted to concentrate on was the metal "disk," the circular part that supports the fan blades. Developing a good disk requires solid all-around technological capabilities, especially considering that fan disk failures can cause serious problems. When we were working on the V2500, we didn't have the kind of technical prowess we needed. That shortcoming got to me, I guess; I knew I wouldn't feel comfortable until we could do the job right ourselves. Then this project came along, giving us the perfect opportunity to get where we had to be to design and manufacture the metal disks on our own. By focusing on composite materials and integrating things like aerodynamic, structural, and noise-reduction technologies, we wanted to put ourselves in position to make our fan modules more competitive in the market.

—— It's important project for IHI.

Imanari: It is. Increasing the high bypass ratio leads to a larger fan diameter in a turbofan engine, but it also adds to the overall weight. That makes CFRP, which boasts impressive strength levels in lightweight configurations, an ideal material. Composite materials are where IHI excels—we successfully used composite materials for the fan exit structural guide vane and fan casing of the PW1100G-JM engine, an achievement that put us in charge of designing and manufacturing those components. The fan blades are still metallic, and that just gives IHI another target to shoot for. We've got our sights set on making CFRP blades a reality as soon as we can. That last

An overview of the aFJR project

Global warming, the depletion of oil reserves, and other problems have led to stricter global environmental standards in many fields, and the aviation sector is no exception. Aircraft engines, for example, now need to deliver improved fuel efficiency, reduce CO_2 and NOx emissions, and limit engine noise levels. Through the development of next-generation engine technologies, JAXA is aiming to help reduce the environmental impact of future aircraft—and the aFJR project is one part of that mission.

The goal of the aFJR project is to develop and demonstrate technologies that can enhance the environmental compatibility of fans and low-pressure turbines. Japanese manufacturers have extensive experience in these two components. The team will aim for a technical level that can help Japan spearhead the design portions of joint international development projects for next-generation aircraft engines. To achieve that goal, the aFJR project is a collaborative effort, with IHI as an industry player and universities from academia playing important roles.

Toshio Nishizawa
Project Manager
aFJR Project Team
JAXA

*2 Lighter than metal, resistant to heat, and resistant to oxidation, CMC material also includes ceramic fibers that help prevent cracking. See FLIGHT PATH No. 9/10 for more information.

piece of the puzzle is the metal disk. If we can handle the disk, we'll be able to design every element of our fan module.

Nishizawa: Disks are "life-limited parts," which means that they have to be replaced after a certain amount of service time. The potential for profitable returns is there, obviously, considering that disks will continue to generate revenues through maintenance work after users purchase engines. In that sense, disks can help expand the scale of the industry.

Taking advantage of the synergy between JAXA and the manufacturing sector

—— Are materials the central focus of the aFJR effort, then?

Nishizawa: Yes. In terms of the fan, IHI is handling the CFRP material development, and manufacturers are already doing work on the fan blade molds. The task for the aFJR project team is to find ways of making the designs hollow. For the disk, meanwhile, the effort is going to focus on researching the trade-off between lightweight designs and lifespan. JAXA's in charge of getting the component into proper position for manufacturers, who will then add in extra features to get the design ready for the market. It's a collaborative arrangement between JAXA and the manufacturing sector, one that can help the product reap the benefits of synergy. Our effort is paying attention to trends abroad, too.

—— Besides materials, what are the other key technological features of the aFJR project?

Imanari: When you're dealing with high bypass ratios in this class, you can laminarize the fan flow to boost efficiency. That's exactly what we're doing for this project. We've managed to show just how much of a positive effect laminarization can have. From my perspective, it's really important output.

Another one of our breakthroughs has to do with "flutter," a type of vibration phenomenon that people normally associate with fans. Theoretically, turbines are also susceptible to flutter. We take steps to make sure flutter doesn't happen, but the phenomenon gets harder to deal with in lighter designs—the lighter you go, the more flutter you see. That's where JAXA's CFD proved useful once again, allowing us to identify the optimal countermeasures. The aFJR turbine also uses CMC, an innovative new material. The only problem with using a new material is that there's no available data on it. With CFD, we had a great solution for making better predictions of how flutter would happen. It was amazing how accurate the results were, especially compared to where they used to be. I think we can be pretty proud of that progress. We're definitely on a competitive playing field with Europe and the United States now.

Nishizawa: The goal of predicting flutter with simulation technology led the project team down an unconventional path. We ended up using the altitude test facility, designed for a totally different purpose, as a wind tunnel for assessing turbine flutter. That transformed the test setup into a kind of demonstration facility, giving the simulations an even higher level of reliability.

—— Where is the aFJR project at right now, in terms of overall progress?

Nishizawa: We're doing our final demonstrations for each element. In early 2016, we finished validating the foundations for the technologies that we need to incorporate into the prototypes for demonstration. The stage we're at right now involves designing each prototype, one by one. JAXA's done reviewing the designs for around 80% of the target components, which means that we've started prototyping those pieces. The design process for the remaining 20% is going to wrap up by the end of FY2016. After that, we'll test the validity of the developed prototypes and then go step by step through the final tests during FY2017. That'll bring everything together at the end of 2017. We'll do our final evaluations to determine how the improvements in fan and low-pressure turbine performance can boost the fuel efficiency of the complete engine. Right now, we're basically a step away from finishing the project off.

—— How has the experience been for IHI?

Imanari: In a word, great. The project has been such a valuable experience. The tough thing about aircraft engine development is that you only get one chance ever 20 years or so. Timing is important. You need to make everything line up right in the end. Putting all your eggs in one basket isn't the only approach, though. There's always the potential for using the output of the project in upgrades to the current engines. That's another thing we try to keep in mind. I think we're almost ready to pounce on any opportunity to use what we've come up with. With long-term research on one side and short-term applications on the other, we're hoping to maintain a dual stance on making the most of our efforts.

An F7 engine as an engine test bed

—— JAXA is going to introduce a new engine test bed, an F7-10 engine.

Nishizawa: The F7-10 engine is the 100% made-in-Japan turbofan engine that the Acquisition, Technology & Logistics Agency developed. It will take demonstrations to the next level and help sharpen the competitive edge of Japan's engine component technologies.

Imanari: When you work with the major engine manufacturers in the global market, they tend to propose joint-development projects if the collaboration can either generate new added value or bring manufacturing costs down. Focusing on cutting costs doesn't make for good business, so we're going to keep pushing the added-value angle. Here, manufacturing partners' concerns center on whether new features are really feasible in terms of performance and reliability. The best way to put those concerns to rest is to install the added-value component in an actual engine, run the setup, and show the partners exactly how things went. Technical demonstration results are huge difference-makers; if you can't prove viability with hard, valid data, potential collaborators can get hesitant. The F7-10 engine to be installed at JAXA will be a big asset as a civil engine demonstration platform.

Nishizawa: You're definitely right. We've known for a long time about the difference between having and not having that kind of engine test bed. Why did the FJR710 evolve into the V2500? One of the biggest reasons was that we had Asuka, our own infrastructure, to do the demonstrations on. If we were going to try to follow in those footsteps, we needed an F7-10 engine test bed that'd suit today's technological levels.

—— What kinds of outcomes has the aFJR project had so far?

