

*JAXA Aeronautics Magazine*

# **FLIGHT PATH**

*Shaping Dreams for Future Skies*



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Aeronautical  
Technology

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Feature story

**The Safety Technology for Aviation and Disaster-Relief Program (STAR)**  
**How JAXA researchers envision the aircraft of tomorrow**



*This issue profiles two captivating initiatives: the “Safety Technology for Aviation and Disaster-Relief Program” (STAR), which aims to improve the safety of both aircraft and the society we live in, and the “Sky Frontier Program,” an effort designed to broaden the possibilities of air transportation.*

On the cover is a conceptualization of a next-generation supersonic passenger aircraft.

JAXA is currently researching a quiet supersonic passenger aircraft that uses a duckbill-shaped nose to reduce the occurrence of sonic booms by a considerable margin.

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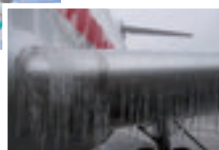
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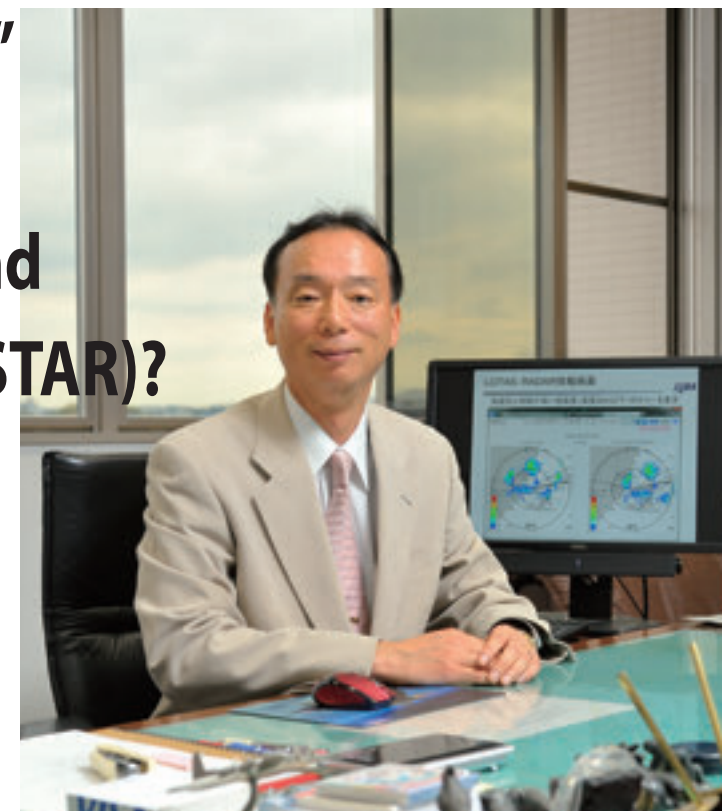
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## Feature story > > The Safety Technology for Aviation and Disaster-Relief Program

# What goes into the “safety” at the heart of the “Safety Technology for Aviation and Disaster-Relief Program” (STAR)?

It goes without saying that the most important feature of an aircraft is its safety. However, the idea of “aviation safety” stretches beyond aircraft: it also means thinking about comprehensive safety considerations for things like airport security, the safety of airline operating controls and maintenance, and mission control and other ground systems. This type of all-encompassing management is the core focus of STAR—a new research and development program launched this fiscal year to develop unprecedented, next-generation safety technology. We discussed STAR with Masatoshi Harigae, Director of the Operation Systems and Safety Technology Research Group.



— Could you give us a basic overview of STAR?

Through its initiatives in environmental and safety-related research and development, the Institute of Aeronautical Technology aims to make valuable contributions to society. The STAR program centers on aircraft safety, which is one of the main areas where we want to create social benefits.

In the aviation context, the concept of “safety” tends to relate mostly to improving the safety of the aircraft involved in order to reduce accidents. STAR, however, includes much more in its “safety” scope: besides aiming to enhance aircraft safety, it also focuses on boosting the safety of overall aviation systems—including ground support—and even using aircraft to make society safer.

Part of the effort will be creating technologies in various areas, including safe technologies for operating controls and maintenance, as well as support technologies for deploying aircraft when disaster strikes.

By bringing a broader perspective to the field of aircraft safety, STAR will create more opportunities for our research to make a positive impact on society.

— What kinds of research has JAXA done on safety technology?

JAXA has now been active for 10 years. Along the way, the organization has been consistently committed to conducting research on operations and safety.

One of the most important aviation-related developments in recent years was the Ministry of Land, Infrastructure and Transport’s “Collaborative Actions for Renovation of Air Traffic Systems” (CARATS), Japan’s long-term vision for future air traffic systems. Working with the CARATS organization, JAXA has created the DREAMS project and continued to conduct research and development in the field. We’ve also made enough

progress in our safety-related initiatives to start making returns to society. With this growing foundation in place, JAXA launched the STAR program to help encourage further research.

— What does the “STAR” name signify?

“STAR” stands for “Safety Technology for Aviation and Disaster-Relief Program.”

The “Safety Technology for Aviation” part of the name corresponds to what I said earlier about the expanded scope of safety: the program concentrates on not only “aircraft” safety but also the safety of aviation systems and the ground systems used by airports and airlines. “Disaster-relief,” meanwhile, means making an effort to use our technologies to make society safer through the utilization of aircraft.



Feature story ▶▶▶The Safety Technology for Aviation and Disaster-Relief Program

— Was the Great East Japan Earthquake & Tsunami one of the motivating factors behind JAXA's disaster reduction-related efforts?

JAXA's first real foray into disaster reduction-related research and development came in the aftermath of the Chūetsu Offshore Earthquake in 2004. As large numbers of aircraft made their way into the intermountain region, operators ran into problems keeping safe distances between aircraft and providing effective command and control. JAXA responded by launching disaster relief-oriented research and development projects designed to solve these issues.

