JAXA Aeronautics Magazine

FLIGHT PATH

Shaping Dreams for Future Skies

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Feature Stories

- JAXA Aeronautics at the heart of "all-Japan" R&D landscape
- D-SEND#2 Successful flight
- Flight system technology for making aircraft safer and more familiar

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This issue introduces JAXA's commitment and everyday efforts in supporting Japanese aviation industry, together with updates on recent projects. Two topics from a new serial 'Aeronautics in depth' are introduced as well.

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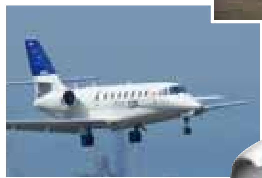
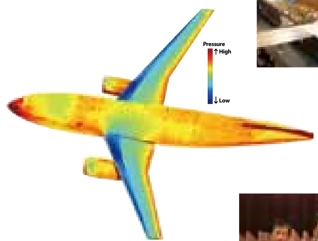









On the cover

Close up view of the electric propulsion system developed by JAXA. Electric motor glider applying this system was successfully flown in February 2015, demonstrating the feasibility of JAXA's electric aircraft technology. (See page16)

Interview

JAXA Aeronautics at the heart of "all-Japan" R&D landscape

Supporting the aircraft industry to grow into one of Japan's major economic forces

In April 2015, JAXA embarked on its new journey as the National Research and Development Agency. By further enhancing its research and development capabilities in the aerospace field and incorporating input from diverse areas of study, JAXA will aim to fulfill its new role as the National Research and Development Agency, the core objective of which is to "optimize its research and development results as an all-Japan force." The organizational transition has also reshaped the JAXA Institute of Aeronautical Technology into the Aeronautical Technology Directorate, which will foster research initiatives within a new framework in hopes of making even more valuable contributions to the Japanese aircraft industry. We spoke with Kazuhiro Nakahashi, Vice President and Director General of the Aeronautical Technology Directorate, about the primary goals of the new setup and the projects that the organization will be pursuing.

Kazuhiro Nakahashi
Vice President
Director General,
Aeronautical Technology Directorate

JAXA's approach to help stimulate the growth of Japanese aircraft industry

——How has JAXA's transition into the National Research and Development Agency changed the structure of the Aeronautical Technology Directorate?

JAXA has always focused its efforts on "projects," a framework that involves commitment at the management level in all aspects of the project process, from defining the technological goals and planning to monitoring progress to delivery. That approach has helped us develop and operate satellites and explorers, including DAICHI-2 (the Advanced Land Observing Satellite-2) and the HAYABUSA 2 asteroid explorer. In the field of aeronautics, aFJR (Advanced Fan Jet Research) and FQUROH (Flight demonstration of QUiet technology to Reduce nOise from High-lift configurations) has been operated under this type of project framework in hopes of transferring developed technologies to industry. Although the organization will continue to pursue this project framework, we will also bolster our basic research structure so that we can also create new innovations. Building on these two foundations, we are committed to generating as much output as we can.

With experts predicting that aviation demand will more than double over the next two decades, the Japanese aircraft industry has started to exhibit substantial growth in the last few years. Japan's share of the global aviation market may only account for 4% as it currently stands, and this amount is expected to grow further to around 10% within the next 10 years. In the "Strategic Vision for Researching and Developing Next-Generation Aircraft," which the Ministry of Education, Culture, Sports, Science and Technology released in 2014, the ultimate goal is to bring that share all the way up to 20% and develop the aircraft industry to the point where it can stand shoulder to shoulder with the auto industry as one of Japan's key industrial forces. It's our role at JAXA to make that happen—and to do so, we need to spark breakthroughs that put Japan at the head of the pack. The new organizational framework puts JAXA on the front lines of that effort.

——What does that entail, specifically?

We have to forge close bonds with the aircraft industry to create new technologies, always making sure that what we develop finds applications for use by industrial partners in their operational settings. The new projects that we've launched this year are part of that effort.

For the past two years, the JAXA Aeronautical Technology Directorate has been initiating a program with three main pillars: the Environment-Conscious Aircraft Technology

Program (ECAT), the Safety Technology for Aviation and Disaster-Relief Program (STAR), and the Sky Frontier Program (Sky Frontier). These programs, which encourage application-oriented research, have fostered the seeds for the new projects aFJR and FQUROH. Then, at the beginning of 2015, the organization formed respective project teams to develop technologies further under the "project" framework in hopes of making an impact on the aircraft industry in the next several years. Also, the "R&D of onboard safety avionics technology to prevent turbulence-induced aircraft accidents (SafeAvio)" is mapped out as an emerging research initiative for the Aeronautical Technology Directorate. In our work on the aFJR project, we are making a joint effort with engine manufacturers to develop technologies for more fuel-efficient engines. The efforts are centered around developing technologies for lighter and higher-efficiency fans and low-pressure turbines through the use of composite materials, which is an area of expertise where Japan has the edge over the international competition. (see FLIGHT PATH No. 1/2 for details). The FQUROH project, meanwhile, will serve to create technologies that reduce airframe noise and thereby help aircraft comply with tighter noise limits in the years to come (see FLIGHT PATH No. 1/2 for details). SafeAvio is a research and development initiative designed to establish technologies, by using lasers, to detect clear-air turbulence, which cannot be detected with conventional weather radar systems (see FLIGHT PATH No. 3/4 for more details). As these new projects and initiative are designed to work toward achieving shared goals with manufacturers, they represent our stronger commitment. We are confident about what these synergized efforts with industry can bring about for Japan as a whole. It's also a reflection, I think, of how hopeful and confident the manufacturing community is about what we can do. The "Strategic Vision for Researching and Developing the Next-Generation Aircraft" has also positioned these unique technologies as priority targets that give Japan an advantage over foreign competitors, making the Japanese aircraft industry more internationally competitive.

The core of the "all-Japan" structure The "Next Generation Aeronautical Innovation Hub Center"

——This April, JAXA created the "Next Generation Aeronautical Innovation Hub Center." Could you tell us a bit more about this new framework?

Giving life to revolutionary technologies that will provide benefits in the long term requires more than the expertise JAXA has at its disposal—it also demands knowledge of new fields. In addition to utilizing our assets in aerodynamics, thermodynamics, structural dynamics, composite materials, control, and other areas that we've traditionally prided ourselves on, we'll also be needing human resources in less familiar fields like electrical engineering and chemistry. The Innovation Hub exists to provide an environment where JAXA can collaborate with people from universities, other research institutions, and manufacturers on creating new technologies through an all-Japan framework. With the Innovation Hub, I'm expecting that all the different parties involved are benefiting from this flexibility in forming groups by topic and taking multi-disciplinary approaches across organizations and areas of expertise.

——Whether it's a project or an innovation hub, there needs to be an industrial element to the initiative for JAXA to contribute to the aircraft industry. What do you envision along those lines?

The research initiatives at the Innovation Hub need to conform to industrial needs and seeds. Otherwise, we won't be able to attract human resources or industrialize our technologies. Building on the many steps that JAXA has taken to make its intellectual property as accessible as possible to partnering researchers, we're now committing ourselves to giving participating manufacturers more freedom to use the intellectual assets that come out of the Innovation Hub as they wish. That way, we'll be able to ensure that manufacturers will be able to participate strategically with a view to industrialization.

I hope that the Innovation Hub can get university professors and students involved, too. If we want to attract students from outside the metropolitan area, we'll need to be able to provide support for longer-term stays. That's one area that I want to focus on. Students will be able to flourish at the Innovation Hub, I think, and put themselves in position to lead the aircraft industry into the future. The Innovation Hub has the potential to be a liberating platform for young JAXA researchers, as well—by sharing goals with manufacturers and academics, our up-and-coming generation of JAXA scientists will have extraordinary opportunities to try new things.

——The IT field is another important area, right?

The IoT (Internet of Things) field is drawing enormous attention in fields of all kinds, and engine manufacturing is no exception: overseas engine manufacturers have started to build networks for round-the-clock engine status monitoring and develop their creations into viable services. In my view, these types of health monitoring frameworks are only going to expand in scope as time goes on. Information technologies are also going to take on increasingly important roles in areas like operations management and information sharing.

——What sorts of research topics are you going to be working on?

As we work to identify potential research topics ourselves, we're also currently gathering ideas from manufacturers, universities, and other sources on interesting possibilities. Some of the areas that we've already started looking at are main wings that reduce air drag, quiet core engine technologies that cut down on gas emissions, and de-icing and anti-icing technologies. Quiet supersonic aircraft technologies are another target for future research at the Innovation Hub.

Our work on the FEATHER (Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution) initiative, which focused on developing an electric propulsion system for aircraft use, wrapped up in February 2015 with a successful manned flight demonstration. These types of aircraft electrification technologies are going to be some of the biggest factors in propelling aviation technology further into the future. Just as cars have started shifting from traditional gasoline fuel to biofuel and hydrogen fuel, aircraft are starting to follow similar trends across the globe. As the Japanese aircraft industry works to keep pace with these changes, I think that the success of the FEATHER initiative will draw positive attention to what Japan is doing—but JAXA will also need to keep leading the way forward.

——Finally, what are your hopes and goals for the future?

Through its research and development activities, the JAXA Aeronautical Technology Directorate has been a core driver of Japan's aircraft industry. For the Japanese aviation sector to become a key economic contributor to Japan, we are determined to support and lead the growth of the sector by better serving as a central site for all-Japan research and development.

Feature Story

D-SEND#2 Successful flight

July 24, 2015 Flight test conducted at the Esrange Space Center in Sweden

On July 24, 2015, a flight experiment was held for the D-SEND#2, the second phase of "Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom (D-SEND)" at the Esrange Space Center in Sweden. The supersonic experimental airplane was flown as originally planned and it has been confirmed that a sonic boom was captured and measured by multiple microphones. This article features an interview with Masahisa Honda, Sub-Manager of the D-SEND Project Team, who participated in the flight experiment at Esrange.

Taking all possible measures drawing upon past lessons

——I'm sure that you overcame various hardships before realizing this success. How do you feel now that the flight experiment is finished?

I'm relieved! The D-SEND Project was started in 2010. When including the development period, the project has taken six years in total. It felt so long. Of course, I'm overjoyed that the flight experiment was successful. At the same time, I realized that I won't have to come back to Sweden again next year. It's been three years since I have started working on the D-SEND#2 campaign. Over the past three years, I spent three months per year in Sweden. Although I will miss working in Sweden a little, my strongest feeling is one of relief.

——Please explain your role in the flight experiment.

In 2013 and 2014, I served as chief manager responsible for overseeing the entire experiment. In 2015, I also took on the additional role as administrative manager in charge of supporting team members' daily life over the test period .

——Based on results for 2014, what measures did you take for this year's flight experiment?

In 2014, we were forced to suspend the flight experiment because appropriate weather conditions did not exist throughout the set experiment period. In response, we reviewed various measures to increase experiment opportunities even when faced with weather like last year. For example, one measure was to secure a experiment period which was twice as long as last year's.

As a technological measure, we took action to increase the timing of separation from the balloon. For example, in order to separate the experimental airplane from the balloon and fly it directly over the boom measurement system (BMS) at the designated speed, altitude and flight-path angle, it is necessary to perform separation within a concentric, donut-shaped range centered on the BMS. Through additional review of the flight path, we were able to maximize the donut width (+3 km outwards at an altitude of 30 km) and thickness of the altitude direction (altitude of 28 km to 30 km increased to an altitude of 28 km to 33 km). Furthermore, until last year, we had only "Pattern A," in which the balloon needed to go up to an altitude of 33 km first, then come down to an altitude of 30 km for level flight for the separation of the experimental airplane . For this year's flight experiment, we added an option to balloon trajectory (Pattern B) in which the experiment airplane was separated upon reaching an altitude of 30 km during the ascent.