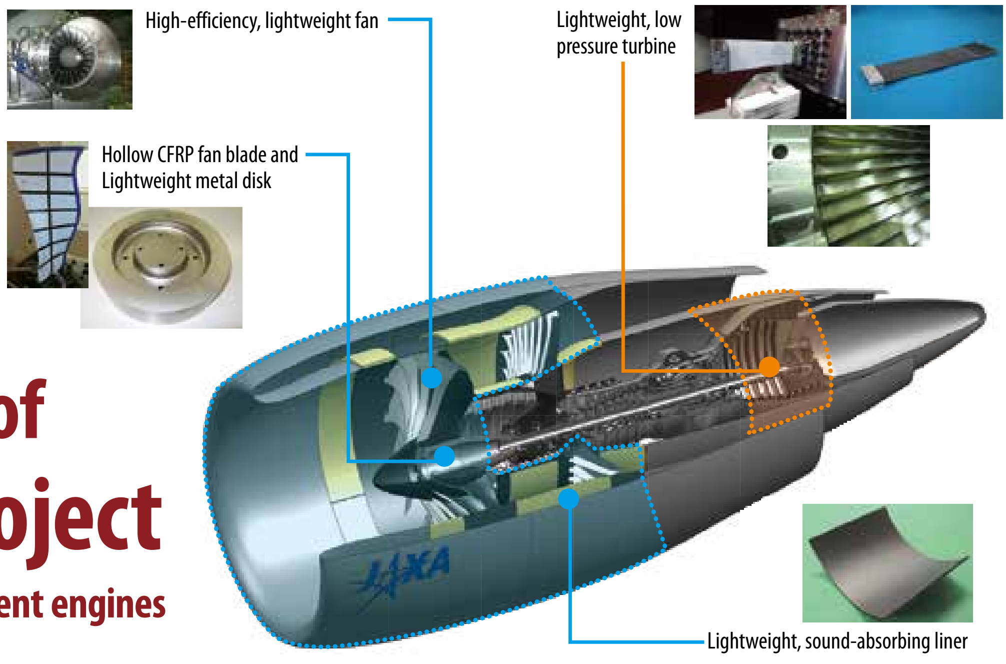
Nishizawa: I think it's had two big effects. First of all, it's changed the way JAXA tackles research and development. We have usually based our operations around basic or fundamental research, but the aFJR project embraces a different approach. The end vision—making a jet engine, installing it, and flying the aircraft—is shaping everything we're doing. It's a more applied style. Under the aFJR framework, the demonstration data at the element level is going to be an integral resource in the subsequent, manufacturer-led phases.

The other thing we've seen come out of the aFJR project is a new approach for projects to take. We're working with manufacturers and universities through joint-research arrangements. Whereas previous collaborations have operated along the boundaries of individual research areas, with each project focusing on one specific field, the aFJR project unites a variety of fields together in the pursuit of a single goal: making a turbofan engine. JAXA hasn't really done that type of research and development before—and that makes it a big step forward, I think.

Imanari: We joined the aFJR project because we wanted to bolster our strengths in low-pressure systems. Being part of the project has given us an amazing opportunity to create an innovative model with such a diverse makeup. We're taking the technologies that the aFJR team has created, the things we've developed with other organizations besides JAXA, and all the unique research by different manufacturers and putting everything into the F7-10 engine, validating the results, and making proposals to Western engine manufacturers. It's a really dynamic process—and if it goes well, I think it'll give JAXA a blueprint for its next project. I hope JAXA keeps the momentum going.

Technologies of the aFJR project

Creating lightweight, efficient engines

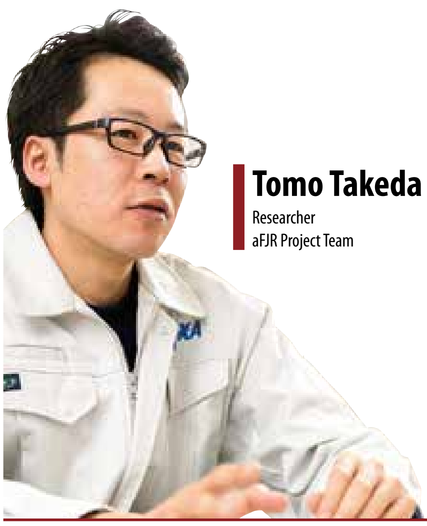


The goal of the aFJR project is to develop technologies for a next-generation engine that has higher efficiency levels and weighs around 10% less than existing engines. This section introduces four different technological endeavors of the aFJR project: high-efficiency, lightweight fan technology, lightweight disk technology, lightweight, sound-absorbing liner technology, and lightweight, low-pressure turbine technology.

High-efficiency, lightweight fan technology

Making fans lighter through new approaches to materials and Structures

Recent demands for more fuel-efficient turbofan engines in various types of aircraft, including passenger jets, have led manufacturers to pursue higher-bypass-ratio*1 designs. Increasing the bypass ratio of an engine, however, generates larger volumes of air intake—and thus leads to larger fan diameters. When fans get larger, engines get heavier; and when engines get heavier, the airframes supporting the engines follow suit, considering that they need the sufficient rigidity. As a result, the increase in overall weight can end up offsetting the improvements in fuel efficiency.



Tomo Takeda
Researcher
aFJR Project Team

To create engines with high-bypass ratios and better fuel-efficient performance, then, manufacturers need technologies for reducing engine weight.

"We're trying to make engines lighter by replacing metallic fan blade designs with carbon fiber reinforced plastic (CFRP)-based designs," says Tomo Takeda, who leads the effort on lighter fan technologies at JAXA. The project involves other goals, too: using a hollow structure for the CFRP fan blade interiors, which makes the engine lighter, and designing a structure capable of withstanding bird strikes and other forms of impact.

"For our impact simulations to estimate impact-resistance performance, we started out by working with several university partners to build complete fan blade models," Takeda explains. "We then used computer technologies like JAXA's supercomputers and RIKEN's 'K' supercomputer to do an enormous amount of calculations—more than we've ever done before." As they conducted the many tests and calculations, JAXA researchers drew on the results to modify the structure of the hollow portions of the fan blades and making important advances toward a lightweight fan blade design with good impact resistance.

Rethinking fan blade configurations from an aerodynamic perspective

The aFJR project is about more than making fans lighter—improving overall aerodynamic efficiency is another part of the initiative. With the "3D laminar flow blade design," says Daisaku Masaki, who leads the effort to enhance fan efficiency, "we're working to develop fan blades with better efficiency by optimizing the configurations of fan blades from an aerodynamic standpoint." In concrete terms, the team is working to improve aerodynamic efficiency by creating a configuration that extends the laminar boundary layer on wider sections of the fan blade surface. The air in a laminar boundary layer flows in a smooth, orderly fashion without turbulent eddy, thereby reducing the resistance drag on the blade surface and improving overall efficiency. While the tip of a fan blade also generates shock waves, higher bypass ratios help neutralize that problem: A high-bypass-ratio engine makes fan diameter larger, which makes optimum pressure rate ratio lower and reduces the rotating speed of the fan, thereby weakening—or even eliminating—the shockwaves coming from the blades and its loss. If the engine fan blade can keep tip shockwaves under proper control through a 3D design, the laminar boundary layers on the surfaces of the fan blades last longer. JAXA is using the results of the Clean Engine Project, which aimed to create a quiet, low-CO_2-emission engine, to create a fan with world-class

*1 The ratio of the amount of air bypassing (flowing outside) the core engine to the amount of air flowing into the core engine; a larger bypass stream leads to a higher bypass ratio.

Daisaku Masaki
Section Leader
aFJR Project Team

efficiency performance.

Establishing new technologies through demonstrations in FY2017

The lightweight fan blade design is progressing. After doing numerical simulations, the team built a half-scale hollow CFRP fan blade and conducted preliminary tests on the prototype. The next step came in November 2016, when the team manufactured a full-scale hollow CFRP fan blade and used it for preliminary tests to investigate impact resistance using a gelatin ball simulating a bird strike. In addition to placing a strain gauge on the fan blade and examining the readings, the researchers also recorded instances of impact with a high-speed camera to observe the resulting changes. In FY2017, JAXA is aiming to conduct final demonstration tests on an improved hollow CFRP fan blade that reflects the findings of the preliminary tests.