These projects were still in progress when the Great East Japan Earthquake & Tsunami hit in 2011. Recognizing the crucial importance of disaster relief-related research more clearly than ever, JAXA decided to begin reshaping its initiatives into the "Disaster Relief Aircraft Information Sharing Network" (D-NET) as part of the DREAMS project.

— It's been two years since the DREAMS project got started. How is it coming along?

The International Civil Aviation Organization (ICAO) released its "Global ATM Operational Concept" in 2003. The document predicted that the operating aircraft would double in number by 2025. Based on this projection, several countries and regions initiated new programs to develop the necessary aviation systems: the United States started work on NextGen (The Next Generation Air Transportation System), Europe launched SESAR (Single European Sky ATM Research), and the Japanese Ministry of Land, Infrastructure and Transport established the CARATS program.

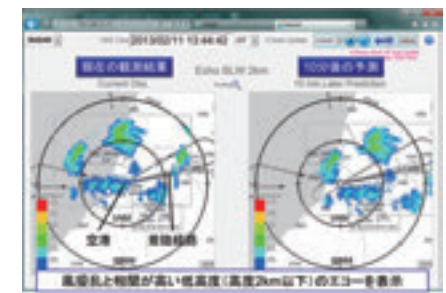
Officially launched in 2011, the DREAMS project is currently in the demonstration testing phase.

One of the major achievements the DREAMS project has made is its research on the Low-level Turbulence Advisory System (LOTAS), a technology that gives airport

operators information to make decisions on whether incoming aircraft can begin landing procedures immediately or likely need to abort and perform a go-around. Should LOTAS prove viable, it will be possible to cut down on the fuel that aircraft waste when doubling back to their points of departure or waiting airborne in holding patterns.

The results of the flight demonstrations performed at Shonai Airport in February 2013 confirmed that LOTAS is an extremely high-quality system. In March 2014, JAXA plans to conduct tests at Narita Airport with the assistance of the Japan Meteorological Agency, ANA, and JAL to put LOTAS on the fast track toward practical use.

D-NET is another significant accomplishment, and the technology continues to make progress. The Kinki Block of the Emergency Fire Response Team tested D-NET during its joint training in October 2012, while the Aichi Prefecture disaster drill/wide-area medical transportation drill and the Iwate Prefecture disaster drill used D-NET to give JAXA



The LOTAS recorder echo screen

valuable demonstration testing opportunities. (For more on how the Iwate Prefecture disaster drill used D-NET, see pages 10-11.)

D-NET makes it possible to share information between aircraft and disaster-response headquarters, which can thereby assign tasks in an optimal fashion. Many of the challenges that operators encountered during the response to the Great East Japan Earthquake & Tsunami, such as voice radio communications being interrupted by mountainous terrain and aircraft congestion leading to delays in fueling and task assignments, could be mitigated by the D-NET technology. The Fire and Disaster Management Agency has decided to use D-NET specifications, paving the way for the installation of D-NET equipment on firefighting and disaster-relief helicopters throughout the country.

— How can D-NET help Japan mitigate the effects of disasters?

JAXA has already begun work on D-NET2—a "Disaster-Relief Aircraft Management System Network."

Whereas D-NET focused mainly on sharing aircraft information, D-NET2 will use a wide range of information from satellites, unmanned aircraft, and other sources. The new technology is poised to have an impact in many areas, including optimizing disaster rescue missions; for example, D-NET2 will allow aircraft and disaster-response headquarters to share images of a disaster area captured from space by JAXA's advanced land-observing satellites.

— JAXA has done some research on turbulence detection systems. What can you tell us about SafeAvio, the new R&D project for onboard safety avionics technology designed to prevent turbulence-related accidents?

The goal of SafeAvio is to not only detect turbulence but also help prevent turbulence-related incidents. By further developing existing turbulence detection systems and combining the systems with autopilot technology, JAXA is confident that SafeAvio can halve the intensity of the shaking that turbulence causes in aircraft and thereby keep turbulence from causing incidents—reducing the size of shaking by 50% would essentially eliminate injuries caused by turbulence. (For more on SafeAvio, see pages 6-7.)

— What kinds of research is the organization doing on enhancing airframe safety?

We launched research into airframe safety management technology to improve the safety of maintenance work on the ground.

Aircraft have to undergo regular legal maintenance procedures. Immediate maintenance is also required in the event of a bird strike, lightning strike, high-impact landing, or any other unexpected problem. If an aircraft sustains damage in flight, it's sometimes hard to determine when it'll be able to fly again after it lands. As a result, operators often cancel flights in anticipation of potential safety issues—a tendency that hurts overall in-service rates. JAXA's research on aircraft safety management technology thus aims to facilitate the process of making decisions on the flight capabilities of damaged aircraft. Managing the historical records of damage and aircraft load more effectively will also add some flexibility to maintenance scheduling, as operators will be able to delay inspections on aircraft that have had relatively light loads over their service times.

— How is STAR, set to begin this fiscal year, different from the research JAXA has already done on operational and safety-related technology?