During the actual flight experiment, it looked like the ascending balloon would pass through the donut range in which separation is possible. Therefore, we initially aimed for Pattern B when we released the balloon. However, when the balloon neared the donut, it became difficult to time the separation due to instability in the surrounding wind direction and wind speed. In response, we switched to the backup Pattern A and performed separation on the western side of the donut.

——Did you encountering any difficulties from the preparatory stage until completing the experiment?

Following last year's experiment, the experiment airplane was stored inside of a temperature-controlled building at the Esrange Space Center. Accordingly, there was absolutely no problem in terms of functionality. However, towards the end of the preparatory stage, there was a malfunction in which GPS data could not be received. We realized that our GPS receiver was encountering interference from experiment signals sent from the stationary satellite of a certain country in order to improve GPS accuracy for that satellite. The satellite started sending the signals from around last October, after the end of our previous flight experiment period. Without removing the receiver from the experiment airplane, we were able to change the configuration to prevent the reception of unrelated signals. If we had had to remove the GPS receiver and send it back to Japan, it would have been a huge setback.

——Again this year, you were forced to wait quite a long time before starting the experiment. What was the mood of the flight team like while you were waiting?

You might assume that we were simply waiting for the weather to change and had nothing to do, but it was an extremely emotionally-exhausting period. Every day, we held a meteorological briefing to determine whether the experiment would be held in two days time. Day after day (generally speaking, including Saturdays and Sundays as well), we were given the no-go for the experiment. These repeated disappointments slowly sapped the morale of our team. The experiment period started from June 29. By the time we reached the third week of July, a feeling of gloom had spread over all our team members. Upon observing such lack of morale, I became worried that team members would not be able to keep up their spirits until August 31. Therefore, I tried to think of ways to give everyone a change of pace. For example, I asked new members who had joined the team from this year to give a one-hour presentation on their research. Although these presentations only lasted an hour, everyone was able to forget about weather conditions. It was a really precious opportunity to refresh our spirits.

On a different note, our team heard a story about a certain rocket launching experiment that had been held at the Swedish Space Corporation (SSC). According to the story, the weather conditions needed for the experiment did not align and the team was forced to wait. Then, when team members wore green clothes to the meteorological briefing, the "go-sign" was given. Upon hearing this story, our team started a movement to wear something green to meetings. As another diversion for team members, the project manager purchased a green t-shirt at the space center (looking back, I now wonder why the center was selling green t-shirts...), and other members wore green sweaters and shoes. I'm sure it was just a coincidence, but we got the go-sign in about a week after starting the "green movement."

Masahisa Honda
Sub-Manager of D-SEND Project Team

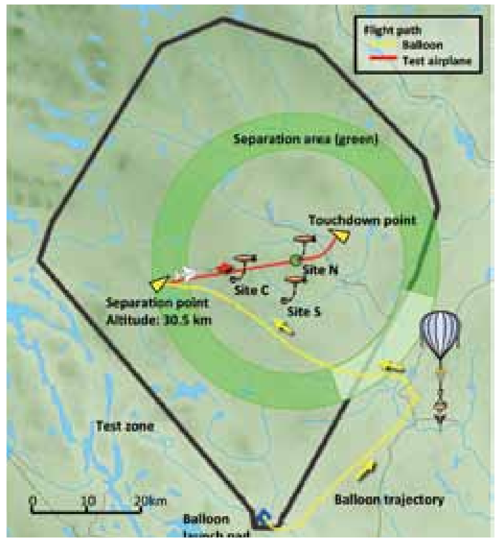
Preparation to completion

——How did you arrive at the decision to conduct the experiment?

First, every day at about 11:00 am local time, our JAXA team held a pre-briefing session to forecast the weather for two days later and to make a decision on whether or not to carry outthe experiment. JAXA conducted preliminary review based on weather conditions such as temperature, humidity, wind speed and wind direction, and by considering factors such as the predicted flight trajectory of the balloon and measuring conditions for the sonic boom. Then, from 2:00 pm, we attended a meteorological briefing held by the Swedish Space Corporation (SSC), who operates and maintains the Esrange Space Center. At this meeting, the SSC confirmed factors including weather conditions, the balloon trajectory, and the status of preparations by JAXA, and then issued a final decision regarding the experiment. This process was repeated every day, even Saturdays and Sundays, until we finally got the go-sign.

Unlike in 2013, when we aimed for the slight chance of conducting the experiment amidst poor weather conditions, the end of this year's experiment period gave us several consecutive days of appropriate weather conditions. When making a decision, we classified six weather conditions into the categories of red, yellow and green. I remember how everyone clapped their hands on the first day when all weather conditions were green. Even better, several of these "green days" continued in a row. It really seemed like our prayers via the green movement had been answered. In fact, there were so many green days that we had our choice of when to release the balloon. It was so fortuitous that we started worrying that something had been overlooked!

All weather conditions indicated in green. The go-sign for the flight experiment was given at the meteorological briefing.



Actual flight path. The balloon moved along the yellow line. The experimental airplane was released within the donut-shaped separation zone at an altitude of 30.5 km. . While following the path shown by the red line, the experimental airplane passed over the BMS Site N before touchdown.

——How was the team's mood on the day of the experiment?

For the majority of airplane team members, it was their third year. They had rehearsed the operation procedures countless times. Accordingly, everyone was confident that they could follow all the necessary procedure correctly without any problems .

The experiment site of the Esrange Space Center is extremely expansive, measuring about 100 km from north to south and 70 km from east to west. The control site and the BMS sites were located separately. As a result, in order to prepare for the experiment, team members in charge of the BMS had to travel to the BMS sites via helicopter about 10 hours prior to the balloon release. Each BMS group consisted of two members, and there was a total of three BMS sites. Four of these members were new to the project. Although they had undergone repeated preliminary training at an indoor site, training at the actual BMS site had only been held once. I imagine that these members were quite nervous at the time of the actual experiment.

Even after the go-sign was given for the experiment and preparations were started, it was still necessary to make a go or no-go decision at certain points such as deploying the balloon and filling the balloon with gas. During that process, it started raining lightly prior to transportation of the experimental airplane from the hangar. Consequently, the experiment countdown was put on hold, and there was a delay in preparations by the SSC technicians who were responsible for releasing the balloon. Overall, the time required until releasing the balloon was longer than planned. Since the support team located in Japan didn't have detailed information on local conditions, I am sure that they were filled with anxiety.

—— What was the situation after releasing the balloon?

The experiment team was divided into an Operations Center where the SSC operated the balloon and JAXA confirmed flight safety for the experimental airplane, and a Science Center where the status of the flight airplane and BMS sites was monitored. I watched over the release of the balloon from the Balloon Operation Center at 4:43 am. I had heard that our experimental airplane would be the heaviest payload that SSC had ever tested by balloon, so I was holding my breath at the moment that the balloon was released. I stared at the sky for a while after the balloon was released, worrying that it would burst and fall down. After seeing that the balloon was rising steadily, I entered the Science Center and began working with other team members to check wind conditions and the balloon flight trajectory.

Initially, we had planned to use Pattern B and separate the airplane three hours after the balloon release. During that three-hour period, there was some heated debate regarding the separation timing. In the end, the timing was not right for Pattern B separation, so we gave up and switched to Pattern A. Afterwards, while checking the altitude and wind direction, we guided the balloon in an attempt to realize the best possible conditions (to the outside of the donut where the experimental airplane will pass over two BMS sites).

We were able to perform separation under outstanding conditions about two hours later, at 10:00 am. After overseeing the separation countdown at the Operations Center, I ran to the adjacent Science Center and stared intently at the control monitor. The monitor in the Science Center showed a real-time display of the scheduled flight path and the actual flight path taken by the experimental airplane. Of course, the actual flight didn't go exactly according to plan. As I watched the control monitor, every single light indicating a deviation from the scheduled flight path increased my nervousness. Team members in charge of aerodynamics and flight control also remembered the flight deviation which had occurred in 2013, so everyone was extremely nervous.

The BMS sites were being monitored in real-time, so I knew right away that we had succeeded in measuring the sonic boom. However, I didn't truly feel like we had succeeded until I collected measurement devices which had been attached to the BMS and then played back the data. Thanks to swift response by the leader of the BMS group, I was able to check the data the day after the experiment.

Leading the world in sonic boom reduction technology

——Please tell us what is known about experiment results at the current time.*

Flight control for the supersonic airplane went smoothly and the flight proceeded according to plan. For the BMS, all recorders, both airborne and on the ground, operated correctly. We recorded many sonic booms. From among the three BMS sites, we succeeded in measuring low sonic boom waveforms at Site N. Microphones at the other two sites (Site C and Site S) measured several sonic booms. When combining all of these recordings, we succeeded in measuring a total of 196 sonic boom signatures. This is the first time that such a large amount of valuable sonic boom data was acquired through a single flight experiment.

From the acquired sonic boom data, we confirmed a sonic boom reduction effect. However, since the flight environment and other factors differed slightly from our original forecast, we are currently taking a more detailed look through CFD (Computational Fluid Dynamics) analysis and sonic boom propagation analysis. We still need a little more time before we can validate the "low sonic boom design concept" which is the objective of the project.

——When will detailed analysis results be released?

I hope to report on detailed analysis results at the SSTG (Supersonic Task Group), a meeting of the ICAO (International Civil Aviation Organization), which will be held in Canada at the end of October.

I would also like to present the experiment results at a general meeting of the CAEP (Committee on Aviation Environmental Protection) of the ICAO, which will be held in February 2016. At the meeting, discussion will be held regarding the formulation of international sonic boom standards in preparation for the operation of supersonic passenger airplane in the future.

——What aspect of the D-SEND Project has been the most difficult?

The experimental supersonic airplane doesn't have an engine or wheels for running on the ground. Therefore, it wasn't possible to conduct testing in the stages of ground runs, subsonic flight, and supersonic flight. Instead, prior to the actual flight, we were only able to test functions on the ground. In that respect, this project may have had more in common with the launch of a rocket or satellite than the flight test for an airplane. It's truly an all-or-nothing experiment. While being conscious of our budget and schedule, we had to think creatively, consider all possible happenings, and conduct development to ensure the success of our flight experiment.

On a different note, the SSC staff working at the test site in Sweden are easygoing and laid back. I felt some culture shock at the difference with Japanese people. An important part of my job as sub-manager was to engage in close communication with the SSC. In order to facilitate an environment for smooth implementation of the flight experiment, I had to overcome differences in culture and sensibility.

——In closing, please tell us your future plans and aspirations.

In the recent experiment we conducted supersonic flight for an experimental airplane which was designed with a low sonic boom nose and tail. We succeeded in acquiring a large amount of sonic boom data which includes low sonic boom signatures, and we are conducting detailed analysis and evaluation of this data. In doing so, I can say with confidence that Japan is one step ahead of the rest of the world. In the future, in addition to summarizing the results of the D-SEND Project, I hope to use these results as a base for pursuing new research themes in supersonic airplane technology.

*As of mid-September 2015

Flight system technology for making aircraft safer and more familiar

It is important for aircraft to be structurally strong and environmentally friendly. However, if aircraft built to possess such characteristics cannot be controlled, safe flight is not possible and passengers will lack peace of mind during flight. Aircraft are sometimes operated by pilots and sometimes flown via control by a program. In order to realize safe flight, it is necessary to formulate measures by assuming a variety of conditions including human error by the pilot and loss of control due to equipment failure. An extremely broad range of technology is needed to resolve such issues. What kind of technology is being researched at JAXA?