To evaluate the efficiency enhancements of its 3D laminar flow fan blade designs, JAXA created a roughly 1/3 sub-scale model prototype in FY2016. The tests involved installing an airflow-regulating device on the engine test cell and simulating the flow conditions with less turbulence at the intakes relative to what aircraft experience during actual flight. Moving forward, JAXA is planning to incorporate the results of its analyses into a new sub-scale model and proceed with more testing in FY2017 to verify the technology developed under the aFJR project.

A prototype of a hollow CFRP fan blade; the colors and lines are for observational purposes.

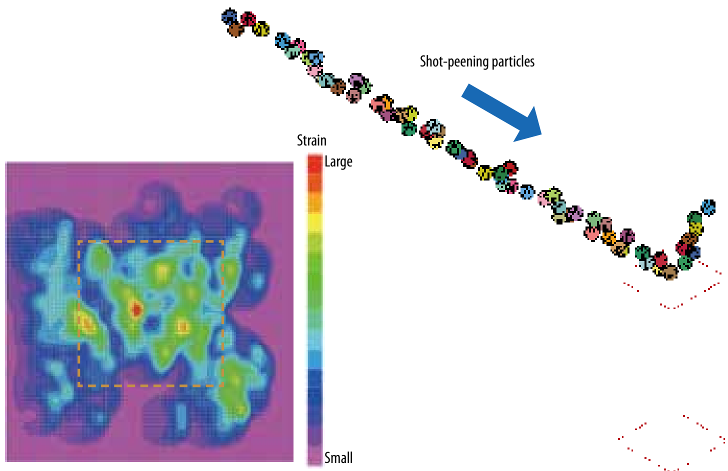
Lightweight disk technology

The fan disk: An important component that works behind the scenes

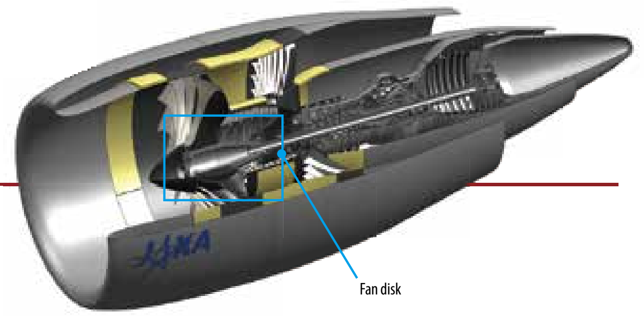
A fan disk must firmly support fan blades that rotate at high speeds. Therefore, fan disks are “life limited parts,” which require replacement before reaching the end of the defined fatigue life. The larger the fan blade becomes, the larger the load that the fan disk must withstand grows. Herein lies the demand for technologies to make fan disks lighter and tougher. To increase the fatigue life of fan disks, manufacturers often use “shot-peening” treatment—a metal processing technique that involves impacting metallic surfaces with small, hard balls of “shot” at high velocities. By applying a compressive stress to the surface of a metal, the shot-peening treatment effectively delays the initiation and growth of cracks. However, the increases in fatigue life that shot-peening treatment creates do not factor into the designs of fatigue life for conventional disks.

JAXA has been researching shot peening simulation technology and developing a design tool that can accurately estimate the increases in fatigue life resulting from shot peening. By applying the estimated increase in the fatigue life, based on the results of both the shot peening simulation and the actual testing, to the design process, JAXA could find ways of creating smaller, thinner fan disks while maintaining the same fatigue life as conventional disks.

The aFJR project team has been conducting its first series of fatigue tests on shot-peened sub-scale disks, simulating engine operation conditions with repeatedly changing rotational speeds. In the planned second phase of fatigue tests on sub-scale disks, the team is going to



A shot peening simulation (R) and analysis results (ex.) (L) verify the accuracy of the fatigue life predictions of the shot peening simulations.



Lightweight, sound-absorbing liner technology

Resin: A lighter alternative to aluminum

The goal of JAXA's research on lightweight, sound-absorbing liners technology is to reduce the weight of the liner, which helps decrease engine noise, by making the liner with resin instead of metal (aluminum). According to Tatsuya Ishii, "Resin is more than just a lightweight alternative to aluminum; you can also cast resin into single-piece configurations using molds—and that makes it a more cost-effective solution."

A standard sound-absorbing liner panel consists of a perforated surface sheet, a back sheet, and a hollow, honeycomb-type structure between the two sheets. When sound propagates through the small holes on the surface-sheet side, it gradually decays as it passes through the sound-absorbing liner panel (the honeycomb-type structure). Modifying the aperture ratio on the surface sheet and the size of the honeycomb cells alters the frequencies that the liner can absorb, thus making it possible to specify target frequencies as needed.

Researchers in front of the testing apparatus for evaluating the sound-absorption rates of sound-absorbing liner panels in airflows

JAXA's advantages in evaluation technology

JAXA is currently researching lightweight, sound-absorbing liners in a collaborative study with manufacturers. For this research activity, JAXA is in charge of a variety of evaluation tests on sound-absorbing liner panels. The tests have two basic components: acoustic tests and strength tests.

There are three stages of acoustic testing. The first stage is "normal-incidence" sound-absorption testing, which involves placing a small piece of a sound-absorbing liner on one end of a duct, generating sound from the other end, passing the sound through the duct, and determining how well the liner absorbs the sound (the sound-absorption rate) at a vertical (normal-incidence) angle. For the next stage, researchers place a sound-absorbing panel in a flow field, propagate sound through the field, and measure the corresponding sound-absorption rate. In an actual aircraft engine, the sound-absorbing liner is placed in a position that comes into contact with airflow (on the nacelle interior wall, for example); therefore, testing the liners requires measurements of sound-absorption rates under both static conditions (normal-incidence sound-absorption testing) and grazing flow conditions. JAXA thus tests liners using special a testing apparatus that places sound-absorbing panels inside a long duct with airflow running through it. The last stage of the acoustic testing process is "fan rig testing," which evaluates the acoustic performance of a liner by placing a cylindrical sound-absorbing panels in a test apparatus to simulate an actual fan setup. JAXA uses a fan-testing apparatus from one of its joint-research partners for the fan rig testing component—an important step that helps identify practical issues to address, including sound decay levels, frequency properties, airflow effects, and structural integrity.

Strength testing verifies whether the resin sound-absorbing liner panel prototype is structurally strong enough to function effectively under actual usage conditions. Strength testing includes static load testing, which involves slowly applying load to the component and evaluating the component's strength, and impact testing, which confirms that damage resulting from impact (hail, etc.) on the surface of the panel stays within an acceptable range. For this portion of the research project, JAXA uses weight-drop testing—an approach that involves dropping weights on the sound-absorbing liner panel to see if any breakage occurs. The weights and drop distances that the researchers use in their testing procedures are determined by the kinetic energy of the impact.

Taking advantage of JAXA's extensive range of evaluation technologies, the research team continues to drive progress in lightweight, sound-absorbing liner technologies.

Tatsuya Ishii
Function Manager
aFJR Project Team

Lightweight, low-pressure turbine technology

How ceramic components make turbines lighter

A low-pressure turbine, which generates the power necessary to rotate the fan rotor, generally has about seven stages. Each stage has a great number of rotor blades and stator vanes. Considering how many blades and vanes there are in a low-pressure turbine, reducing the weight of the blades and vanes brings the overall engine weight down considerably. Through the aFJR project, JAXA is researching the possibilities of replacing metallic low-pressure turbine blades and vanes with blades and vanes made of a Ceramic Matrix Composite

Takashi Yamane
Function Manager
aFJR Project Team

(CMC) in hopes of achieving the weight-reduction targets: around 30% of the low-pressure turbine weight or 9% of the total engine weight.