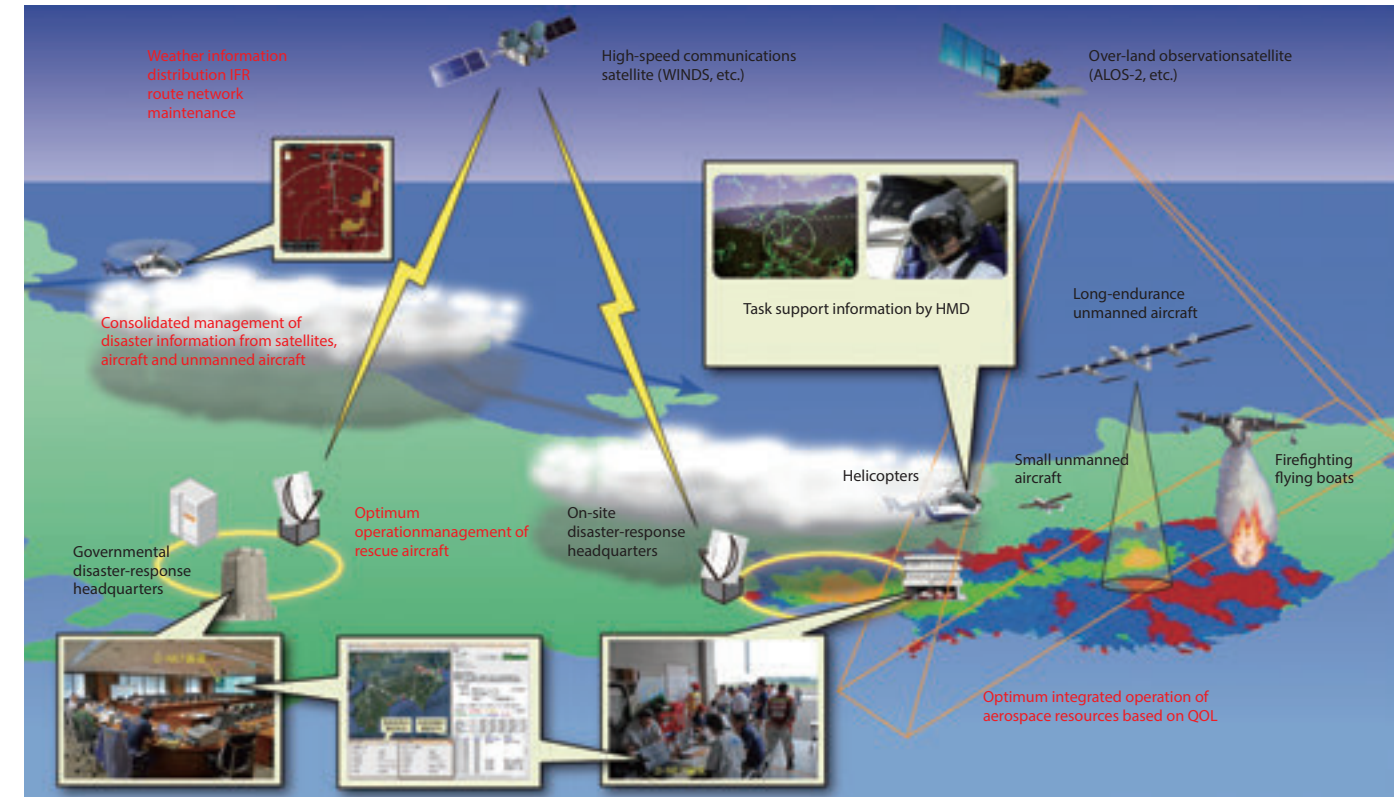
JAXA inaugurated the Institute of Aeronautical Technology in April 2013 and adopted a new corporate slogan—"Explore to Realize"—in October 2013. The new organization and renewed slogan reflect JAXA's commitment to creating value in society. That's the vision that we're going after.

Although many of JAXA's past research and development activities have been aimed at making social contributions, the specific goals have tended to be technical and benchmark-oriented in nature. In the D-NET initiative, for example, we wanted to know exactly how much wasted time the technology could save. When we started work on turbulence detection systems, we wanted to make sure the technology could pick up turbulence as far ahead of the aircraft as possible.

Through STAR, we want to make our social contributions into benefits that people can really sense and appreciate: lower incident rates through SafeAvio, better rescue rates through D-NET2, and more.



Masatoshi Harigae  
Director of the Operation Systems and  
Safety Technology Research Group



JAXA's "Disaster-Relief Aircraft Management System Network"(D-NET 2) has three key features: the collection of disaster-related information via the integrated control of manned aircraft, unmanned aircraft, and satellites; enhanced information sharing and the development of optimal operation plans; and execution support. The system uses quality of life (QOL) indices to ensure that rescue activities in each affected area proceed in a steady, optimal manner.



<Roundtable>

# How JAXA researchers envision the aircraft of tomorrow

Developers have worked hard to make aircraft carry large quantities of passengers and goods faster and farther. The issues of noise and environmental load—problems that have surrounded aircraft for many years—have gradually improved, enabling the kind of convenient, safe air transportation that society enjoys today. Although it may seem that aviation technology has reached the proverbial finish line, there is still much work to be done: we need to discover new value and look for new utilization methods to make flying even safer and more convenient. To delve deeper into what this ongoing quest entails, we spoke with young JAXA researchers about their visions for the aircraft of the near future.

<b>Participants</b> (Moderator: Kei Shiratori)		<b>Hideyuki Taguchi:</b> Hypersonic Technology Section Leader, Propulsion Systems Research Group
<b>Yasushi Watanabe:</b> System Concepts Section Leader, Aircraft Systems Research Group	<b>Koji Muraoka:</b>	UARMS Team Leader, Technology Demonstration Research Office
<b>Masahiko Sugiura:</b> Rotary Aircraft Section, Aircraft Systems Research Group	<b>Atsushi Kanda:</b>	Structural Functionality Section Leader, Structures Research Group

**Moderator:** Today, we'll be talking about the concepts you're working on for new aircraft and your thoughts on how aviation technology and aircraft will be changing in the near future. Before we get started, though, could you introduce yourselves and talk a little bit about why you got involved in aviation technology research?

**Kanda:** My major in college was shipping and marine sciences, but I decided to take a job in aviation because I really saw future potential in the aerospace field. Back when I was a student, I was a bit afraid of flying—I'd never been on a plane, actually. Ever since I started researching aircraft, though, I've learned just how much work goes into making the designs as safe as possible.

**Sugiura:** I was into rockets when I was in junior high school and high school, but airplanes started to seem more interesting when I got to college. The unpredictability of airplanes is what got me, I think; rockets fly a set path on a set orbit, but airplanes are subject to so many different variables in



An advanced rotary-wing aircraft

*Helicopters normally fly at around 200 km per hour. We want to double that speed.*  
——— Sugiura



*I think new aircraft will create unprecedented new value.*  
——— Watanabe



A quiet supersonic aircraft



the air.

**Muraoka:** I was set on becoming a pilot. As I studied mechanical engineering in college, though, I found myself feeling more drawn in by airplanes themselves—the actual flying machines.