JAXA flight testing facilities are unlike any other in the world

The efficiency of research and development for flight technology has increased dramatically due to the use of wind tunnel experiments which have been utilized since long ago and to remarkable advancements in computational fluid dynamics (CFD) in recent years. However, as the final step for realizing actual operation, it is necessary to guarantee performance by conducting flight demonstrations in the actual operation environment. Aircraft manufacturers, onboard equipment manufacturers, airline companies and research institutions all have a wide range of varied needs which include evaluation of new sensors, actuators, avionics and control programs through flight demonstration, establishment of flight demonstration technology required for aircraft development, and flight evaluation for safe and efficient operation technology. In order to respond to these needs, JAXA operates three research aircraft (helicopter, propeller aircraft and jet aircraft) which possess different flight envelope (altitudes and speeds), as well as two flight simulators for fixed-wing aircraft and rotorcraft, whose control characteristics are completely different (see page 11 for details). In addition to responding to various demonstration needs, we are working to establish efficient testing technology, and to improve the level of testing technology and measuring technology.

The twin-engine turboprop aircraft MuPAL-α is equipped with an experimental Fly-By-Wire (FBW) control system in addition to the original mechanical system. This enables MuPAL-α to simulate the motion of various other aircraft. Aircraft with this functionality are rare and unique even on a worldwide level. These functions make it possible to conduct simulated flights by replicating the control of aircraft under development and the conditions of aircraft involved in accidents. As part of joint research with the University of Tokyo, MuPAL-α is being used in experiments for control technology which enables malfunctioning or damaged aircraft to continue safe flight and to land safely.

The research jet plane Hisho was unveiled in 2012 in order to enable flight testing at high speed and higher altitude. Hisho was used to conduct noise source measurements during JAXA's FQUROH (Flight demonstration of QUiet Technology to Reduce nOise from High-lift configurations) project. Furthermore, Hisho is scheduled for use in future flight demonstrations of technology for reducing noise. Hisho will also be used to conduct performance testing of evaluation instruments for flight testing of Japanese commercial aircraft, as well as confirmation for operation in flight testing.

The helicopter BK117C-2 was implemented in 2013 as the successor to the retired MuPAL-ε.

Flight data visualized on DRAP monitor

Tunnel-in-the-Sky displayed in cockpit

Currently, while enhancing the functions as a research aircraft, the BK117C-2 is being used in demonstrations of the Situational Awareness and Visual Enhancer for Rescue Helicopter (SAVERH) system which utilizes Helmet Mounted Display (HMD), and in measurements of wake turbulence.

As ground facilities, JAXA possesses two types of flight simulators which provide pilots with the same controllability and sensation as actual aircraft.

The flight simulator has the same cockpit display program, which are used in the FBW system of the MuPAL-α. This makes it possible to perform preliminary confirmation using the flight simulator before actual flight demonstrations.

"One advantage of JAXA is that we do much more than simply fly aircraft," explains Kenji Fujii, Director of the Flight Research Unit. "We possess technology and know-how related to measurement technology and flight testing. We will continue to contribute to the growth of the aeronautical industry through joint research with private sector companies, universities, and other public organizations by using our flight testing facilities."

Preventing human error by pilots

As one type of technology for preventing human error, Crew Resource Management (CRM) training is widely conducted by airline companies, the Japan Self-Defense Forces, the Japan Coast Guard, and organizations which train pilots. JAXA has also contributed to the implementation of CRM, which is a concept in which safe and efficient flight operations are realized through the effective utilization of all resources; specifically, people (pilots, air traffic controllers, mechanics, etc.), objects (manual, airports, etc.), and information. JAXA is currently developing a tool to evaluate the effectiveness of CRM education. Furthermore, from the viewpoint of human elements, JAXA plans to establish a system which comprehensively evaluates various human factors which include pilot emotions, mental state, ability, skill and fatigue.

One JAXA technology which has already been put into practical use at several airline companies is the Data Review and Analysis Program (DRAP), which replicates actual flight conditions as three-dimensional visual information. By using DRAP to reconfirm their own flight conditions and maneuvers, pilots can reduce future errors and improve their skills.

Another technology which has already been put into practical use is Tunnel-in-the-Sky. Tunnel-in-the-Sky is a flight support system which displays a tunnel-shaped flight path on the cockpit display. By flying inside of the displayed range, pilots can realize smooth flight and landing. By explaining this technology as drawing an imaginary tunnel in the sky and flying inside the tunnel, the technology might be easily understood. In addition to use in JAXA flight demonstrations which require precise flight trajectories, Tunnel-in-the-Sky is also being use at private helicopter companies for airborne laser surveying which also demands precise flight trajectories.

JAXA is also focusing on research and development for the aforementioned SAVERH as a human interface for supporting control of helicopters for which only visual flight is possible. This system combines infrared

SAVERH display

Various information projected by HMD (display image)

Pilot using HMD

cameras and topographic data to reduce workloads on pilots and increase flight safety even in poor weather conditions without sufficient visibility.

Topographic information, flight path information, infrared camera images and other required information are displayed on the HMD, and the system automatically measures the distance to specified obstacles.

Also flight control systems are important to enable safe control for broad flight envelope such as from takeoff, landing, to high-speed flight at high altitudes, as well as supersonic flight for the future theme. In addition, flight control systems should be able to handle emergencies and sudden changes in weather conditions such as turbulence. JAXA is conducting research to develop tools which enable efficient design and evaluation of such flight control systems.

"Through advancement of such technology, we hope to realize aircraft which can be controlled easily by anyone," says Fujii. "Accordingly, our goal is to develop a safe flight system which can be controlled easily and which responds under any conditions." The establishment and spread of this technology will make aircraft a more familiar tool of our lives.

Toward expanding the use of helicopters

In Japan, a country which has little flat ground and is filled with mountains and islands, helicopters (rotorcraft) account for roughly 30% of all registered aircraft. This is an inordinately high ratio when compared to other countries. Helicopters are used in a variety of situations including search and rescue, emergency transport, and shipping of goods. However, the further expansion of helicopters is hampered by threats to safe flight due to poor visibility as well as by noise control issues in urban areas. In order to improve these conditions and expand the usage of helicopters, it is necessary to develop safer flight support technology.

Fixed-wing aircraft cause wake turbulence during takeoff or landing. This wake turbulence has a significant impact on the takeoff or landing of the following aircraft. For many years, research has been conducted on the occurrence and disappearance of this wake turbulence. As a result, global rules have been established for the takeoff and landing interval at airports according to the size of fixed-wing aircraft (see FLIGHT PATH No. 7/8). However, the air flows created by helicopters are more complicated than the wake turbulence caused by fixed-wing aircraft. Little research has been conducted and no international rules exist for helicopter wake turbulence. In order to realize efficient and safe flight for many helicopters, it is necessary to understand the occurrence mechanism and impact of helicopter wake turbulence. JAXA is conducting research by flying helicopters over runways, using LIDAR* and a supersonic anemometer to measure the resulting wake turbulence, and visualizing the air flow. Data obtained through these experiments will be used in the future to predict helicopter wake turbulence.

Additionally, in combination with D-NET2 (Integrated aircraft operation system for disaster relief; see FLIGHT PATH No. 7/8) technology for efficient aircraft operation during emergencies, JAXA is researching technology which uses millimeter-wave radar and infrared cameras to detect power lines which are a dangerous obstacle during low-visibility conditions and then notifies the pilot. We are also working to enable flight during poor weather conditions using instruments only.

*A sensor which uses a laser to irradiate airborne particles and then measures wind speed based on the scattered light.

Kenji Fujii
Director, Flight Research Unit

JAXA's research aircraft and flight simulators

Flight testing facilities include research aircraft for collecting data through actual flight and flight simulators for simulating aircraft flight conditions on the ground.

Research aircraft

Hisho

This jet airplane enables flight demonstrations in high-speed, high-altitude environments. Hisho is based on the Cessna 680 and equipped with devices/antennas for precise measurement of flight conditions and attitude, as well as a camera aperture which provides a view of directly below the cabin. Hisho started operation from 2012.

MuPAL-α

Based on the twin-engine turboprop airplane Dornier 228-202 (19 passengers and 2 pilots), MuPAL-α is equipped with an experimental Fly-By-Wire control system and can perform in-flight simulation.

Research helicopter

Based on the Kawasaki BK117C-2, this research helicopter was implemented as the successor to the MuPAL-ε which was retired in February 2013.

Flight simulators

FSCAT-A

The fixed-wing aircraft simulator FSCAT-A uses an actuator to move the cockpit and simulate the acceleration felt during flight.

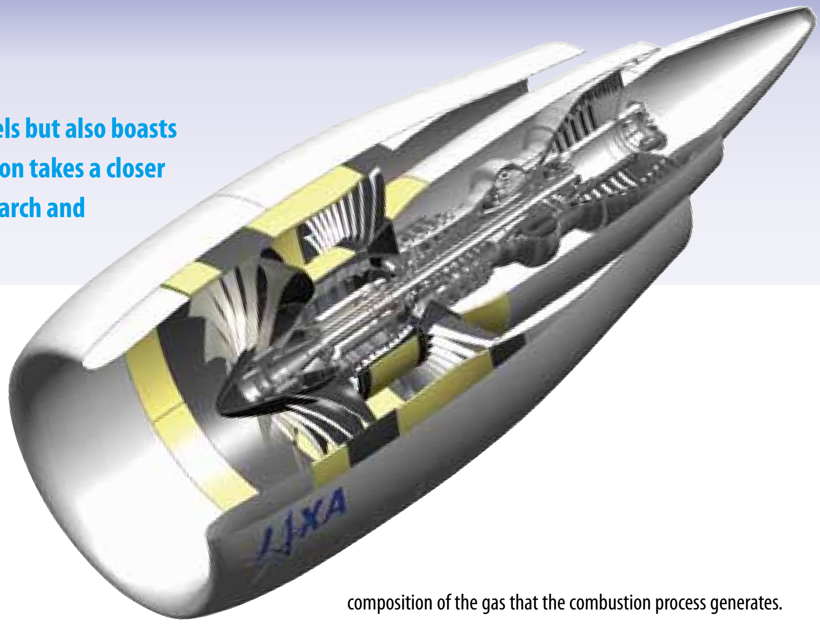
FSCAT-R

The rotorcraft flight simulator FSCAT-R realizes an environment close to actual controls by projecting images on a hemispherical screen to create a broad field of vision. FSCAT-R is used in research and development such as SAVERH.

Supporting Japan's aircraft engine technology

with JAXA's engine test facilities and measurement technologies

JAXA's Chofu Aerospace Center not only features wind tunnels but also boasts a wide variety of aircraft engine testing facilities. This section takes a closer look at how these facilities have driven aircraft engine research and development and how the testing equipment will open up the skies to new possibilities in the future.



Jet engine structures that facilitate component research and development

A jet engine has a "modular configuration" that comprises several components in series: the fan (which feeds in air), the compressor (which compresses the air), the combustor (which mixes the compressed air with fuel and burns the mixture), and the turbine (which uses the high-temperature gas that comes from the combustor to rotate the engine). Unlike the structures of piston engines and other engine types, the modular configuration of a jet engine has an independent, four-step cycle—intake, compression, combustion, and emission—that makes it possible to develop and test each component separately and thereby create an optimal engine by combining the components that ensure proper performance. The modular configuration of a jet engine is also why the aFJR project, which began in 2015, can concentrate specifically on developing technologies for environmentally friendly fans and low-pressure turbines. Taking advantage of the unique benefits that modular configurations offer, the Chofu Aerospace Center features facilities for developing and demonstrating components on an individual basis and jet engines in complete packages.