"A CMC is a ceramic material, reinforced by ceramic fibers, that has extremely low density and high heat resistant characteristics," Masahiro Hojo explains. "Engine manufacturers abroad are already getting to the point where they can equip engines with some CMC components. It looks like CMCs are going to be playing bigger and bigger roles in the future." Nickel alloys are currently used for low-pressure turbine material. If CMCs were to replace nickel allows, they could cut the weight by a quarter to a third relative to the present weight level—but CMCs come with their own share of unique challenges.

Flutter and tangling design

According to Takashi Yamane, "We need to establish technologies for flutter design and tangling design in order to make CMC blades and vanes more reliable."

Masahiro Hōjō
Associate Senior Researcher
aFJR Project Team

Flutter is a phenomenon that causes blades and vanes to vibrate—the same type of thing that happens when wind blows through the blinds on a window. Increasing levels of flutter can cause damage, which means that manufacturers aim for anti-flutter designs. Because new materials like CMC have different characteristics, it is necessary to identify and predict the flutter margin accurately. In order to evaluate the accuracy of prediction technology, it is also necessary to conduct tests that cause a flutter. "We've developed some test rigs for low pressure turbines and done some flutter testing with aerodynamic vibrations," says Jun'ichi Kazawa, who is in charge of flutter research. In 2017, JAXA is planning to conduct tests on actual-size models and compare the results with CFD analyses.

"Tangling design" is a kind of structural design that intentionally breaks low-pressure turbine rotor blades. Jet engines require fail-safe designs in order to ensure that no critical failures occur if the engine components break. For instance, the low-pressure turbine disk—sharing an axis with the fan—could lose resistance and start rotating at extremely high speeds above the designed rotating speed. The disk fragments from the breakage could penetrate through the engine containment case and shoot out of the engine, exposing the airframe to significant potential damage. Engine manufacturers thus apply structural designs that can eliminate the torque power of the low-pressure turbine in case of shaft breakage by intentionally breaking rotor blades with stator vanes.

CMC rotor blades would need to conform to the tangling design methodology, as well. To date, the tangling design methods of breaking CMC rotor blades at the root have emerged through a series of low-pressure turbine tangling simulations and preliminary tests. The next step is to demonstrate the tangling design methodology of breaking the high-speed rotating CMC rotor blades through contact with stator vanes using a spin tester.

Supporting Japanese industry through CMC design technology

CMCs can increase the service temperature limit by roughly 100 to 200°C relative to metals. Although the improvement of temperature-related performance lies outside the scope of the aFJR project, since low-

A low-pressure turbine prototype for flutter testing

pressure turbines do not currently require any cooling, the extraordinary heat-resistant attributes of CMCs could provide a significant benefit if future advances in engine performance lead to higher temperatures. JAXA is currently studying the potential for utilizing CMCs in high-pressure turbines, which operate at higher temperatures and pressure levels than low-pressure turbines do.

CMCs continue to draw attention thanks to their lightweight, heat-resistant properties. In addition to potentially revolutionizing engine turbine technologies, CMCs could also find applications in gas turbine power generation systems. Research projects along those lines are already underway. There are two major CMC material manufacturers—and both are Japanese companies, giving Japan a unique asset capable of giving the country an international competitive edge. If the aFJR project succeeds in establishing CMC design technologies, the results could both transform the aircraft industry and benefit Japanese manufacturing industry as a whole.

Jun'ichi Kazawa
Associate Senior Researcher
aFJR Project Team

"Navigating activities for the certification of aviation equipment"

Takeshi Fujiwara

Associate Senior Researcher
Technology Demonstration Research Unit

Takeshi Fujiwara joined the National Aerospace Laboratory of Japan (NAL) in 1999 after obtaining a doctorate from the Department of Aeronautics and Astronautics at the University of Tokyo's School of Engineering. From 2007 to 2008, Fujiwara was a visiting scholar at Stanford University.

Fujiwara stands in front of the GPS experimentation dome*1

Takeshi Fujiwara is an associate senior researcher who focuses mainly on developing air navigation systems. His current efforts also include creating certification standards for developed avionics systems. In this story, he talks about what brought him to his current work at JAXA.

—— Could you tell us a bit about your professional background?

I've been interested in astronautics and robotics since I was a little kid because I grew up with the popular TV animation "Gundam," where characters with robotic suits transform into humanoid vehicles. I ended up following that passion all the way up to graduate school. As a university student, I learned about satellite dynamics and interplanetary trajectories in the department of aeronautics and astronautics, and my doctoral thesis was on satellite motion estimation. Ever since I joined JAXA (which was then the NAL), I've been researching aircraft navigation—technologies that help users understand the aircraft position and motion.

Occasionally, I took part in various projects. For instance, I was involved in the flight demonstration project using a small supersonic experimental airplane named NEXST-1*2. I was responsible for analyzing flight data to help figure out how the experimental aircraft flew. The experiments we did at the Woomera Test Range in Australia left a lasting impression on me.

Another initiative I got involved in was the DREAMS Project*3, which came up with technologies that we're now working to implement on a society-wide scale. As part of that effort hinges on formulating a system of global rules, we're currently proposing our ideas to the Radio Technical Commission for Aeronautics(RTCA), a private, not-for-profit association in the United States.

I'm also assisting with airborne equipment certification activities at the Next Generation Aeronautical Innovation Hub Center, as well.

—— What goes into airborne equipment certification?

All the equipment that makes up an aircraft needs to obtain certification from various authorities, including the Japan Civil Aviation Bureau, the US Federal Aviation Administration, and other aviation authorities. At JAXA, we're pushing to secure certification for a newly developed inertial navigation system that combines satellite navigation and inertial navigation technologies. The new system actually operates on a software algorithm that we originally developed for unmanned experimental aircraft.

The interesting thing about the process, though, is that there are no set standards for certifying this new navigation system. Therefore, JAXA is making proposals to the RTCA to help create the technical standards ourselves for the system. That kind of approach, where a product developer helps write the rules governing the product, is actually fairly common abroad: Companies in the US and Europe quite often use this approach for their products. In that sense, Japan is gradually working its way up to a position where it can make its voice heard in rule-setting negotiations.

Size has a big impact on a company's influence, however. Considering that most Japanese equipment manufacturers are much smaller than their foreign counterparts are, it's hard for them to hold much sway. It's JAXA's job to create appropriate input to support Japanese manufacturers, ensuring further benefits for Japan through being involved in the certification rule-setting process.

—— Negotiation processes must be tough in many ways.

I think the toughest part will be software reliability assurance operated under the US regulations. One of the problems is that the basic principles in the regulations sound abstract and vague to us, and there aren't any clear checklists or other resources that we can use to check verification criteria or requirements. US and European companies with long lists of successful certifications often get through the process with ease, but Japanese companies—which still lack the credentials of their peers—often run into road blocks. The new navigation system that we're working on is based on JAXA's technology. Through developing technical standards for the system, I believe we'll be able to take a step forward.

—— What are the challenging and rewarding aspects of your research on air navigation systems?

One thing about inertial navigation is that you can figure out an aircraft's position and motion using pieces of indirect information, like acceleration and angular velocity. I enjoy experimenting with those elements—and the more you tweak a system, the more accurate the results get. The challenges are worth it.

Today's navigation systems have almost reached full maturity as standard flight technologies, which makes it hard for new technologies to emerge. As GPS-based satellite navigation has showed, however, compelling new technologies have the potential to revolutionize the way the world works.

—— What kinds of research do you want to address in the future?

I'd like to keep working on air navigation systems, since I have plenty of ideas I want to try for improving performance and usability. I'm also interested in developing a customized navigation system that provides optimal functionality and takes user needs and environments into accounts.

*1 The hemispherical dome is made out of a material that transmits GPS signals, giving researchers an indoor environment where they can conduct experiments without having to care about weather conditions.

*2 An unmanned experimental airplane designed and built for flight demonstrations of JAXA's low-drag airframe design concept; JAXA conducted experiments in 2002 and 2005 as part of its research on silent supersonic passenger transport.