**Watanabe:** I've been interested in shock waves and supersonic speed ever since my days in college, where I majored in airframe systems engineering. I guess those interests just kind of naturally gave way to an interest in building fast planes—and that's why I became a researcher in aviation technology.

**Taguchi:** Watching "Space Battleship Yamato" and "Star Wars" as a kid made me fall in love with the idea of flying. When I watched the maiden flight of the space shuttle on live TV later on, I knew I had to work in the aerospace field.

## The new value in higher speeds

**Moderator:** The Concorde supersonic passenger aircraft ceased service in 2003. Did that effectively end the development of supersonic passenger aircraft, as well?

**Watanabe:** Not at all. I think supersonic aircraft still have plenty of potential. They're actually one of the topics I'm researching right now. The Concorde had to deal with a lot of issues, like producing sonic booms that were too big and not being able to fly at supersonic speeds over land, but the quiet supersonic passenger aircraft that we're researching at JAXA can reduce the occurrence of sonic

booms by a considerable margin. The nose of the aircraft is shaped like a duckbill, which helps disperse the shock waves heading for the ground and limit the magnitude of sonic booms.

**Taguchi:** My target concept is a plane that flies at Mach 5—a "hypersonic" passenger

aircraft that would fly more than twice as fast as the Concorde did. At Mach 5 speeds, a plane would be able to cross the Pacific in just around two hours. The hypersonic passenger aircraft we're working on now would experience air temperatures of 1,000°C at Mach 5, so we're researching a way to use -253°C liquid hydrogen fuel to cool the air before it enters the engine.

**Sugiura:** I'm working on a high-speed helicopter. Helicopters can hover and don't need long runways for takeoffs and landings, so they're invaluable resources for search-and-rescue and disaster-monitoring activities in mountainous areas like Japan. The problem is that they can't fly at high speeds: helicopters generally travel at around 200 km per hour. If we could make medevac helicopters twice as fast as they currently are, for example, they'd be able to travel greater distances per unit of time, pick up time-critical patients, and get them to regional flagship hospitals more quickly than ever.

In hopes of doing that, we're creating an advanced rotary-wing aircraft that combines the same kind of main rotor that you see on a

conventional helicopter, an airplane-type main wing, and a ducted fan on the wing tip (see the Figure for an illustration). For the rear of the airframe, we're using a horizontal stabilizer and vertical stabilizer—both airplane-type features. The ducted fan provides additional thrust while the aircraft is cruising, thereby achieving higher speeds, and controls horizontal rotation in place of a tail rotor. We want to make the ducted fan electric, too.

**Muraoka:** While Mr. Sugiura's aircraft pushes rotary-wing aircraft into faster territory, my approach is aimed at making regular airplanes faster. I'm at work on a four-engine tilt-wing VTOL business aircraft (see the Figure for an illustration), a small plane that would seat around 10 people. The aircraft has two sets of main wings for a total of four propellers. The engines and propellers of tiltrotor aircraft like the Osprey change directions, but our aircraft points the main wing and propellers up together during takeoff and landing and gradually angle them forward when the aircraft reaches a safe altitude. While cruising, the aircraft can fly at roughly the same high speeds as a regular turboprop.



A four-engine tilt-wing VTOL business aircraft

*High-speed flight is possible for four-engine tilt-wing VTOL business aircraft.*  
——— Muraoka





Feature story ▶▶The Sky Frontier Program

**Moderator:** How do you think the advances will translate into actual use?

**Muraoka:** You might be able to get on a flight at a spot near your house, fly to Haneda Airport, get off at your specific target spot, and board a passenger airliner bound for another country. That would do away with so much of the wasted time that people have to put up with when they travel. Another possible application would be transportation and rescue missions to isolated islands that lack long runways or an airport altogether.

**Watanabe:** High-speed performance is extraordinarily valuable. Aircraft that travel at higher speeds would be an enormous help in situations where you have to get something to a specific destination as quickly as possible—an organ transplant, for example. A business jet might be enough to get things where they need to go if the origin and destination are both in Japan, but if there's someone waiting for a transplant in India, you'd have to have a higher-speed aircraft to make an emergency transport mission from Japan to the target location. High-speed aircraft could save lives in the event of a

shipwreck, too: if there's a vessel in distress all the way across the Pacific Ocean, you could dispatch a high-speed aircraft to head straight for the position and drop lifeboats and food supplies. One of the biggest benefits that high-speed aircraft and supersonic aircraft offer is a far-reaching scope of service potential.

**Taguchi:** Taking the idea of high-speed performance from another angle, it's really amazing how hypersonic aircraft could impact business. A conventional airplane these days can cross the Pacific Ocean in about 10 hours, but a hypersonic passenger jet traveling at Mach 5 could cross the Pacific Ocean in two hours—in other words, it could make two round trips in the time it takes a normal passenger jet to make a single one-way trip. If you do the math, an airline with a hypersonic passenger jet could see the profits from its trans-Pacific flights quadruple. That would trigger a major transformation in the air transportation business model, I think. I once worked on a market research project on hypersonic aircraft. We figured that the people most enthusiastic about traveling on hypersonic jets would mostly be from the first-class passenger segment, but the results indicated significant

A hypersonic passenger aircraft



A sub-orbital spacecraft



interest among normal economy passengers, as well. Given these and other conditions, JAXA and European aircraft manufacturers are currently narrowing the development focus to hypersonic passenger jets and sub-orbital spacecraft. Capable of crossing the Pacific in just two hours at Mach-5 speeds, the hypersonic passenger jet we're working on is a 40-meter-long small business jet with two pilot seats and 10 passenger seats (see the Figure for an illustration). After taking off, the aircraft ascends to an altitude of about 25 km and then cruises at Mach 5. A sub-orbital spacecraft (see the Figure for an illustration) uses a hypersonic jet engine and rocket engine to accelerate at a nearly vertical angle and eventually reach space at an altitude of 100 km. In addition to playing a pivotal role in space tourism business, these spacecraft can also provide microgravity environments for scientific testing.

What is the new value of aircraft?