The "fan and compressor test facility," capable of rotating test items several tens of thousands of times per minute at high horsepower levels, allows researchers to evaluate fan, compressor, and other component parts at the rotational speeds that they would experience in actual operations. At the "high-pressure and high-temperature combustion test facility," meanwhile, researchers can feed compressed, heated air and fuel into combustors to assess the combustion flames and the composition of the gas that the combustion process generates. The "materials test facilities" enable researchers to test turbine materials and more under real-life usage conditions.

In addition to housing these component testing facilities, the Chofu Aerospace Center also boasts a host of other testing facilities: the "jet engine test cell," which operates jet engines for aircraft up to the regional jet class for performance evaluations, the "altitude test facility" (ATF), where researchers can quickly and easily replicate the high-altitude environments that jets fly in, and the "noise test facilities," which measure the noise emitted by exhaust nozzles, are just several examples.

Fan and compressor test facility

At the fan and compressor test facility, researchers test fans and compressors under high-speed rotation conditions.

Hisao Futamura
Director
Propulsion Research Unit

Facilities that have evolved together with aircraft engine research in Japan

Most of the aircraft engine testing facilities at the Chofu Aerospace Center went into use after the research and development project for the FJR710 (during the 1970s and 1980s), the high-bypass-ratio turbofan engine that represented a first for the domestic Japanese market and laid the foundation for the country's aircraft engine industry. The jet engine test cell—one of the post-FJR710 installations—allows researchers to test engines ranging from ultra-small engines with 2.5 kN of thrust to regional jet-class engines with up to 100 kN of thrust. Since the turn of the century, the Center has revamped the facility for testing various engine control technologies by enabling partial engine operation functionality during testing (variable turbine nozzles, etc.) and supporting controls of fuel flow volume and other parameters.

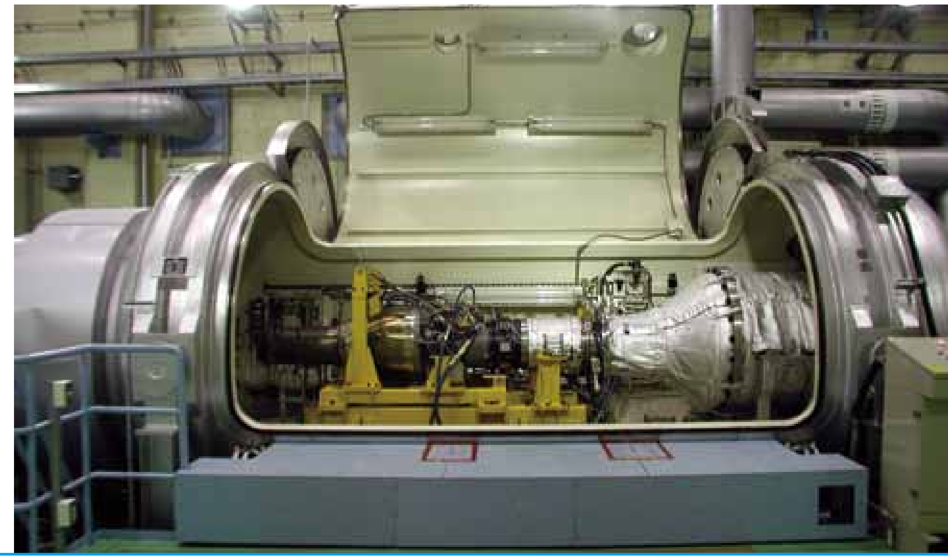
The altitude test facility recreates airborne flight environments in a sealed chamber and features engine testing equipment that allows researchers to simulate conditions at speeds of up to Mach 2 and thin-air altitudes of 15 km. The facility provides an optimal setting for two main test types: direct-connect testing, which involves feeding air directly into the engine and measuring the performance levels of the engine itself at subsonic speeds, and semi-free-jet testing, which measures performance under supersonic flight conditions with the air intake on the engine. To provide researchers with information on shockwaves that occur inside the air intake, the design of the facility also enables schlieren*1 measurements.

From the late 1970s through to the 1980s, the "Moonlight Project"—a Japanese governmental initiative to create energy-saving technologies—used JAXA's engine testing facilities to research and develop electricity-generating gas turbines. As jet engines and gas turbines have essentially the same basic structure, the JAXA testing facilities offer that kind of versatility. In the late 1990s, JAXA, the National Institute of Advanced Industrial Science and Technology, aircraft engine manufacturers from Japan and around the world, and other organizations used the engine testing facilities as part of the ESPR project for the development of next-generation supersonic engines.

"There might be bigger facilities abroad," says Hisao Futamura, Director of the Propulsion Research Unit , "but the

Jet engine test cell

Users can assess the operations of jet engines all the way up to the 100 kN class from the ground and test engines with large bell mouths on engine air intakes.



Altitude test facility

The altitude test facility recreates aircraft flight environments for testing purposes. At the facility, researchers install an engine inside the chamber, seal the environment, and modify temperature and pressure parameters to test the corresponding conditions.

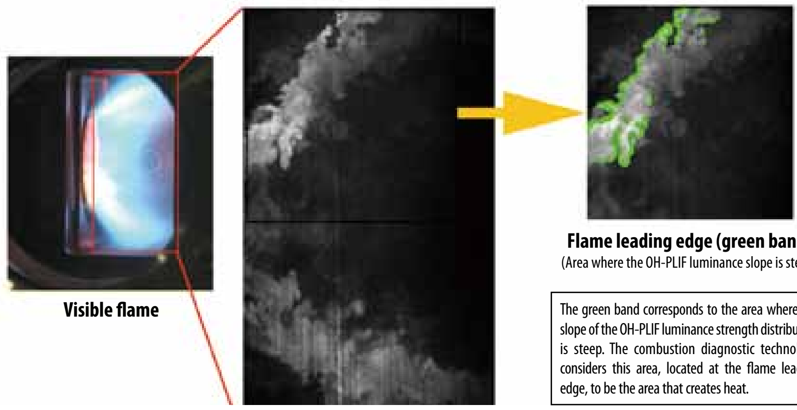
*1 An optical method that involves passing a parallel light beam through a flow and observing the variations in the resulting light to measure changes in (the gradient of) gas density.

facilities we have in place right now can make valuable contributions to regional jet-class engines." The ongoing aFJR project (see FLIGHT PATH No. 1/2 for details) is assessing fans made of carbon fiber reinforced plastic (CFRP) at the fan and compressor test facility and planning to test low-pressure turbines made of ceramic matrix composite (CMC) at the materials test facilities. In the effort to research engine noise reduction technologies, researchers have placed microphone arrays at the noise test facilities, the jet engine test cell, and other facilities to determine noise sources, evaluate the effects of noise-reduction devices, investigate noise propagation conditions, and more.

Like JAXA's wind tunnels and other facilities, several of the testing facilities at the Center are open to outside organizations like companies and universities. At the high-pressure and high-temperature combustion test facility, for example, oil for jet engine fuel is just one of many materials that users can test—the facility also enables testing of natural gas and hydrogen gas, helping companies research and develop industrial-use gas turbines that use non-jet fuel.

A sample image of OH-PLIF under a high-pressure condition

Combustor inlet air pressure: 700 kPa; combustor inlet air temperature: 760 K



Shown here is an OH-PLIF image obtained by synchronizing laser pulses with the capture timing of a light-receiving device (comprising a camera and a light-amplifying image intensifier) to the order of several nanoseconds. According to the measurement, the exposure time (the gate time of the image intensifier) was 20 nanoseconds. The intensity of the white color corresponds to the intensity of the OH-PLIF luminance. This sample OH-PLIF image was taken at a sampling rate of several Hz with a conventional measurement system. Now, we are applying a 10,000 Hz system for similar testing conditions.

Creating environment-friendly aircraft engines

Responsible for mixing and burning compressed air and fuel, the combustor has a significant impact on an engine's environmental performance. In the recent drive to meet aircraft fuel efficiency requirements, enhanced combustor performance has been a vital element in improving environmental adaptability through reduced emissions of nitrogen oxide (NOx) and other substances.

Jet engine combustors are usually shaped like donuts (rings) with a series of equally spaced fuel nozzles on the upstream side. When researchers do development testing on a combustor, they normally follow a step-by-step process to assess combustor performance: after starting with a partial model for a single fuel nozzle (a "single sector") or a cylindrical combustor, they then proceed to a "multi-sector" of three to five fuel nozzles and finally the annular combustor. To facilitate that process, JAXA has implemented a high-pressure and high-temperature combustion test facility that allows researchers to test single sectors and multi-sectors under actual temperature and pressure conditions and an annular combustor test facility capable of supplying large airflows.

Another essential element in developing high-performance combustors is the ability to analyze combustion mechanisms in detail. Thanks to advances in computational fluid dynamics (CFD) technologies, we are now gradually getting to the point where we can produce analysis results that reflect real-life conditions with impressive degrees of precision—but we still lack the resources to make accurate predictions of all the phenomena that can occur with fuel and combustion gases. JAXA thus used the high-speed OH-PLIF measurement method (see FLIGHT PATH No. 1/2 for details), which makes it possible to photograph flame movements at high speeds, to develop a technology for diagnosing combustion dynamics. The PLIF (Planar Laser Induced Fluorescence) method measures how specific molecules distribute in space by photographing the light that molecules produce in response to an excitement stimulus from a laser sheet of a specific wavelength. The high-speed OH-PLIF method, meanwhile, lets users measure the concentration distribution of the OH radical (a molecule combining oxygen and hydrogen and an intermediate of a combustion reaction) at blazing speeds of 10,000 frames per second. By pinpointing exactly how flame structures move over time via the OH-PLIF methods, researchers can improve various contributors to combustor performance—from exhaust gas and combustion efficiency to heat resistance.

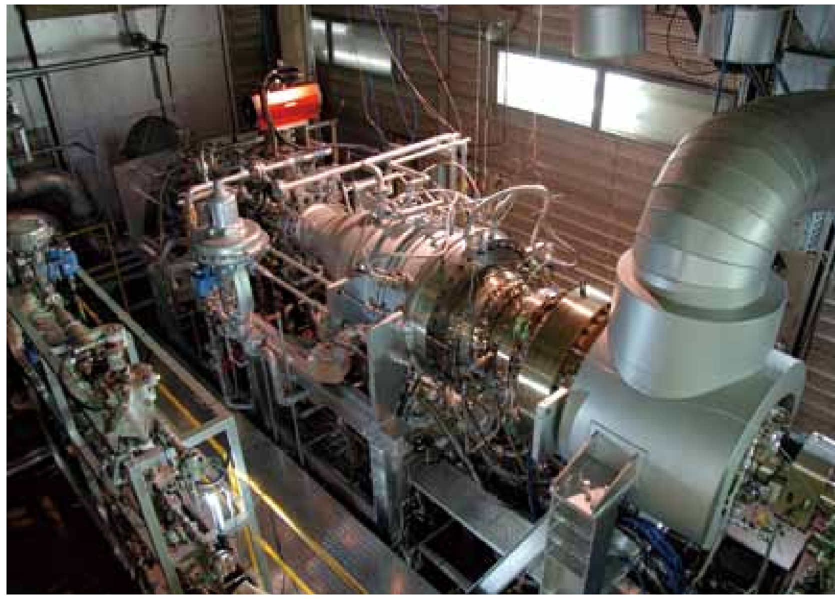
These testing facilities and sophisticated measurement technologies have allowed JAXA to establish a clearer understanding of combustion mechanisms and work on combustors with minimal NOx emissions—in fact, JAXA researchers have already created a combustor that cuts NOx emissions by 82% relative to the criteria that the Committee on Aviation Environmental Protection (CAEP) of the International Civil Aviation Organization (ICAO) issued in 2004 (CAEP/4). JAXA is also engaged in research and development efforts geared toward reducing NOx by 75% relative to CAEP/6 (issued in 2008)—an even stricter standard than CAEP/4—and ensuring practical viability of the resulting technology.