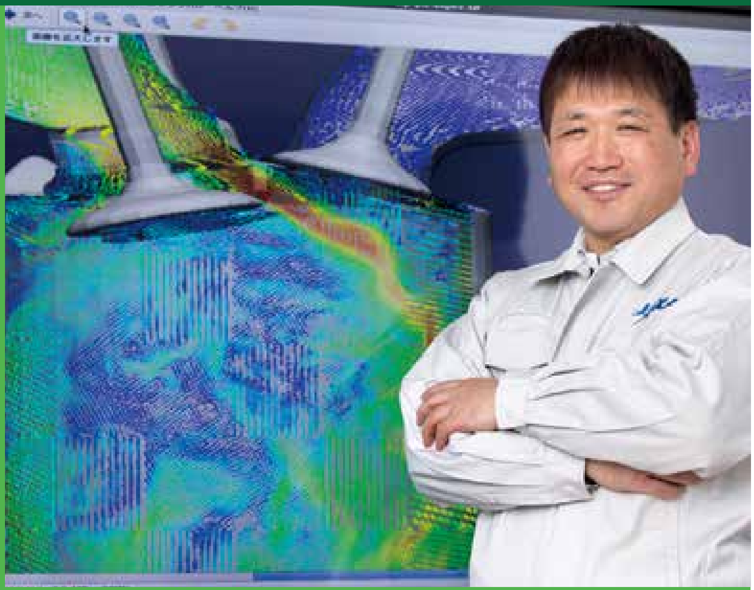
*3 DREAMS (Distributed and Revolutionarily Efficient Air-traffic Management system) is a project designed to develop the key technologies for enabling next-generation air traffic management systems; see FLIGHT PATH No. 7/8 for details.

"To glean insight from simulation results, you need to understand the fundamentals of combustion phenomena"

Yasuhiro Mizobuchi

Leader of the Combustion and Turbulence Section
Numerical Simulation Research Unit

After graduating from the Department of Aeronautics and Astronautics in the Faculty of Engineering at the University of Tokyo in 1989, Mizobuchi went on to obtain his master's degree from the Department of Aeronautics and Astronautics from the University of Tokyo's Graduate School of Engineering in March 1992 and his doctorate from the same department in March 1995. In April 1995, Mizobuchi joined the National Aerospace Laboratory (NAL) of Japan's Science and Technology Agency.



Mizobuchi poses with the automotive engine combustion simulation, which draws on aerospace technology-related input

In addition to fostering the younger generation as a section leader, Yasuhiro Mizobuchi constantly works to shed new light on how flames behave, analyzing the various forms of combustion phenomena that occur in aircraft and rocket engines.

—— Could you tell us a bit about your research, past and present?

When I first joined the National Aerospace Laboratory of Japan (now JAXA) about 20 years ago, most of my work was on simulating gas combustion. The Laboratory had a big computer capable of generating huge volumes of data, but I learned that technology alone isn't enough to produce insight: If you don't have a solid grasp of the fundamentals at the root of a physical phenomenon, you won't be able to obtain new findings no matter how many calculations you do. Whether or not you can glean insight from a set of results depends on whether you understand the basic physical principles and know the essentials of combustion phenomena. When you look at something burning, you might just see a single flame—but there are situations where the flame is actually a mix of different components with different properties. If you analyze the structure of a jet lifted flame, for example, you can see that the flame is a complex of three different flame elements (see the Figure in the bottom-right corner). I actually made that discovery based on some advice from one of my senior colleagues. The key to making new, eye-opening findings is having lots of people look at the same thing from lots of angles. With that diversity of perspectives, you get a better read on the different sides of the phenomenon you're studying.

These days, my research tends to focus on enhancing simulation technologies for analyzing combustion phenomena in aircraft engines and rocket engines. I do detailed, large-scale numerical simulations on supercomputers and, using that information to understand the physical nature of combustion phenomena, create models from the results.

Using the computational fluid dynamics (CFD) technologies that we've cultivated in the aerospace sector, I'm also developing the core components of software that could eventually become a platform for automotive engine combustion analysis in Japan. That project got its start when an automotive engine researcher saw our analyses of rocket-engine combustion and asked whether we'd be able to apply our technology—which could produce analyses of the high-velocity combustion flows in rocket engines—to automotive engines, too. The biggest difference between the engines in cars and the engines in aircraft or rockets is that the automotive engine has moving pistons and valves. JAXA happened to have a substantial background in that area, having researched potential methods for covering those types of engines. We then got the opportunity to take part in the Innovative Combustion Technology Project for the Cross-ministerial Strategic Innovation Promotion Program (SIP)*[1], which began in 2014. The project unites multiple organizations, including universities and automotive companies. JAXA's role is to establish the basic framework for analyzing automotive-type engines, and to integrate the individual sub-models for the various operational processes in engines that other universities and organizations have built. We call the software we are developing "HINOCA," naming it after a fire god in Japanese mythology.

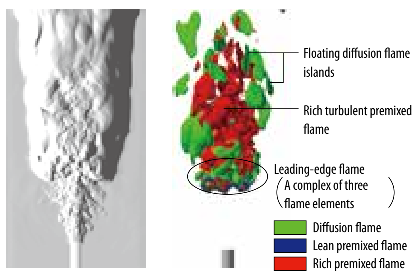
—— What do you find rewarding about your work?

Now, as a supervisor, the biggest reward for me is seeing younger researchers in my organization do good work. One of the most important parts of my job is making sure the junior staff members have an environment where they can really thrive. It's always great to see those efforts pay off. HINOCA is another initiative that I get a lot out of. All the simulation software currently driving automotive development is foreign-made. Since the software suites are all black-box systems, too, there's no way to modify the code on the user end. Even if you develop a good model, you can't install it right away. There's a big need for Japanese-made software—and if we create a viable solution, users are going to be able to cut down on the numbers of experiments they do, minimize test piece-production costs, and change the automotive design process. A software package with high-precision simulation capabilities would not only aid in final product checks but also enable CAE*[2] and simulation technology-driven design.

By constantly working to shed new light on how flames behave, I think we'll be able to push progress along and move past the conventional simulation-based design process. We'll eventually make it possible to create designs that maximize the potential of combustion fluids. With that ability, I'm confident we'll be able to make a difference in more than just the Japanese aircraft industry—the results could impact the automotive industry and the rest of the industrial community in Japan.

*1: Led by the government's Council for Science, Technology and Innovation, the SIP is a national project that aims to lead science, technology, and innovation beyond the framework of government ministries and traditional disciplines. For each of its research and development initiatives, the project selects a program director (PD) responsible for guiding the corresponding effort from basic research to practical application and commercialization.

*2: CAE (Computer-Aided Engineering) facilitates preliminary examinations for product design, manufacturing, and process design by enabling pre-production computer simulations and analyses that help streamline prototyping, reduce the experimentation workload, and predict a wide variety of potential problems.



Schlieren visualization of numerically simulated jet lifted flame

A flame Index-based flame structure analysis

The structure of a jet lifted flame

Sky Frontier

Hydrogen-utilization technologies play critical roles in limiting CO_2 emissions. JAXA's ongoing efforts go beyond simply creating aircraft that conform to the coming "hydrogen society"—they also involve research that makes hydrogen utilization more efficient. This article introduces a comprehensive outlook of JAXA's hydrogen-related work with Takayuki Kojima, Associate Senior Researcher from the Next Generation Aeronautical Innovation Hub Center.

Hydrogen-utilization technologies

The heat exchanger for the hypersonic pre-cooled turbo jet currently in development at JAXA features heat-transfer tubes with a design that accounts for temperature difference-induced deformation.2

The need for CO_2 reductions in the aviation field

To stop global warming, it is imperative to cut emissions of CO_2 and other greenhouse gases on a global scale. At the 2015 United Nations Climate Change Conference (COP21), representatives from around the world negotiated the "Paris Agreement."