**Kanda:** Automatic control is a really big part of it. If the technology keeps moving forward, we could ultimately get to the point where we have pilot-less "unmanned" aircraft. Due to safety concerns, though, I doubt we'll ever have unmanned passenger jets.

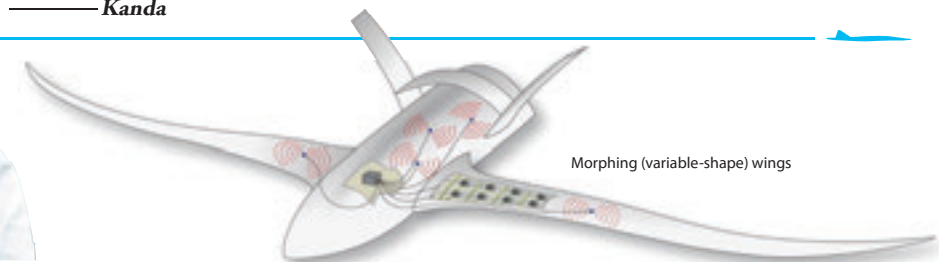
My concept is for an airplane that uses functionalized structure technology to enable high-speed, quiet, and stable flight. Traditional airplanes are designed to have hard, strong, and light wings. The concept I'm working on goes a different direction by aiming for a soft, flexible structure and uses an actuator inside the wing to change the shape of the wing surface, thereby distributing the load effectively.

**Moderator:** Are we talking about morphing wings?

**Kanda:** We certainly are. When an airplane exceeds a certain speed, part of the wing experiences a type of vibration called "flutter." Controlling the surface of the wing makes it possible to minimize flutter—and less flutter means being able to fly at higher speeds. Morphing wings also spread out the load on the airframe, enabling high-load maneuvers that traditional airplanes haven't



*I want JAXA to be breaking away from foreign competitors in functionalized structure technology 20 or 30 years from now.*  
——— Kanda



been capable of. They really expand the operational profile (motional range) of the airplane. By creating a bowed wing configuration, morphing wings also make for a more simplified structure without the control surfaces of ailerons. When you're working with a simpler configuration, you have less maintenance work to worry about.

**Moderator:** That would require soft, strong, and light materials. What do you think you'll be using?

**Kanda:** We're just starting to look at our options, but development is moving forward with stronger, lighter metallic materials. If we get those two pieces in place, we'll look for the softest one we can find. As we get to work on exploring airframe designs and control systems, I'm going to keep my initial focus on building experience with unmanned aircraft and making sure that we can eventually break away from foreign competitors in 20 or 30 years.

**Moderator:** Aircraft need to be able to travel at high speeds and transport large volumes, but they also have to be safe. What kinds of technological trends are going to shape the safety of future aircraft?

**Kanda:** Planes crash when they lose speed. We won't be able to eliminate speed loss completely as long as we're using fixed wings, but functionalized structure technology will at least be able to slow down the speed loss process. The technology makes it possible to control the entire wing surface, an ability that could allow aircraft to fly areas where conventional planes have tended to lose velocity. I think the technology will contribute to improved safety.

**Watanabe:** The arrival of large-sized, double-deck aircraft like the A380 have made the idea of mass transport one major trend, but some people are actually expressing doubt that you really need large-sized airplanes for mass transport. I don't even think we need to keep designing

aircraft like we currently do. One emerging trend lies in unconventional designs like the "blended wing body" (BWB) concept, which Boeing has incorporated into its experimental designs. A blended wing body aircraft integrates the body with the wing, creating a more spacious cabin that would accommodate more passengers. **Moderator:** But passengers in the middle of the plane wouldn't be able to see outside, right?

**Taguchi:** I totally agree. Fossil fuels are eventually going to dry up, so we'll have to keep thinking about new propulsion systems for aircraft. Hypersonic aircraft run on liquid hydrogen, an environmentally friendly form of fuel that generates no carbon dioxide. No matter how high aviation demand grows, aircraft that use liquid hydrogen for fuel will never pollute the environment. Why not explore the possibilities of installing liquid hydrogen engines on subsonic aircraft, then? That potential is there. You can also create hydrogen by electrolyzing water, so we might be able to use it for centuries—without having to rely on fossil fuels—if we can produce it efficiently. Another option is shale gas, which has gotten more and more affordable in recent years. We could potentially convert shale gas into liquid methane and use that for fuel, too. I really think that new technologies are bound to create

exciting new value.

**Moderator:** The shift toward electric technology is going to drive trends, too, I'd assume. Battery performance might not be sufficient yet, but once it is, aircraft will probably start changing radically.

**Watanabe:** Current technological forecasts say that there will be a real business market for 15- or 16-seat passenger electric aircraft in just 20 years' time. Hoping to be part of that progress, JAXA is going to conduct flight demonstration tests on manned electric flight.

**Kanda:** From a manufacturing standpoint, lighter structures lead to improved fuel consumption. That's why we're seeing more and more companies using composite materials to minimize overall weight. It's not just about the materials you use, though; the structures you design can have a big impact on how light the end result can be. I want to make contributions in that area.

Some of the aircraft that the researchers in this roundtable discussed are still in the basic research stage or waiting for full-fledged research and development to begin, but they all go to show how JAXA researchers are determined to chart new territory in aviation through innovative endeavors in "new frontier." The JAXA Institute of Aeronautical Technology is promoting its Sky Frontier Program to propel initiatives to explore the enormous potential of the air transportation field from a long-term perspective. To help Japan keep pace in the skies of the future, Sky Frontier will continue to take on the challenge of unlocking the evolving potential of air transportation.

*If we figure out ways to produce hydrogen efficiently, we'll be able to break free of our dependency on fossil fuels.*  
——— Taguchi



Protecting passengers and crew members from turbulence

How SafeAvio detects turbulence in advance to help reduce shaking



Shigeru Machida, SafeAvio Pre-project Team Leader

Turbulence is a common occurrence — most commercial airline passengers know what it’s like to see the seatbelt sign come on and then feel the plane wiggle and jerk side to side or up and down. In some severe cases, turbulence can cause injuries and other incidents. Reducing the number of accidents linked to weather phenomena like turbulence, which plays a role in roughly half of all passenger aircraft accidents in Japan, is an important focus for efforts to improve aircraft safety. JAXA is making its contribution through the “R&D of Onboard Safety Avionics Technology to Prevent Turbulence-Induced Aircraft Accidents (SafeAvio)”. Here’s some more about JAXA’s new technology.