Takeshi Yamamoto
Senior Researcher
Chief Manager for Planning
Propulsion Research Unit

High- pressure and high-temperature combustion test facility
The high- pressure and high-temperature combustion test facility tests partial models of jet engine combustors.

Noise test facilities
Noise test facilities serve to determine noise sources, evaluate the effects of noise reduction devices, check noise propagation conditions, and perform other functions.

Materials test facilities
At these facilities, researchers test turbine materials and other items under actual usage conditions.



Annular combustor test facility
The annular combustor test facility tests jet engine combustors as complete components.

If researchers put new components into an engine and attempt to evaluate the results with the current testing equipment, however, they have no way of knowing exactly how the component affects the engine as a whole or whether the components will function according to plan when the engine starts up or accelerates. "I hope we can work on implementing demonstration-use engines, which would provide the infrastructure for validating the component technologies we develop in a full-engine context," Futamura says. "If we can gather demonstration data on engines, I think we can start building technologies for doing simulations on and evaluating engine designs. That will help cut engine development costs by substantial margins."

Serving as an "all-Japan" research and development center

Engine-oriented companies, gas turbine-related companies, and research institutions in Japan certainly have some in-house engine testing facilities, but the Chofu Aerospace Center is the only place in the country with such an extensive collection of aircraft engine-testing equipment. In order to give Japan a competitive edge in the international aircraft industry arena, JAXA will need to serve as a research and development center where people from universities and manufacturers alike can come together and collaborate. According to Futamura, "Aircraft are a part of our social infrastructure—and they have a particularly long lifespan, as well. That's why we have to sustain our technology development. There's no point to thinking in the short term. I think we need to improve on the technologies that our predecessors have given us, train young engineers, and establish a structure that can raise the standard on a nationwide, 'all-Japan' basis."

Recent years have seen many examples of multiple companies teaming up on jet engine development projects. Thanks to the modular nature of jet engine structures, individual manufacturers can combine their respective fans, compressors, and other components into a complete engine. "Right now, we're involved in joint research with Japanese engine manufacturers on core engines[*2]—an area where Japan has never led a cross-border joint development effort," explains Takeshi Yamamoto, Chief Manager for Planning at the Propulsion Research Unit. "When the top-quality technologies that come out of that effort go into practical use, Japan will be able to secure a larger chunk of the market."

*2 The compressor/combustor/high-pressure turbine portion

JAXA's electric aircraft!

Exploring the technologies that the FEATHER (Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution) project has demonstrated

During FEATHER (Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution) flight demonstration tests in February 2015, JAXA successfully achieved manned flight for approximately 17 minutes at an altitude of around 600 m. This section takes a closer look at the realm of electric aircraft technology, where organizations around the world are competing to establish technologies that could spark aircraft innovation.

Advances in battery technology have opened up new possibilities for electric aircraft

"For about ten years now," says Akira Nishizawa, FEATHER Team Leader, "electric propulsion technologies for aircraft have been making rapid progress all around the world."

One of the catalysts behind that accelerated development activity was the arrival of the lithium-ion rechargeable battery (lithium-ion battery). Lead and nickel-metal hydride batteries, which had been the main power sources before the lithium-ion battery came along, were too heavy to install onboard aircraft and often failed to ensure sufficient endurance and cruising distance levels. A lithium-ion battery—even one light enough to install onboard an aircraft—has enough energy density to generate the power it takes for an aircraft to fly. The introduction of lithium-ion batteries has opened up a world of new possibilities in electric propulsion technologies for aircraft.

Unlike reciprocating engines, which run on aviation fuel, battery-driven motors produce no carbon dioxide (CO_2), nitrogen oxide (NO_x), or any other exhaust gases and also deliver amazing energy conversion efficiency levels of 90% or higher. The structures and mechanisms of a battery-powered motor are simple, too: they eliminate the need for elements like oil piping, thereby reducing the overall engine weight and cutting maintenance costs. However, batteries lack the energy capacity per unit of weight (weight energy density) of traditional fossil fuels. Even a lithium-ion battery, a battery type with a relatively high weight energy density, needs to be heavy in order to enable the same duration of flight as a reciprocating engine; that added weight can prevent an aircraft from taking off.

That does not mean that electric aircraft are totally impractical, though. Around 10 years ago, the United States created a "Light-Sport Aircraft" (LSA) sub-category of smaller, sports-oriented aircraft that fall into the broader "small propeller aircraft" classification. As LSA only have to be able to fly for short periods of time, electric aircraft can meet user needs. Efforts to develop airworthiness criteria for electric aircraft in the sub-category are already in motion. The way things are going, research and development on electric aircraft are going to be progressing even faster than they have over the last decade.

JAXA's unique "redundant motor" and "regenerative air brake" technologies

Small, single-propeller planes that use reciprocating engines are prone to accidents caused by engine failure and the resulting loss of thrust. To help remedy that problem, the FEATHER project developed a "redundant motor system" that uses four serially linked electric motors to drive the propeller. Even if some of the motors fail, the redundant configuration makes it possible to maintain flight and complete a safe landing with the remaining motors. Overall, a redundant motor system makes electric aircraft operations safer and more reliable than a traditional reciprocating engine can. In February, researchers tested the motor by setting the output of one of the motor components to zero. The results showed that the remaining motor components were enough to allow the aircraft to climb, maintain the minimum necessary thrust, and remain safely in flight.

Some companies and organizations outside Japan are also working on ways of driving the tail rotors of helicopters using redundant electric motors with two motor components. If the current efforts are any indication, redundant motors might represent a key piece in the development of electric propulsion technologies.

JAXA's "regenerative air brake," another unique technology, uses the rotation of a propeller—which acts as an air brake—to supply the aircraft with power. Hybrid and electric cars have regenerative systems that regenerate kinetic energy into electric energy during deceleration and use that new electric energy to charge the vehicle's battery. With the regenerative air brake system that came out of the FEATHER project, an aircraft can recover power as the wind turns the propeller during descent procedures and other situations where the electric motor is not powered. At the same time, propellers that are not using any motor drive also serve as aerodynamic resistance (air brakes). As gliders usually have high lift-drag (L/D) ratios, they deploy air brakes on their main wings during landing procedures to expedite the descent process. Regenerative air brake systems not only help save energy but also eliminate the need for these types of main wing air brake devices, a benefit that brings the overall weight of the aircraft down and improves maintainability. Although pilots normally have to use both the throttle lever and air brake controls, regenerative air brake systems reduce the overall workload for electric aircraft pilots—all a pilot needs to do is switch the power lever for adjusting output from the drive side to the regeneration side.

The propellers of reciprocating engines and electric aircraft produce the same aerodynamic noise, but electric aircraft engines generate less vibration and noise. When a pilots who flew JAXA's electric aircraft experimental flights in February went back to flying the same aircraft models with reciprocating engines, he was apparently surprised at just how much shaking and noise they experienced. Electric aircraft also save pilots the trouble of having to check hydraulic pressure and engine temperature levels, which are two of the many things that they have to keep an eye on with reciprocating engines. With fewer items to monitor, pilots have an easier job of flying their aircraft.

Reciprocating engine aircraft vs. Electric aircraft

Item for comparison	Reciprocating engine aircraft	Electric aircraft
Fuel consumption	×	◎
Maintenance cost	×	◎
Cruising range	◎	×
Noise/vibration	△	○
Pilot work load	△	○

Flight testing
at the Japan Air Self-Defense Force's Gifu Air Base

Specification of the experimental motor-driven glider system

Original motor glider	Diamond Aircraft Industries GmbH HK36TTC-ECO
Width	16.33m
Max. takeoff weight	850kgf (flight tests were performed at 800 kgf)
Max. output	60kW
Crew members	1 person

Setting precedents in the skies with revolutionary new aircraft

To secure flight clearance for revolutionary, brand-new aircraft, JAXA started implementing its electric propulsion system in aircraft in 2014, conducted sufficient ground-based static tests (where researchers rotate the motor with the motor fixed to the ground), and performed the necessary ground-based runway tests (where the aircraft travels on the ground until it reaches a speed that it would attain just before takeoff). The Civil Aviation Bureau finally grants flight clearance once these tests are complete. Immediately after receiving flight clearance, JAXA conducted jump flight tests—assessments where aircraft "jump" several meters off the ground. For the final testing procedures in February 2015, JAXA performed demonstration flights by sending aircraft into traffic patterns at an altitude of 600 m.

Ranging from flight clearance protocol and wind tunnel testing to load testing, discharge testing, full-aircraft ground-based testing, and flight testing, the breadth of the experience and expertise that JAXA has gained through the FEATHER flight demonstration process will be useful resources for electric aircraft flight tests at Japanese companies and universities.

Could electric aircraft technology be a Japanese specialty?

For the experiments, JAXA took a glider that had originally had a reciprocating engine and modified the configuration so that the aircraft would run on an electric motor and battery. Researchers also made sure that the modifications would not alter the glider's airframe weight or center of gravity—conditions that made it impossible to install a heavy battery. During the February flight demonstration tests, researchers successfully flew the aircraft for up to around 17 minutes using a battery that had about 20% to 30% of its power left. Had they been using an unmodified electric aircraft, however, they would have been able to load a heavier battery and achieve longer flight duration.

Looking back on the process, Nishizawa says, "The technologies are unique products of JAXA's research and development initiatives. It's really encouraging to know that we have achieved something that has never been done in Japan before—manned flight in an electric aircraft." The FEATHER project's efforts to demonstrate an electric propulsion system may have come to an end in March 2015, but the drive to demonstrate aircraft electrification technologies is still pushing forward across the globe.

Just as electric and hybrid cars have given non-automotive companies inroads into the automotive sector, electric aircraft technologies have the potential to bring other industries into the aircraft market. That opportunity for involvement is sure to accelerate the electrification of aircraft, which requires technologies for high-performance electric motors, high-output, high-capacity batteries, fuel cell systems that enable longer cruising distances, and systems for controlling those various components. These are all fields where Japan boasts some of the best technologies available. If the country can unite all of its cutting-edge technologies in these areas, Japan will be able to establish electric aircraft technologies that stand a head above the international competition.

Akira Nishizawa
Associate Senior Researcher
Emission-Free Aircraft Section
Advanced Aircraft System Research
Aircraft System Research Team
Next Generation Aeronautical Innovation Hub Center

In response to demand for more fuel-efficient aircraft, research and development are being conducted throughout the world for jet engines which are more efficient and weigh less. One method attracting attention is the use of ceramic matrix composites (CMCs) which can withstand high temperatures in areas such as turbines. JAXA is conducting research for high-quality, low-cost CMCs.

Composite materials for next-generation jet engines What are ceramic matrix composites (CMCs)?

CMC attitude control thruster used for combustion test

Composite materials which withstand severe high-temperature environments

In the case of aircraft and spacecraft such as rockets or satellites, a reduction in weight leads to increased performance. For this reason, an emphasis has been placed on the use of composite materials such as carbon fiber reinforced plastics (CFRPs). However, CFRPs are not able to withstand high temperatures in hot parts of jet engines and rocket engines. Accordingly, there is a strong demand for a lightweight and durable material which can withstand high temperatures. For example, the bottom of the fuselage of the retired NASA space shuttle was lined with heat-resistant tiles which protect the airframe from high temperatures caused by aerodynamic heating when reentering the Earth's atmosphere. Made mainly from silica glass, these tiles are extremely lightweight and provide superior heat resistance, but are as fragile as pumice.