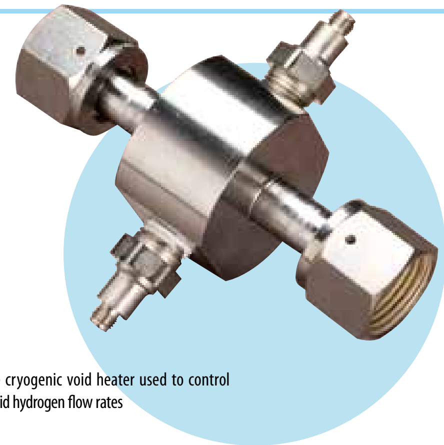
The transportation field currently accounts for around 14% of the world's total CO_2 emissions, with the aviation realm representing 11% of that ratio—just 1% or 2% of the whole. While those transportation-related emissions might now be just a small fraction of the total, efforts to cut back on CO_2 emissions are already in full swing in the non-aviation transportation arena as manufacturers continue to develop hybrid vehicles, electric cars, and more. Considering the environment-focused trends in other sectors, the aviation field will likely make up a larger proportion of all CO_2 emissions in the near future. The International Civil Aviation Organization(ICAO) has placed rigorous restrictions on CO_2 emissions, as well, making the need for research into CO_2-reducing technologies for the aviation field even more pressing.

Leveraging Japan's strengths into viable hydrogen-utilization technologies

Fossil fuels like coal and oil are the major sources of CO_2 emissions, and most of today's aircraft use fossil fuels (jet fuel, etc.). Alternative fuels that emit less or no $CO2_2$ would make it possible to bring CO_2 emissions down across the board. One such candidate is hydrogen. Availability and accessibility are two of hydrogen's biggest advantages: Producing hydrogen is as simple as electrolyzing water, and the substance is a natural byproduct of the industrial gas-refining process. According to Kojima, hydrogen could also be an extremely cost-effective solution. "Along with imports from other countries like Australia, there are plans to use solar-power and wind-power facilities in Japan to produce hydrogen," he explains. "Those kinds of efforts will definitely help make hydrogen more affordable in the future."

Hydrogen generates about three times as much heat as jet fuel per unit of weight, but that heat only amounts to one-quarter of what jet fuel can produce per unit of volume. While it does have extremely lightweight properties, in other words, hydrogen requires considerable amounts of storage space. Making the most of hydrogen's weight advantage means storing the substance in a light, compact, space-minimizing fashion, which would require composite solutions for lightweight storage tank capable of withstanding high-pressure conditions.

JAXA can apply its wealth of expertise in developing a viable hydrogen solution; JAXA has been researching composite materials and structures to make lightweight yet strong aircraft structures, and JAXA also has technologies for producing and storing hydrogen for use in launch vehicles. In addition, JAXA's efforts now extend to integrating expertise with non-aeronautics technologies, such as superconducting motor technologies for maglev vehicles and fuel cell technologies for automotive applications. Such efforts will definitely help bring Japan's technological prowess together into far-reaching, dynamic research.

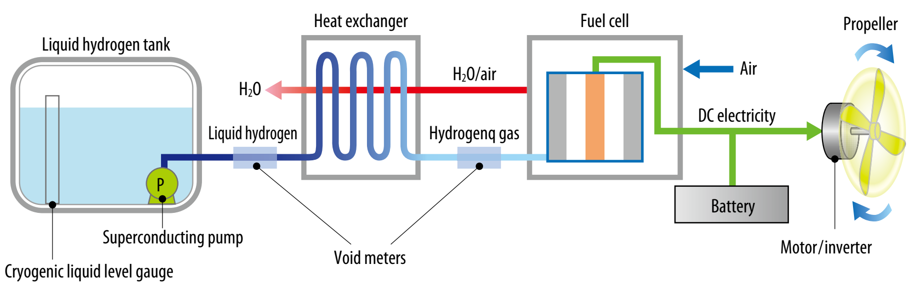


The cryogenic void heater used to control liquid hydrogen flow rates

JAXA's efforts in developing hydrogen-utilization technologies

Another example of JAXA's research on hydrogen application is on a hypersonic pre-cooled turbojet engine, which started in 2006. Designed for use in hypersonic aircraft capable of flying at Mach-5 speeds, the engine burns hydrogen for a dual purpose: generating propulsion and cooling (pre-cooling) intake air.

JAXA is also at work on electric propulsion utilizing liquid hydrogen. The system uses a superconducting pump to supply hydrogen from a liquid hydrogen tank to a fuel cell, which then generates electricity to rotate a fan and thereby produces a propulsive force (see the Figure). To develop the system further, researchers are currently looking into using the electric propulsion-based aircraft from the Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution (FEATHER; see Flight Path No. 9/10 for details) for experimentation purposes. Other ongoing initiatives include research into a two-phase flow sensor (cryogenic void meter), which would detect the flow rates of liquid hydrogen transported under cryogenic conditions. All of these project for hydrogen application technologies will help create a sustainable and recycle-oriented society.

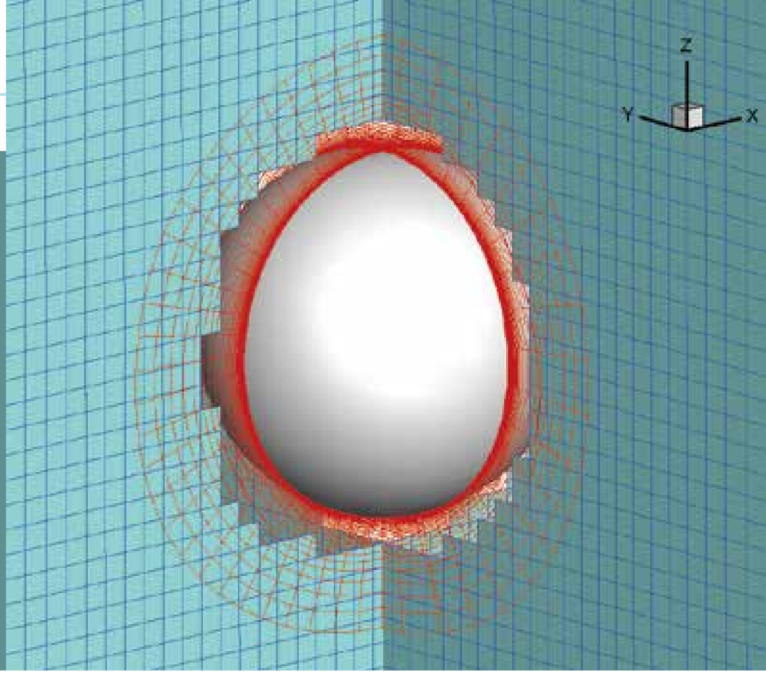


An overview of the liquid hydrogen-driven system for superconducting fuel-cell propulsion
The system uses a superconducting pump to supply hydrogen from a liquid hydrogen tank to a fuel cell, which then generates electricity to rotate a fan and thereby produces a propulsive force.

FaSTAR-Move

Analyzing the airflow around moving/deforming objects

Researchers have routinely struggled to compute and analyze the complicated airflow generated by the movement and/or deformation of airframe: airflow around the landing gear, flaps, and other high-lift devices that are deployed and stored during flight. This article summarizes an interview with Takashi Ishida, a researcher at the Next Generation Aeronautical Innovation Hub Center, who explained JAXA's ongoing efforts to develop a CFD solver called FaSTAR-Move—an innovative solution to provide high-speed computational analysis on the complicated airflow around moving/deforming objects.