What is turbulence?

Turbulence is an area of unstable airflow in the atmosphere. There are two basic types of turbulence: turbulence caused by atmospheric phenomena and turbulence caused by geographical features such as mountains and buildings.

Turbulence comes in many forms, including turbulence that occurs in cumulonimbus and other convective clouds, clear-air turbulence, which occurs without the presence of clouds that occurs near jet streams at altitudes of 10 km or higher, and downbursts, which are caused by strong downward currents from cumulonimbus clouds.

Meanwhile, there are also several varieties influenced by geographical features. Mountain waves, for example, occur on the leeward sides of mountains, while low-level wind shears arise from buildings, undulations on the terrain, and other features on the ground. Another type of turbulence is wake turbulence, which forms behind an aircraft as it passes through the air.

To keep their aircraft out of turbulent patches of air, pilots check the weather conditions before taking off, locate airspace that looks prone to turbulence, and then proceed to fly around these areas of potentially choppy air. On-board weather radar systems also keep pilots informed of cloud areas during flights, making it easier to avoid turbulence.

Weather radar bounces radio waves off water droplets and picks up the resulting reflecting waves. These systems

can easily detect clouds, which are large masses of water droplets, but have a much harder time with areas of cloudless clear-air turbulence — the most vexing form of turbulence for pilots. Analyses of meteorological charts simply do not provide enough information to predict clear-air turbulence with any certainty.

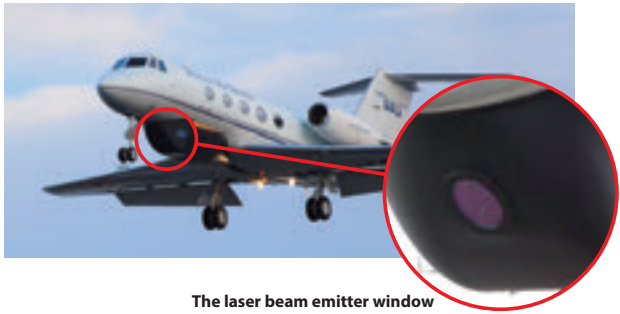
JAXA has been developing technology to detect this invisible turbulence since the 1990s.

JAXA’s turbulence detection technology

How does one go about detecting invisible turbulence, then? The key is aerosol — minute particles of dust that range from 0.3 to several micrometers in size and float in the air even in dry, cloudless expanses of air. JAXA’s turbulence detection technology transmits laser beams in the direction of travel, receives the light scattered by the aerosol in the air, and detects turbulence by analyzing how the aerosol is moving.

Called “Doppler LIDAR” (LIght Detection And Ranging), the technology measures the difference between the wavelengths of the transmitted light and the received light and then applies the principles of the Doppler effect (wavelengths moving away get longer, while wavelengths moving closer get shorter) to determine the movement of the aerosol particles.

The turbulence detection system in flight testing



The laser beam emitter window

A series of tests using JAXA’s MuPAL-α experimental aircraft and Gulfstream II business jets has shown that Doppler LIDAR is capable of detecting clear-air turbulence 9 km ahead at high altitudes around 10 km. NASA and EADS have also installed Doppler LIDAR systems on aircraft, but their equipment is much larger and heavier than JAXA’s. With its compact technology, JAXA is leading the world in the Doppler LIDAR field.

A passenger aircraft can cover a distance of 9 km in about 30 or 40 seconds at cruising speed, which means that the pilot can’t do much more than turn on the seatbelt sign before the plane hits the turbulence. Aircraft will need systems that can emit more powerful laser beams to detect turbulence further out, but stronger laser intensity would make the equipment larger, heavier, and harder to install on aircraft.

JAXA thus decided to develop a technology that would detect turbulence in front of the aircraft and automatically control the shaking of the aircraft to help

bring the number of aircraft accidents down by half. The end result was the SafeAvio’s Onboard Safety Avionics Technology for Preventing Turbulence Accidents, a system that helps eliminate aircraft shaking by not only warning the pilot of approaching turbulence but also moving the control surface with automated controls.

The majority of passenger aircraft now flying use fly-by-wire systems, a type of interface that moves the control surface by sending electric signals via a flight computer. To implement SafeAvio, all an operator would have to do is install new software on the flight computer. In the future, JAXA plans to develop efficient gust alleviation technology that places innovative small-scale, lightweight, high-response actuators on aircraft in the ideal configuration for reducing shaking and enables precise, finely tuned automatic control.

To reduce vertical shaking with control surface movements, one needs to know the vertical airflow in the

turbulence. JAXA’s turbulence detection system accomplishes this by emitting two laser beams at slight angles. Another point that needs to be taken into consideration is size, as larger, more sophisticated equipment needs to be kept as small and lightweight as possible. Over the next four or five years, JAXA hopes to streamline SafeAvio so that it can be installed on the MuPAL-α experimental aircraft and perform flight demonstrations of gust alleviation control and other features.

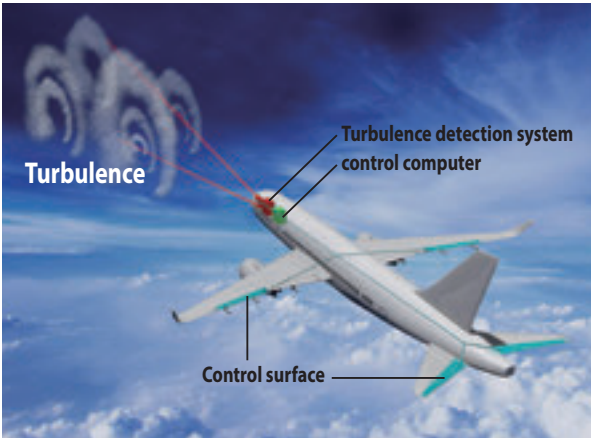
If everything goes as planned, SafeAvio will be able to fit on regular passenger aircraft in 10 years or so. Future flight demonstrations might even be able to use Boeing aircraft, as JAXA has been working with the American manufacturer for the last few years on the development of the turbulence detection system.