As a result, much attention has been given to ceramic matrix composites (CMCs) in recent years. Since the 1990s, JAXA has conducted research for the application of CMCs to high-temperature structural materials of space planes. Made of ceramics, CMCs weigh less than metal, and are highly resistant to heat and oxidation. Furthermore, the use of ceramic fibers makes CMCs resistant to cracking. "CMC materials are difficult to crack and may stay intact even when colliding with a small foreign object," says Takuya Aoki of the Structures and Advanced Composite Research Unit. "They have the possibility of increasing the reliability of space planes." JAXA has used CMCs to manufacture prototypes of attitude control thrusters (see top-right photograph) for spacecraft, and has conducted combustion tests and other performance evaluation for the prototypes.

Currently, nickel-based alloys are the main material used in jet engine turbines. However, CMCs began to attract attention on a global scale from around 2000, and high-pressure turbine shrouds made from CMCs are close to being type approved. JAXA started research on CMCs for use in jet engines from around 2005.

Toward next-generation CMCs which provide high performance at a low cost

CFRPs, which are used in the structural components of aircraft and spacecraft, are a composite material in which carbon fibers woven into a flat surface or three-dimensional shape are solidified using a resin (plastic). CMCs are made by weaving silicon carbide (SiC) or other ceramic fibers with a diameter of 7 µm to 20 µm into a flat surface or three-dimensional shape. Next, raw materials such as silane gases or organic silicon polymers is injected into the gaps among fibers, and the raw materials are then converted into ceramics. This hardened portion is called the "matrix." However, the CMC will crack easily if the bond between the fibers and matrix is too strong. Therefore, it is necessary to moderately weaken the adhesive strength between the fibers and matrix. Compared to ceramic cups or other monolithic ceramics which do not use fibers, CMCs manufactured in this way are much more resistant to cracking.

CMCs are finally being put into practical application in the aircraft industry. In JAXA's aFJR (Advanced Fan Jet Research) project*1 , we are working to resolve technical issues arising from the application of CMCs to low-pressure turbines in cooperation with a Japanese engine manufacturer. With an eye on the application of CMCs to next-generation jet engines, JAXA is conducting research on CMCs which are inexpensive and can withstand even higher temperatures.

There are several manufacturing methods for CMCs. The most prevalent of these methods is the polymer infiltration and pyrolysis (PIP) method. In this method, polymers which convert to SiC through heat treatments are injected into the gaps among SiC fibers and then baked to solidify. Another prevalent method is the chemical vapor infiltration (CVI) method, which consists of infiltrating source gases to enact vapor deposition of the SiC. In both methods, formation of the SiC matrix requires from one to two months and the manufacturing cost is high. The molten silicon infiltration method consists of impregnating the gaps among fibers with SiC or carbon powder, and then pouring in melted Si. Compared to the two methods described earlier, the melt infiltration method significantly shortens the time required for matrix formation. However, the processing temperature when pouring molten silicon is high, so it is necessary to use expensive SiC fibers which are highly resistant to heat. JAXA is currently reviewing a "melt infiltration method using silicon alloys" in which a silicon-titanium alloy with a lower melting point is poured instead of pure silicon. This method makes it possible to use inexpensive SiC fibers, and the resulting CMC has moderate levels of heat resistance. Through this method, we believe it is possible to reduce cost in terms of both materials and manufacturing.

Item	PIP method	CVI method	SiC powder + melted Si impregnation method	Molten Si alloy infiltration method
Matrix forming temperature	1000 -1200℃	1000 -1200℃	>1414℃	<1400℃
Matrix forming time	1 to 2 months	1 to 2 months	Several days	Several days
Matrix forming cost	High	High	Low	Low
Fiber gap	Large	Large	Small	Small
SiC fiber	Inexpensive	Inexpensive	Expensive	Inexpensive

Comparison of CMC manufacturing methods

CMCs still have a low level of technological maturity when compared to metal materials and CFRPs. "Although manufacturers are interested in CMCs, they are hindered from taking action due to factors such as manufacturing time, cost and profitability," explains Toshio Ogasawara. "JAXA seeks to contribute to the aerospace industry by pioneering research in CMCs."

SiC fibers were invented at Tohoku University, and two Japanese manufacturers hold approximately 100% of the global share. Accordingly, contributing to the spread of CMCs will also contribute to Japanese industry as a whole. "In order to expand the use of CMCs, it is necessary to develop a variety of technologies required for practical implementation," says Masaki Kotani. "These technologies range from design to inspection and maintenance. JAXA will continue our work to make new advancements in these areas."

(from right)
Structures and Advanced Composite Research Unit *2
Takuya Aoki, Associate Senior Researcher
Toshio Ogasawara, Senior Researcher
Masaki Kotani, Associate Senior Researcher

*1 JAXA's project to develop and demonstrate aero-engine technologies that improve the environmental compatibility of fans and low-pressure turbines . Refer to FLIGHT PATH No. 1/2.
*2 As of August 31, 2015

To enable short-term R&D return: SafeAvio industry-academia-government collaboration

SafeAvio*1 is JAXA's R&D initiative that seeks practical solutions to prevent turbulence induced aircraft accidents. The uniqueness of the SafeAvio initiative is its R&D framework that accommodates diverse opinions and expertise through the "SafeAvio Research Committee," a collaborative community consisting of universities and the aviation industry including avionics and airframe manufacturers and airlines.

Let 's look into what makes the SafeAvio initiative different from conventional R&D.

Yielding return with shorter R&D cycle

With a view towards speedy R&D and smooth commercialization of a system that prevents turbulence-induced aircraft accidents, the SafeAvio Research Committee was formed in 2012 under the leadership of Professor Shinji Suzuki of the University of Tokyo. In addition to the University of Tokyo, Tohoku University and JAXA, the committee consists of many key players involved in all stages from R&D to practical implementation, such as airframe manufacturers, avionics manufacturers, the Society of Japanese Aerospace Companies (SJAC), and airline companies serving as advisors.

Working towards the shared goal, the committee functions as an open discussion platform where participating members exchange ideas and expertise for better solutions from their own perspective. The initial step has started by developing and maturing "turbulence detection and information provision technologies". JAXA and avionics manufacturers are the major players leading this R&D phase planned over a 4-years period, and are currently developing a Doppler LIDAR*2 system which detects turbulence and provides warnings to pilots. Universities are cooperating with the R&D by addressing studies on sophistication and advanced technologies. These studies include "airflow estimation algorithms" for predicting airflow transitions from observed data, and "pilot workload evaluation" to find out how pilots react when receiving the turbulence information as well as to analyze associated burden put on pilots. Meanwhile, airframe manufacturers bring their own ideas as to how best to mount the completed detection system onto airframes, and airline companies provide feedbacks and opinions on the pilot interface from an end-user perspective. Incorporating these opinions and ideas from the development stage will facilitate smooth implementation after commercialization of technology. It will also allow researchers, engineers and manufacturers to co-produce final products that function smoothly in actual operational settings and that are user-friendly. Accordingly, the whole R&D cycle and timeline towards implementation to commercialization can be shortened significantly while optimizing operationability and usability.

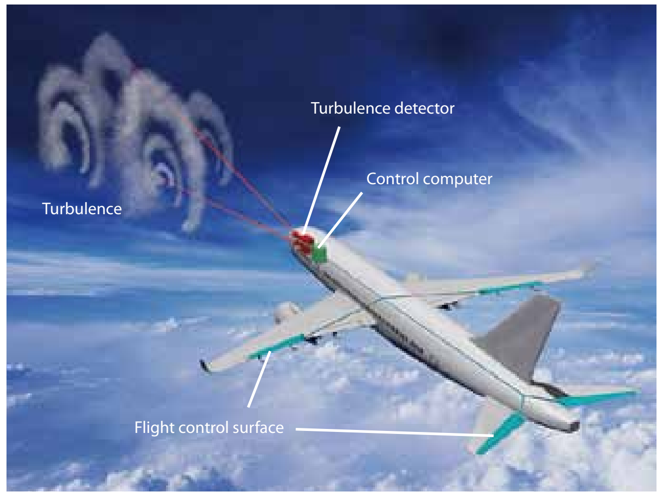


Image of clear air turbulence detection system

Making the most of an "all-Japan" system

Once the initial four-year R&D phase is completed at the end of fiscal year 2016, the core players in the committee will shift to avionics manufacturers and airframe manufacturers for commercialization.

Focusing on after commercialization, the committee has already started discussion on how to make use of the detected turbulence information for realizing safer flight. Firstly, regarding conditions in the passenger cabin of a passenger aircraft, a standard model for 5-minute intervals was proposed to airline companies. Furthermore, assuming that turbulence has been detected, the committee is conducting a case study regarding how to convey information to passengers and what behavior should be taken by cabin crews for each time interval until encountering turbulence (30 seconds before, 60 seconds before, etc.). Based on this study, the committee is discussing a draft of guidelines which include response procedures. Being able to facilitate such discussion while taking the actual operating conditions into consideration would be a major feature of the SafeAvio Research Committee.

The future steps include improving above mentioned technologies. JAXA has a plan to integrate the turbulence detection technologies into "gust alleviation technologies" which automatically suppress shaking of the airframe (airframe heaving/wing tip vibration) by controlling the flight control surface with a computational algorithm when encountering turbulence, and thereby decreasing the risk from sudden aircraft shaking.

The SafeAvio Research Committee is also working to achieve the future goal of creating Japanese passenger aircraft featuring high performance and advanced safety through this all-Japan system. SafeAvios's industry-academia-government collaboration has the potential to serve as a model case for other R&D which seeks to achieve commercialization in a shorter period of time.

*1 SafeAvio (R&D of onboard safety avionics technology to prevent turbulence-induced aircraft accidents) is JAXA's R&D initiative. The ultimate goal is to reduce turbulence-induced aircraft accident. Technologies under development with this initiative include a turbulence detection system, information provision system to warn pilots, and gust alleviation technology to automatically suppress aircraft shaking caused by sudden turbulence. See FLIGHT PATH No. 3/4.
*2 Technology which measures airflow transitions by irradiating aerosol particles with a laser and then detecting scattered light. See page 20.

Aeronautics in depth

Doppler LIDAR

This section goes deeper into the research going on at the JAXA Aeronautical Technology Directorate. Although the details are a bit technical, the content will give you a glimpse of how JAXA technologies are making the skies a better place. The first technology in the "Aeronautics in depth" series is Doppler LIDAR, which detects clear-air turbulence.

Requirements for onboard Doppler LIDAR systems

JAXA is currently researching and developing an onboard Doppler LIDAR system to detect clear-air turbulence, a cause of aircraft incidents. Compared to radar, sodar, and other remote-sensing technologies, Doppler LIDAR makes it possible to conduct airstream measurements in clear-air conditions at longer distances.

A Doppler LIDAR system emits laser light into the space in front of the aircraft, receives the light backscattered by aerosol particles in the atmosphere, and measures the difference in wavelength between the transmitted laser light and the received scattered light to detect aerosol particle movements. "Aerosol particles," which refer to tiny airborne particles with radii ranging from 1 nm to 100 µm in size, ride around the atmosphere on airstreams. To identify clear-air turbulence, then, one could measure aerosol particle movements and look for significant "shifts."

There are some challenging elements to installing a Doppler LIDAR system on an aircraft and using it to measure clear-air turbulence, however. One of the issues is that the amount (density) of aerosol particles in the air—the key resources for measuring airstreams—is extremely low at aircraft cruising altitudes. When an aircraft is flying at an altitude of 10,000 m, for example, there might only be one aerosol particle with a grain diameter of at least 0.3 µm per cubic centimeter of air. Detecting these rare aerosol particles requires better detection efficiency, which comes from higher levels of laser light output.

How JAXA technologies achieve higher output levels in smaller packages

However, higher laser output causes the equipment to generate more heat and thereby creates the need for large cooling devices. In other words, you need to achieve two different, generally incompatible objectives to install a system on an aircraft: higher output and smaller size. JAXA thus simplified the detection process by integrating faint signals N times to isolate the actual signals from the background noise. To do that, researchers defined the following Figures of Merit (FOM) to serve as indicators.

$$FOM = E \times \sqrt{N}$$

"E" represents the pulse energy of the laser.