An example of an overset grid used by FaSTAR-Move for analysis

Meeting airflow analysis needs

Modern aircraft developers rely heavily on computational fluid dynamics (CFD), which simulates flight characteristics in a computer environment. JAXA has made CFD an important part of its activities, developing HexaGrid—a tool for automatically generating grids at world-class speeds—and a fast fluid analysis tool called FaSTAR (see Flight Path No. 7/8). Hoping to expand the reach of its offerings, JAXA has also provided CFD solutions to numerous organizations, ranging from universities and other educational institutions to corporate development divisions. The solutions have not been complete, however: FaSTAR does not offer the CFD resources that actual aircraft developers need for analyzing the airflow around moving/deforming objects. Although some commercial software suites overseas do offer that type of support, they tend to fall short of user needs due to high price tags, slow analysis speeds, and other problems.

FaSTAR-Move, which JAXA is developing as a FaSTAR extension, aims to provide users with a fluid analysis tool that delivers accurate analysis results under moving/deforming conditions at FaSTAR's high speeds. "By utilizing FaSTAR-Move, users would be able to conduct analyses on helicopters, tilt-rotor aircraft, tilt-wing aircraft, and airframes with moving/deforming parts like morphing wings," Ishida says.

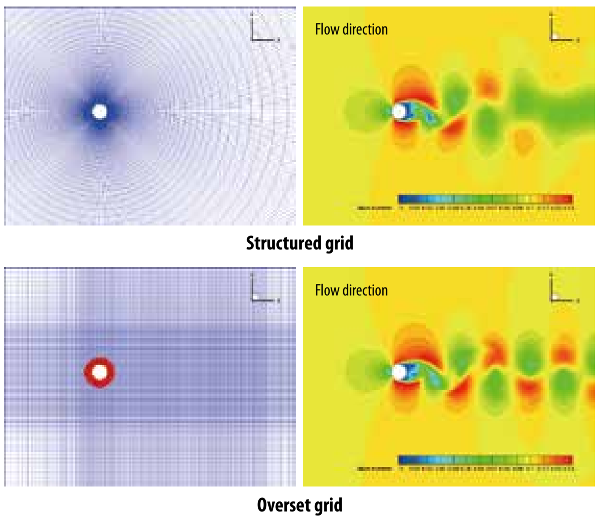
Analyzing the airflow around moving/deforming objects via the overset grid method

CFD involves generating a computational grid by filling the target space with tetrahedral and hexahedral elements (cells) and then performing the corresponding calculations. There are three types of computational grids: a Cartesian grid (where the gridlines cross at right angles), a structured grid (which features a systematic cell arrangement), and an unstructured grid (where the cell arrangement is irregular). Depending on the type and quality (fidelity, etc.) of the grid in use, the accuracy of the resulting analysis varies. FaSTAR-Move employs the "overset" grid method, which layers together multiple Cartesian, structured, and unstructured grids. When a user wants to analyze helicopter flight, for example, it can be difficult to simulate the flight conditions with a single computational grid. FaSTAR-Move enables the user to create and superimpose separate grids for the rotating blade component and the stationary fuselage, thereby making it easier to conduct the analysis. Given its flexibility, the overset grid method thus offers a powerful solution for analyzing airflow around moving/deforming objects. The versatility of the overset approach also pays off in analyses of the vortices that form behind objects in motion—by layering a Cartesian grid over areas where structured and unstructured grids get too rough, users can perform high-resolution analyses in a localized fashion (see the Figure below).

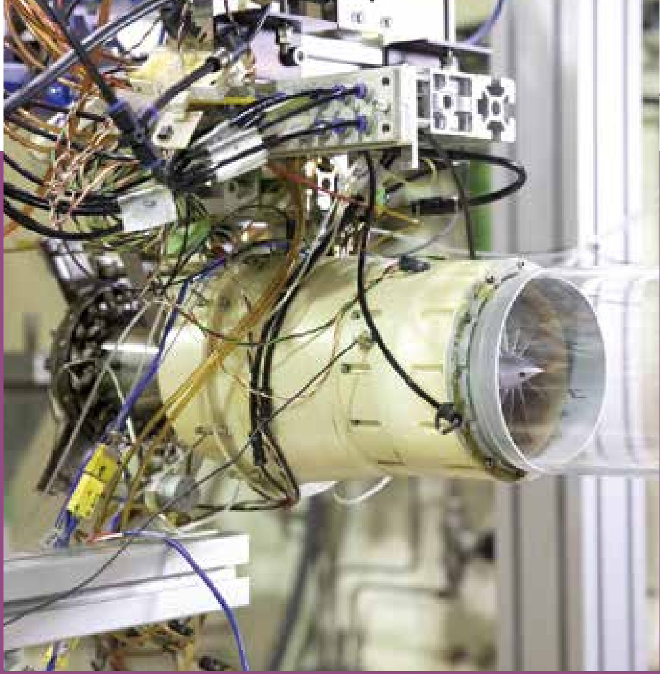
The overset grid method requires an exchange of information between the various grid layers. For the FaSTAR-Move development team, that interconnectedness represents the biggest technical obstacle—especially for exchanges with unstructured, irregular grids, which make finding the proper overlap hard to do at high speeds.

Targeting a Ver. 1 release by the end of FY2017

FaSTAR-Move is a two-part system consisting of a moving/deforming object analysis module, which handles the analysis of airflow around moving/deforming objects, and an engine analysis module, which analyzes the cascades of engine fans, compressors, turbines, and other components. The moving/deforming object analysis module is currently in advance development as the Ver. 1 piece, while the team is planning to start work on the engine analysis module (Ver. 2) in FY2018. Having commenced development in FY2015, Ver. 1 is scheduled for completion by the end of FY2017. Although the software only supported single solid objects during its first year in development, FY2016 has seen developers perform successful analyses of multiple objects. Moving forward, the team is hoping to boost the software's calculation speeds and improve the user interface. JAXA is also at work on HexaGrid's successor, called "BOXFUN," which captures object configurations with greater fidelity and enables large-scale grid generation of more than 100 million cells. Together, FaSTAR-Move and BOXFUN will offer users a high-performance, user-friendly set of fluid analysis tools.



The image illustrates two analyses of a cylindrical form in a given airflow, with the top portion using a structured grid and the bottom portion employing an overset grid. The elements outside the immediate vicinity of the object (the locations in the dotted lines) are relatively indistinct in the structured grid but clearly visible at a high resolution in the overset grid, making the overset grid a clearer depiction of the airflow (L: Computational grids; R: Mach-number distributions).



The NE2013 installed at an JAXA ATF; to monitor fan rotation, a clear-plastic part is applied to the front.

Super-small turbofan engine technology

Research on jet engines involves tackling numerous challenges, including the limited availability of full-scale test facilities for actual engine and the huge costs of the tests themselves. This section profiles JAXA's super-small turbofan engine, which gives researchers the kind of readily available, low-cost research device that they need.

One of the world's smallest turbo jet engines

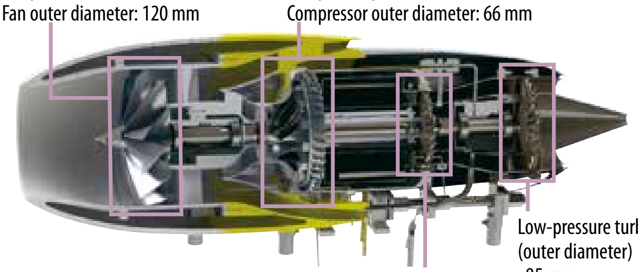
One of the outcomes of the "Applied Research on Small Turbofan Engines" project, which began in FY2011, was the "NE2013" small turbofan engine. Built based on the KJ66 turbo jet engine, a common system around the world, the NE2013 is enhanced with JAXA's unique expertise. In order to create a structure equivalent to those of turbofan engines for passenger aircraft, JAXA applied a biaxial setup for the core engine's main shaft and reworked the compressor, bearings, and other components accordingly. The NE2013 also features new designs for elements like the front fan and adds a low-pressure turbine to the system.