Low-altitude turbulence triggers an alarm

Downburst and low-level wind shear — two types of turbulence that occur at low altitudes — can interfere with landing approaches. When a strong downburst makes a safe landing impossible, the pilot needs to perform a “go-around” and attempt the landing again. Although safety concerns sometimes necessitate a go-around, these procedures are essentially a waste of fuel and time.

A Doppler LIDAR system can detect turbulence at greater distances when the aircraft is flying in aerosol-rich low-altitude air. By advising the pilot around 40 seconds before the aircraft reaches turbulent air during landing approach maneuvers, the system gives the pilot ample time to make a decision on whether to land or do a go-around.

The DREAMS Project, which began its research and development activities before SafeAvio got its start, has developed a “Low-level Turbulence Advisory System (LOTAS)” that uses weather data and Doppler LIDAR equipment at airports to predict weather conditions



around airports and tell operators whether an aircraft will be able to make a safe landing approach. Incorporating this technology from the DREAMS Project, SafeAvio will be able to give pilots the turbulence-related information they need to fly their aircraft as safely as possible.

Contributing to aviation security through global standardization

Making SafeAvio commercially viable will require the cooperation of various parties in the passenger aircraft world: the airlines that operate them, the pilots who fly them, and the companies and universities that develop their parts and equipment. JAXA is currently building a SafeAvio community to accelerate the process of ushering the technology into the market.

The drive to make SafeAvio a reality will also require efforts to amend regulations and authentication standards.

The vast majority of avionics are currently produced by foreign manufacturers, leaving Japanese manufacturers little room to enter the market. “Showing the world the amazing things a made-in-Japan system like SafeAvio can do would give Japanese companies a strong foothold in the market,” say SafeAvio Pre-project Team Leader Shigeru Machida and Associate Fellow Hamaki Inokuchi. “We’re competing against a host of other countries engaged in similar research. It’s a kind of Olympics-type environment — and we’re determined to take home the gold.”

Signal processor

Chiller

WGA driver

Optical transceiver

Optical antenna

1st amplifier driver

Power supply

Performance/specifications	
Pulse energy	1925μJ
Output rate	1~10Hz
Optical effective diameter	150mm
Power consumption	1930W
Weight	148kg



Hamaki Inokuchi, Associate Fellow in the Operation Systems and Safety Technology Research Group



# Protecting airplanes from *ice* with icing detection and anti-icing technology



**“Icing,” or the accretion of ice on an aircraft, is a natural phenomenon that ranks with turbulence as one of the biggest risks to aircraft safety.**

**In order to prevent icing, aircraft feature various anti-icing and de-icing mechanisms.**

**JAXA is currently developing revolutionary icing detection and anti-icing technology.**

**What kind of technology are we talking about—and how will it improve overall convenience?**

## Ice: The nemesis of airplanes

“Icing,” which refers to the accretion of ice on an aircraft’s wings, fuselage, engines, and other components, often occurs when the moisture content in the air is high and the ambient temperature is low. As temperatures can drop below  $-40^{\circ}\text{C}$  at high altitudes, icing is a common problem in clouds and other moisture-laden airspace. Although the common assumption is that water normally “turns to ice” at  $0^{\circ}\text{C}$  in natural environments, water does not immediately solidify into ice at a subzero temperature. “Supercooled water,” for example, is a type of water that remains in its liquid state when the temperature is below zero in a cloud environment. When subjected to a physical stimulus, supercooled water instantly crystallizes into  $0^{\circ}$  ice. Thus, the shock of an airplane entering a cloud containing supercooled water droplets results in the formation of ice on the surface of the aircraft. High-impact components like the leading edge of the wing, the nose, the air intake vent of a propeller jet engine, the fan blade, the hinge parts of the aileron and other flight control surfaces, and the wheels are particularly susceptible to icing.

Icing on the wing alters the airflow moving over the surface of the wing, a change that can reduce lift and

increase drag. Tests have shown that icing just 1.3 cm thick on the leading edge of the wing cuts lift by 50% and elevates drag by 50%.

Icing on the propellers of a propeller aircraft can also inhibit propulsion efficiency and cause abnormal vibrations. On jet aircraft, meanwhile, icing is extremely dangerous—it can enter the air intake vents of the jet engines and damage turbines, for instance. Icing on pitot tubes can interfere with airspeed and atmospheric pressure measurements, while icing on the front windshield of a cockpit can obscure the pilot’s view. Icing thus has a sizable impact on aircraft safety.

To mitigate the effects of icing on overall flight operations, aircraft have anti-icing systems, which serve to



An airplane wing coated with ice

prevent icing from occurring, and de-icing systems, which remove icing from surfaces.

Passenger jets currently in service use “bleed air”—warm air from jet engine exhaust—and electric heaters to heat areas prone to icing. The leading edges of the wings on small propeller aircraft feature rubber membranes (“boots”) that fill up with highly compressed air during flight to de-ice the corresponding area mechanically.

However, using bleed air or electricity means using extra energy from the engine. Given the piping required to feed the air to the appropriate location, bleed air mechanisms also have complex structures that are not only hard to maintain but also add to overall weight.

## New anti-icing technology

Many people have surely seen machines spraying liquid on aircraft waiting at cold, snowy northern airports. The liquid these machines are discharging is a mixture of glycol, water, and a highly hydrophobic thickening agent that repels water, making it harder for snow and ice to adhere to the airframe. The hydrophobic and hydrophilic characteristics of various chemicals continue to play a substantial role in ongoing research efforts in the field of

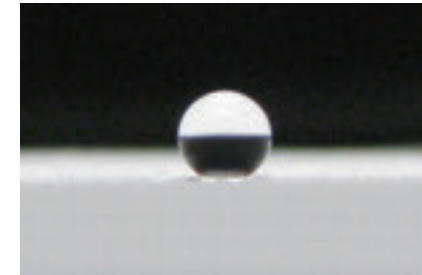
anti-icing technology.