Basically, a higher FOM value means better Doppler LIDAR performance.

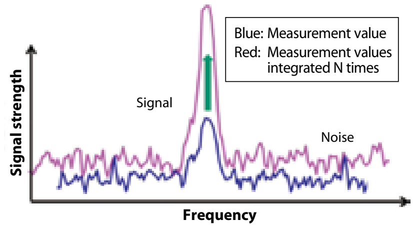


Figure 1: Improving SNR via N integrations

In 2011, after going through several prototypes, JAXA developed a high-altitude model of a Doppler LIDAR system capable of detecting aerosol particles at aircraft cruising altitudes. Table 1 shows a comparison of the corresponding performance characteristics. As aircraft fly at high speeds (covering approximately 10 km every 40 seconds at cruising altitude), pilots need to detect conditions from far out in order to avoid turbulence. The high-altitude model of a Doppler LIDAR system that JAXA created in 2011 successfully detected clear-air turbulence 6 km ahead and 3.2 km above the shore of the Kii Peninsula during testing in 2012. The following year, JAXA achieved observational distances of over 9 km at an altitude of 10 km (Figure 2)—a level of precision equivalent to detecting one or two golf balls floating in a 40-m^3 pool of water from a distance greater than that separating the equator from an object in stationary orbit.

JAXA succeeded in packing that incredible performance into a compact package that fits on an aircraft thanks to two important design approaches: using near-infrared rays at 1.5 µm and applying the light amplifier-based heterodyning technique. Near-infrared rays at 1.5 µm—the wavelength that has the smallest effect on humans—are common in optical communications, compatible with a variety of parts, and inexpensive. Light amplifiers, meanwhile, boast strength in numbers: using more light amplifiers improves efficiency dramatically. JAXA's high-altitude model uses an optical waveguide amplifier instead of the fiber-optic amplifier of previous models as a final-stage power amplifier.

While the high-altitude model weighs 150 kg, researchers are currently working on ways to bring the overall weight to 95 kg but keep the FOM in the same general range. Testing is slated to finish up in FY2016.

Table 1: A comparison of Doppler LIDAR systems

Model		E(µJ)	PRF*(kHz)	Average output(W)	FOM(mJ)	Weight(kg)
JAXA-developed model	Developed in 2002	4.5	50	0.225	1.0	105
	Developed in 2006	58	4	0.232	3.7	51
	Developed in 2007	179	4	0.716	11.3	82
	Developed in 2011	1,925	4	7.7	121.7	150
Company A (USA; airport installation)		2,000	0.75	1.5	54.8	2,600
Company B (Europe; onboard installation)		150	20	3	21.2	N/A

* Pulse repetition frequency

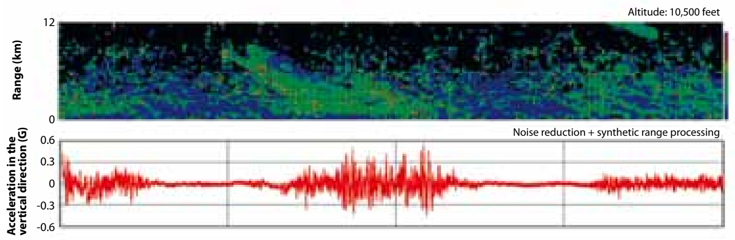


Figure 2: Measurement data on clear-air turbulence

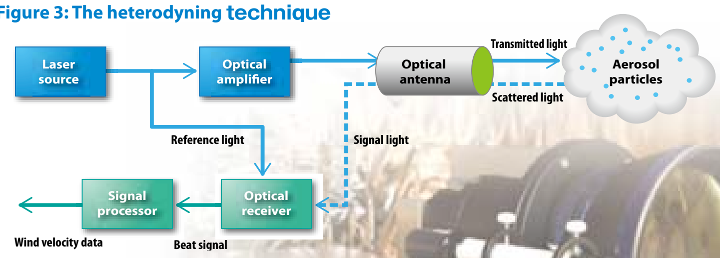


Figure 3: The heterodyning technique

Aeronautics in depth

Pressure-sensitive paint (PSP) measurement

The second "Aeronautics in depth" examines the pressure-sensitive paint (PSP) technique used to measure surface pressure distributions acting on the aerodynamic model for wind tunnel testing.

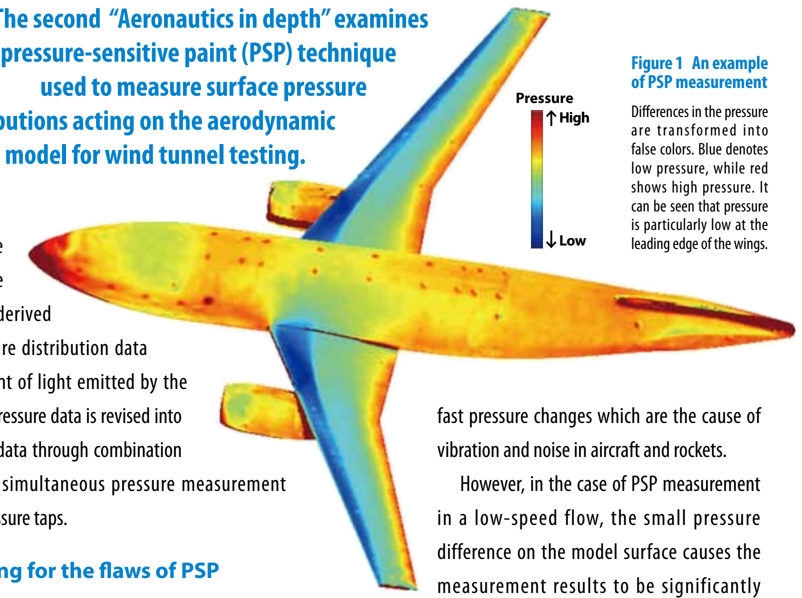


Figure 1 An example of PSP measurement

Differences in the pressure are transformed into false colors. Blue denotes low pressure, while red shows high pressure. It can be seen that pressure is particularly low at the leading edge of the wings.

Effective use of PSP

Pressure sensors have been used to measure the surface pressure distribution acting on aerodynamic models during wind tunnel experiments. Although pressure sensors are capable of high-precision measurement, they conduct measurement at a point known as a "pressure tap." Accordingly, the pressure at areas other than pressure taps cannot be ascertained, and only a limited number of pressure taps can be installed. Conversely, pressure-sensitive paint (PSP) measurement can ascertain the pressure distribution over the entire surface (see Figure 1). Using PSP makes it possible to reduce the number of pressure taps. This helps suppress the cost associated with preparations by reducing the processing of expensive pressure sensors and pressure taps, as well as the laying of sensor cables.

When PSP containing a mixture of polymers and pressure-sensitive dyes such as platinum porphyrin (PtTFPP) is exposed to excitation light, the dye emits phosphorescence (see Figure 2). The amount of emitted light is decreased (darkened) when the oxygen concentration is high (i.e., when pressure is high) (see Figure 3). PSP measurement utilizes this property to calculate pressure from the intensity acquired by cameras.

However, the PSP property in which intensity changes in response to pressure (pressure sensitivity) changes slightly for each PSP or model. Moreover, the intensity of PSP changes according to the temperature (temperature dependence). Therefore, prior to each test using PSP measurement, the automated calibration system developed by JAXA is used to obtain characteristic data for the intensity of light emitted by test PSP in response to pressure and temperature (see Figure 4). In the case of wind tunnel tests, temperature-sensitive paint (TSP) is used together with PSP in order to measure the temperature distribution for the model. Pressure is derived from the temperature distribution data and from the amount of light emitted by the measured PSP. This pressure data is revised into even more accurate data through combination with the results of simultaneous pressure measurement performed using pressure taps.

Compensating for the flaws of PSP measurement

In the case of normal PSP measurement, model surfaces are painted with pressure-sensitive dye mixed into polymers. It takes several seconds for pressure changes to reach the pressure-sensitive dye and a response to be issued. This made it difficult to conduct pressure measurement for ultra-short time periods and for irregular pressure changes caused by unsteady aerodynamics. In response, JAXA has developed anodized-aluminum PSP (AA-PSP) coating technology which eliminates polymers and causes pressure-sensitive dyes such as transition metal complexes to be adsorbed directly onto anodized-aluminum surfaces. This makes it possible to cause changes in the intensity of emitted light during an extremely short period of time (see Figure 5). By using this technology, JAXA has conducted the world's first successful measurement of pressure distribution during the ultra-short time period of 20 milliseconds. JAXA has further advanced this technology to realize unsteady PSP measurement in which a high-speed camera is used to measure the emitted light. As a result, it is now possible to measure extremely fast pressure changes which are the cause of vibration and noise in aircraft and rockets.

However, in the case of PSP measurement in a low-speed flow, the small pressure difference on the model surface causes the measurement results to be significantly affected by noise. This makes it difficult to calculate the pressure distribution with high precision. The current unsteady PSP measurement uses a blue laser diode with an optical output of 7 watts and a high-speed camera which has a spatial resolution of 1280 × 800 pixels and is capable of taking 120,000 images per second. It is now necessary to develop pressure measurement technology with a higher level of accuracy, to develop PSP from which a large amount of emitted light can be obtained even in a low-speed flow, and to use a high-speed camera with superior sensitivity.

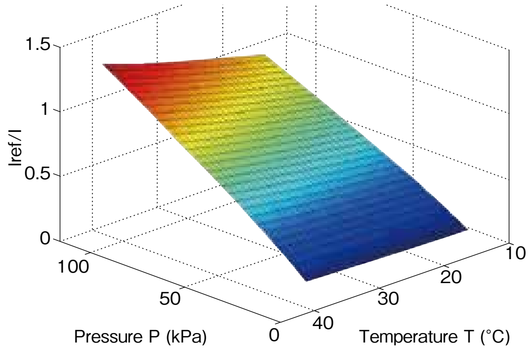


Figure 4 Example of PSP pressure and temperature characteristics

Calibration result using the automated calibration system developed by JAXA.Significant gradient in the pressure direction (pressure sensitivity) and slight changes in the temperature direction (temperature dependence) are observed.

Figure 5 Wind tunnel model with AA-PSP coating

Test model keeps a metallic luster since only pressure-sensitive dye is absorbed after anodizing.

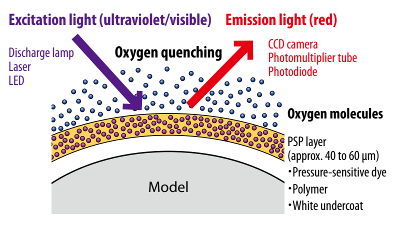


Figure 2 PSP structure

First, a white undercoat is applied as base layer. Next, the base layer is covered with PSP layers which are a mixture of solvents, polymers and pressure-sensitive pigment (fluorescent pigment) such as platinum porphyrin. When the pressure-sensitive dye is illuminated by excitation light including absorption wavelength (purple in the case of PtTFPP) using a light such as a xenon lamp, the pressure-sensitive dye is excited and luminescence is emitted (red in the case of PtTFPP).

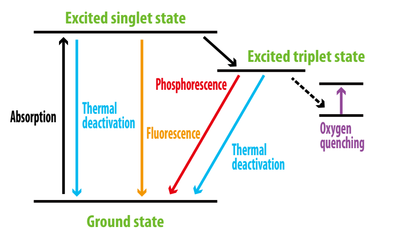


Figure 3 Reaction process for photoexcitation molecules

The pressure-sensitive dye absorbing excitation light transits to excitation state. When returning to a ground state, the emission of phosphorescence during this process results in energy consumption. If there is a large amount of oxygen in the surrounding area, a portion of the excited emission energy shifts to oxygen molecules and the emission of phosphorescence is reduced. This causes pressure sensitivity (oxygen sensitivity) to occur in the emission intensity.