Boasting a maximum thrust of 176.4 N and a bypass ratio of 3, the engine delivers an impressively compact structure with a fan diameter of 120 mm, length of 487 mm, and weight of around 10 kg. The engine also runs on jet fuel or kerosene, ensuring optimal usability.

The impetus driving JAXA's R&D on super-small engines

By creating a super-small turbofan engine like the NE2013, JAXA is aiming to bolster its efforts in researching and developing aircraft jet engines. Recent advances in computer performance have enabled developers to create models digitally, using computational fluid dynamics (CFD) and other technologies, and simulate combustion, as well. When it comes to building individual parts, however, researchers have to create and test prototypes under actual operating conditions. Meeting that need is extremely expensive: Tests on actual turbofan engines require individual parts, which often run up considerable costs. Making a single fan blade, for example, can cost up to tens of millions of yen. Given the cost-intensive nature of the process, there are limits on how many prototype models a team can create.

The NE2013 is a scale model of an actual turbofan engine widely in use. Thanks to the size of the model, researchers can create prototypes for R&D at minimal costs and conduct trial-and-error tests under limited budgets. Even 3D-printed parts can be mounted for testing. Currently, JAXA is carrying out a wide array of testing using the NE2013, from evaluations of turbine stator vanes with variable mechanisms to studies of engine-control programs.



NE2013 structure and specifications

Capturing the potential of mass-produced super-small engines

To run the NE2013, JAXA uses its altitude test facility (ATF), where researchers can simulate actual flight environments. Although the ATFs in Japan lack the capacity to test full-size engines, the facilities offer more than enough space for the small-scale NE2013. In parallel to the ongoing testing at its ATF, JAXA is also looking into the possibility of running the NE2013 in wind tunnels.

JAXA's NE2013 boasts a high-TRL* for a research institution, and its technologies are already in use in Niigata City's "NIIGATA SKY PROJECT" for real engine development (see the column below). JAXA is hoping that initiatives like the NIIGATA SKY PROJECT will help Japanese companies eventually transition the NE2013 into a viable, mass-producible product. Mass-producing the NE2013—already much cheaper to manufacture than the types of jet engines powering today's aircraft—would bring the market price down to several hundred thousand yen. Not only would that low-cost accessibility benefit Japanese research on aircraft engines, but it would also facilitate installations on unmanned aircraft systems and give universities and other institutions an affordable resource for educational applications.

NIIGATA SKY PROJECT

The NIIGATA SKY PROJECT, part of Niigata City's efforts to energize the local community, aims to support aircraft-related industries through industry-academic-government collaboration in the Niigata area. Drawing on local companies' expertise in mechanical metalworking techniques, the initiative is working to develop a quiet, efficient, compact jet engine and an unmanned aircraft system capable of transporting 100-kg cargo (cargo UAS).

* Technology Readiness Level, an index that represents a technology's maturity on a scale of 1 to 9.

JAXA Aeronautics Symposium 2016 "Technological challenges and open innovation"

The JAXA Aeronautical Technology Directorate organized a symposium in October 2016 in Tokyo to introduce its challenges and vision toward future steps. Through keynote presentations and panel discussions, the symposium introduced JAXA Aeronautics's ongoing R&D efforts, with an emphasis on its open innovation policy that tries to incorporate diverse knowledge and insights from universities, companies, and other players.

Opening remarks by Fumikazu Itoh, Director General of the JAXA Aeronautical Technology Directorate

Challenging high-level research that creates added value, while encouraging timely delivery of tangible outputs

On October 13, 2016, JAXA held "JAXA Aeronautics Symposium 2016: Technological challenges and open innovation" at Tokyo Big Sight in Tokyo, Japan.

Emphasizing the synergy between technological prowess and collaboration, this year's symposium profiled JAXA's efforts to bolster society and industry by tackling ambitious technology initiatives and quickly turning its research into real, practical solutions.

The opening remarks, titled "Looking ahead — visions and challenges for JAXA Aeronautics," were made by Fumikazu Itoh, Director General of the Aeronautical Technology Directorate. In his remarks, Itoh addressed how JAXA Aeronautics takes on technological challenges to better serve industry and society. Itoh's remarks not only covered D-NET,[*1] the D-SEND Project,[*2]and other past achievements but also detailed current research efforts like the FQUROH Project[*3] and SafeAvio Project.[*4] Itoh also laid out the Aeronautical Technology Directorate's R&D management strategy : "promoting research and development activities that benefits industry and society," "multi-disciplinary and cross-sectoral collaboration for open innovation," and "incubating high-level research that creates added value".

Stimulating innovation in the aviation sector

The theme for the second part was "challenges for realizing open innovation in aviation". Three lecturers presented initiatives centered around the WEATHER-Eye Consortium.[*5]

The first lecturer was Shigeya Watanabe, Director of the JAXA Next Generation Aeronautical Innovation Hub Center. Watanabe began with an introduction of the Center's three policies: pursuing initiatives that can benefit industry and society, driving open innovation, and delivering high-impact results. In addition to providing an overview of each ongoing initiative, including those related to WEATHER-Eye, he also touched on JAXA's new research on component certification technologies—an emerging area where the social needs are pressing and the potential impact is enormous.

The next presenter was Yuichi Kitada, Deputy General Manager of the Engineering & Maintenance Division at Japan Airlines Co., Ltd. During his address, Kitada introduced issues on special weather from an airline's perspective, such as how wind shear, volcanic eruptions, lightning, airframe icing, and similar meteorological phenomena impact flight. Kitada voiced how airline operators and users can benefit from the technological challenges tackled by the WEATHER-Eye research initiatives, such as better tools for detecting special weather conditions and safeguarding against icing, which will lead to help increase air safety and operational efficiency.

Shigeo Kimura, a professor in the Department of Mechanical Engineering at the Kanagawa Institute of Technology, introduced the detailed mechanisms of how icing occurs, together with several research initiatives on anti-icing, de-icing, and icing detection that the Kanagawa Institute of Technology has been collaborating on with JAXA, manufacturers, universities, and European research institutions.

How MRJ development and JAXA can shape the future of the aviation industry

The third part of the symposium was a panel session featuring Kiyoshi Sakura, Deputy Head of the Engineering Division at Mitsubishi Aircraft Corporation, and Takeshi Ohnuki, Program Director of Aeronautical Technology at JAXA. They spoke about the MRJ project and JAXA's role for the future of the Japanese aviation industry.

After covering the current status of the MRJ development effort, Sakura introduced research collaborations with JAXA to develop and test technologies from the basic design phase. He also expressed his expectations for JAXA's ongoing R&D efforts in innovative technologies while also voicing his hopes for continuing collaborative research with JAXA. Ohnuki (from JAXA) summarized the panel session by underlining the importance of making collaborative research and development efforts with industry while ensuring the benefits that these collaborations can have for the Japanese aviation industry.

In the ensuing question-and-answer session, the presenters exchanged their views on ideas and issues raised by the audience. Themes included more demands for aircraft component research, the need for human-resource development, and more. Sakura added his comments on JAXA's role, saying that it would best help companies if JAXA continued pursuing its research on both short-term and long-term themes that companies lack the resources to tackle. Through a series of presentations and discussions at the symposium, it had become even clearer as to how JAXA and companies could best share their roles and responsibilities.

*1 Disaster-Relief Aircraft Management System Network; see FLIGHT PATH No. 7/8 for details.
*2 Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom; see FFLIGHT PATH No. 11/12 for details.
*3 Flight Demonstration of QUiet Technology to Reduce nOise from High-lift Configurations project; see FLIGHT PATH No. 13/14 for details.
*4 R&D of onboard safety avionics technology to prevent turbulence-induced aircraft accidents project; see FLIGHT PATH No. 13/14 for details.
*5 See page 6.

The panel session included discussions of the MRJ development project