FLIGHT PATH Topics

JAXA completes successful flight tests on its electric propulsion system for aircraft

JAXA has been working on the FEATHER (Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution) project in hopes of establishing an electric propulsion system for aircraft, a technology that has enormous potential for future use.


An electric motor glider equipped with JAXA's redundant motor

JAXA's electric motor glider, which uses a JAXA-developed redundant motor instead of a conventional reciprocating engine, has successfully completed runway testing and jump flight testing at Otone Airport (Ibaraki Prefecture) and other sites. During testing procedures at the Japan Air Self-Defense Force's Gifu Air Base in February 2015, the aircraft rose to an altitude of approximately 600 m and flew a traffic pattern around the runway for roughly 17 minutes.

These test results have demonstrated that JAXA's electric propulsion system delivers the necessary levels of performance (in terms of motor output, torque, battery voltage, current, and system temperature, etc.). In addition, the tests also corroborated the fault tolerance of the redundant motor, which keeps the aircraft airborne in the event of a partial electric motor component failure by using the remaining motor components, and showed that the regenerative air brake functions properly during descent procedures.

See page 16 for details on FEATHER.

JAXA officially partners with DMAT to work on D-NET and D-NET2 research and development efforts

JAXA is currently working on the research and development of Disaster Relief Aircraft Information Sharing Network (D-NET) and Integrated Aircraft Operation System for Disaster Relief (D-NET2).* These systems will increase the efficiency of disaster relief operations by enabling data sharing among ground stations and airborne vehicles. The key to making these systems useful is to have them verified and tested by those directly involved in emergency response. Thus far, JAXA has forged agreements with the Fire and Disaster Management Agency, which manages and operates firefighting and disaster relief helicopters, as well as the Kobe City local government and other related organizations. JAXA also signed a new partnership agreement with the National Disaster Medical Center in April 2015, paving the way for the development of an effective system for the emergency disaster medical field and joint evaluations with professionals in disaster medicine.

The Disaster Medical Center has been the headquarters for the Disaster Medical Assistance Team (DMAT), a group that conducts rescue activities in disaster situations, and continues to maintain and improve EMIS (the Emergency Medical Information System), which allows medical institutions across the country to share information on conditions like operational status and streamlines medical activities in disaster-response efforts. By collaborating with the Disaster Medical Center, JAXA will be able to contribute to safer and more efficient operations of medical service helicopters units and other resources that play a vital role in emergency disaster medicine.

* See FLIGHT PATH No. 7/8 for more information.


Participants undergo the Cabinet Office's wide-area medical transportation training program on August 30, 2014. JAXA installed a D-NET2 terminal at the National Disaster Medical Center (in Tachikawa-shi, Tokyo) and had personnel evaluate the system.

DAHWIN and Doppler LIDAR win MEXT's Prizes for Science and Technology

JAXA's DAHWIN (Digital/Analog-Hybrid Wind Tunnel) and onboard Doppler LIDAR system technologies recently took home Prizes for Science and Technology (in the Development Category) at the 2015 Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, the latest in a series of accolades that the Ministry presents to those who have made noteworthy contributions in the fields of science and technology.

The DAHWIN technology combines wind tunnel testing with computational fluid dynamics (CFD), creating an integrated environment where users can do preparatory work effectively, get easy access to comparative displays, and analyze and fuse data for both areas in a centralized system. With the benefits that DAHWIN provides, users have been able to improve overall efficiency and reliability levels at the design stage in the development of aircraft and spacecraft. The onboard Doppler LIDAR system, meanwhile, detects turbulence—the phenomenon triggering roughly half of all passenger aircraft incidents. Weather radar has never been able to locate clear-air turbulence, which JAXA's LIDAR system uses laser light to identify. By enabling the detection of clear-air turbulence, the system has made valuable contributions to improvements in aircraft safety.


Awardees for DAHWIN (left) and the Onboard Doppler LIDAR system (right) pose for the camera after the commendation ceremony on April 15

In recognition of its advanced initiative, JAXA's Disaster Relief Aircraft Information Sharing Network (D-NET) also received an excellence award at the first Japan Resilience Awards from the Association for Resilience Japan.

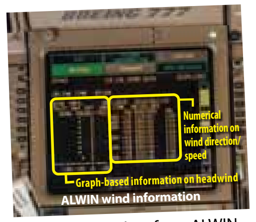
"ALWIN", a joint development project between JAXA and the Japan Meteorological Agency, gets ready to go into practical use

The Japan Meteorological Agency has announced that it will launch system development to prepare the "Airport Low-level Wind INformation" (ALWIN), which the organization has researched and developed with JAXA, for practical applications beginning in FY2016.

Low-level windshear*1 and the turbulent wakes created by topographical features or the buildings around airports are some of the main causes of aircraft accidents and go-arounds. Detecting these types of turbulence is of crucial importance for airlines in ensuring safe, on-time performance. The Japan Meteorological Agency has installed airport weather Doppler lidar and Doppler radar systems at several airports to provide operators with information on low-level windshear risks. However, the current radio-based verbal communication system limits the wind information that pilots can receive in the cockpit to windshear alert, which is so-called "red-light" information. Such alerts occur only when the risk of an accident is highly probable. This means that pilots have little information on winds that are not as severe as "red-light" but serious enough to cause service disruptions. In fact, the lack of this level of wind information has resulted in go-arounds and missed approaches.

Using the weather information technology that JAXA has developed through the DREAMS project, ALWIN makes it possible to inform airline dispatchers and pilots of this important wind information called "yellow-light" information, that help pilots judge the severity of windshear. By using a datalink system named ACARS*2, pilots can obtain the latest wind information in a timely fashion. Given its versatility and benefits, ALWIN will help boost the safety and efficiency of aircraft operations.

*1 Rapid changes in lower-atmosphere wind
*2 Automatic Communications Addressing and Reporting System (a datalink system in use on most passenger aircraft)



Displays wind data from ALWIN in the cockpit

Top executives from NASA and JAXA hold meeting on aeronautics research and cooperation

Four top executives from NASA and JAXA met in Paris for a meeting on aeronautics research and cooperation on the occasion of the 51st Paris Air Show in June 2015. Participants were NASA Administrator Charles Bolden and Associate Administrator Jaiwon Shin of the Aeronautics Research Mission Directorate, and JAXA President Naoki Okumura and Director General Kazuhiro Nakahashi of the Aeronautical Technology Directorate. This was the first face-to-face opportunity where the four executives exchanged their views and opinions on aeronautics research. The agenda included both international and bilateral topics and cooperation.

Both NASA and JAXA have been playing a major role in the International Forum for Aviation Research(IFAR)*, a unique international network of aviation research institutions. JAXA has been serving as IFAR Vice-Chair and is to take over the position of IFAR Chair from NASA in October 2015. At the meeting, JAXA expressed sincere gratitude for how international cooperation has been promoted under NASA's strong leadership of IFAR, while NASA pledged to support JAXA in the role of IFAR Chair. NASA also expressed expectations for JAXA to assume further leadership for public aeronautical research institutions in the Asia-Pacific region.

Other topics raised at the meeting included successful results achieved through joint research by NASA and JAXA. Ongoing efforts being made toward formulating international standards for sonic booms were among them. The top management meeting between NASA and JAXA reaffirmed their intention to continue to enhance their cooperative relationships as outstanding partners in the future.

* IFAR is the world's only international aviation research establishment network, established in 2010 with the aim to connect research organizations worldwide. Currently, IFAR consists of 26 member institutions. (See FLIGHT PATH No. 1/2 for details)


From left: Jaiwon Shin (NASA), Charles Bolden (NASA), Naoki Okumura (JAXA), and Kazuhiro Nakahashi (JAXA)

"Development of Reuse Technology for Recycled Carbon Fiber" wins SAMPE Japan Product & Technology Award

In July 2015, the JAXA Aeronautical Technology Directorate received the Product & Technology Award from the Society for the Advancement of Material and Process Engineering (SAMPE Japan) in recognition of outstanding success in the research project entitled "Development of Reuse Technology for Recycled Carbon Fiber."

The use of lightweight and strong CFRP (carbon fiber reinforced plastics) in aircraft components is increasing every year. However, CFRP recycling technology has yet to be established, despite a probable need in the future. As such, this technology is attracting attention on a global scale. JAXA developed recycling technology and used it to recycle high-quality CFRP for aircraft. We then used the recycled CFRP to manufacture a life-size winglet model. Through this prototype, we confirmed that it is possible to manufacture complex structures using recycled CFRP. JAXA will continue to conduct R&D for CFRP recycling technology with the goal of realizing practical application.


Life-size winglet model manufactured from recycled CFRP technology

Ceramics matrix composites (CMC) testing method proposed by JAXA is adopted as JIS standard

JAXA and the Japan Fine Ceramics Association (JFCA) jointly proposed two testing methods for ceramics matrix composites (CMC) (see page 18): the "Testing method for compressive behavior of continuous fiber-reinforced ceramic composites at elevated temperatures" and the "Testing method for creep behavior of continuous fiber-reinforced ceramic composites under tensile loading at elevated temperatures." In May 2015, each of these methods was issued as Japanese Industrial Standards (JIS) (JIS R1721 and R1723, respectively).


JIS Standards Booklet published by the Japanese Standards Association

In order for advanced composite materials to become widely used in industry, it is essential to standardize testing methods for evaluating the performance of those materials. Through our research in composite materials technology, JAXA has developed testing methods and evaluation methods. We are now working to have these methods adopted as standards of JIS and the International Organization for Standardization (ISO). If JIS and ISO standards are the same, there is no need to change the evaluation method for domestic and overseas targets. For domestic manufacturers, this has the merit of enabling speedy development.

Technological review for the two recently adopted standards was started from fiscal 2010 and a draft was created in October 2013. From 3 to 5 years is required for proposals to be adopted as JIS standards and ISO standards, respectively. In order to contribute to the growth of the Japanese aircraft industry, JAXA will continue to conduct activities aimed at standardization in the future.

Overhaul and upgrade of pyramidal six-component balance for JAXA 6.5 m×5.5 m low-speed wind tunnel

From October 2014 to October 2015, JAXA is performing overhaul and upgrade of the pyramidal six-component balance (pyramid balance) for the JAXA 6.5 m ×5.5 m low-speed wind tunnel. Installed under the floor of the test section, the pyramid balance is the wind tunnel's key component that supports test models via the support device and performs precision measurement for a total of six aerodynamic forces and moments exerted on the model: drag, lift, lateral force, pitching moment, rolling moment and yawing moment. The complex mechanisms incorporated into the pyramidal structure enables the balance to detect minute changes in force while supporting the heavier model.


Transporting the disassembled structure for inspection and upgrade

The JAXA 6.5 m×5.5 m low-speed wind tunnel at the Chofu Aerospace Center started operation in 1965. Over the following fifty years, the pyramid balance had been used in many wind tunnel tests as a very important component of the largest low-speed wind tunnel for aircraft in Japan. In response to the concern that measurement accuracy will decrease due to deterioration and wear occurring over the years, JAXA decided to conduct a large-scale inspection which involves complete disassembly of the balance. This is the first time that such a project has been conducted. After having completed a six-month period of overhaul and upgrade at the manufacturing plant, the balance is now undergoing the final assembly stage back to the Chofu Aerospace Center. This project will restore the wind tunnel to its potential, enabling it to be used for a variety of tests in the future.


Reassembling the structure after inspection and upgrade

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