A hydrophobic chemical has molecules that resist bonding with water molecules, while a hydrophilic chemical has molecules that bond easily with water. If you put a water droplet on a highly hydrophobic substance, the droplet will “ball up” due to the surface tension of the substance. Dewdrops on the leaves of a lotus plant or taro are good examples of this phenomenon—the fine structures on the leaf surfaces repel the water, causing the droplets to roll around like little balls.

These sorts of water-repelling characteristics are called “water-shedding” (or hydrophobic) properties. Surfaces on which the contact angle of a water droplet exceeds  $150^{\circ}$  are “superhydrophobic surfaces.” A contact angle of  $0^{\circ}$  results in the water droplet spreading out completely on the surface; a contact angle of  $180^{\circ}$ , meanwhile, means that the water droplet is perfectly spherical on the surface. Thus, superhydrophobic surfaces trigger a response that produces relatively spherical drops.

Chemicals with water-shedding properties are already used in a wide range of applications, including competition swimsuits and the rain-repelling agents for car windshields. After touching a material with a water-shedding coating, water droplets “ball up” and fly off the surface. Swimmers in water-shedding swimsuits thus meet less resistance in the water, while drivers have clearer views of the road ahead through their water-shedding windshields.

The JAXA Institute of Aeronautical Technology began work on anti-icing coating technology using superhydrophobic coatings around three years ago. The research eventually produced the JAXA coating, a hydrophobic coating agent for use on aircraft. Researchers are now working to iron out the many remaining problems and determine whether the coating is viable for practical use. One of the issues currently under investigation is how the hydrophobic coating tends to freeze when impacted supercooled water enters the microscale cracks in the coating on the front surface of the wing. To solve this problem, researchers are trying out different coating types on the affected area, tweaking coating locations, producing small amounts of heat with heaters to keep the



A drop of water on material with a water-shedding coating

hydrophobic properties of the coating active, and guarding against freezing by applying vibrations.

Research on anti-icing technology has implications for much more than just aircraft—it also has an impact on the electricity industry, which often has to grapple with the accretion of snow and ice on power lines, as well as areas like construction, civil engineering, and shipping. The Kanagawa Institute of Technology and other organizations boast icing wind tunnels, where scientists can conduct various research projects on icing. JAXA sponsors icing-related research seminars for representatives from the academic and industrial spheres, promotes the exchange of information on the subject, and continues to work with a variety of organizations on icing research.

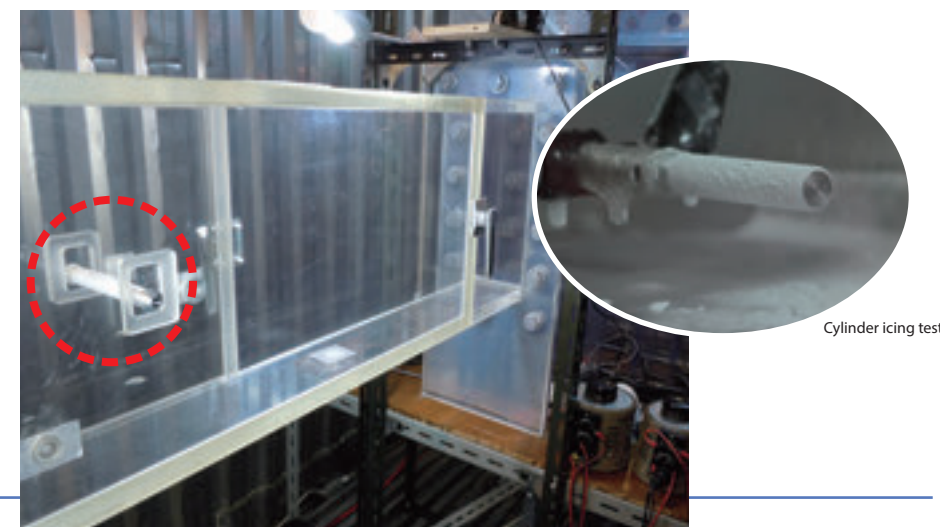
The FP7 Call 5 JEDI-ACE program, a joint research project uniting Japan and Europe in an initiative to create innovative anti-icing technology, also began last November. JAXA joins Fuji Heavy Industries and the Kanagawa Institute of Technology on the Japan side, with Fraunhofer (Germany), Dassault (France), and the Spanish

University System participating on the Europe side.

Superhydrophobic coating technology still has many issues to overcome, including questions about durability. Once practically viable, however, the technology will make it possible to prevent aircraft icing with a single coating—an important advancement that will not only improve safety but also reduce aircraft weight, improve fuel efficiency, and reduce environmental load.

## Detecting icing on airframes

Superhydrophobic coating-based anti-icing technology holds extraordinary potential for the prevention of aircraft icing, but the coating currently in development might not be able to deliver the desired performance under certain environmental conditions. That variability raises the need for technology that can determine icing conditions and apply solutions optimally. As water and ice absorb infrared rays differently, JAXA is attempting to develop an icing sensor system that irradiates a portion of an aircraft wing with infrared rays and uses sensors to capture the light. Based on the light results, the system then determines whether the substance on the wing surface is water or ice and how much ice accretion has occurred. The ability to assess the extent of icing on planes will make it possible to gauge the possibility of safe takeoff in real time and, by giving pilots a constant grasp of icing conditions, enhance operational safety.



The icing wind tunnel at the Kanagawa Institute of Technology

The endeavor to develop a new type of aircraft: One that uses no fossil fuels

# Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution (FEATHER)

Most aircraft nowadays use either jet engines or reciprocating engines with propellers for their sources of power, but there are alternatives, too: one type of aircraft currently drawing a great deal of attention is electric aircraft, which use batteries and electric motors to move. JAXA is also working hard on electric aircraft research and getting ready to perform manned flight demonstration tests in FY2014. What exactly is JAXA's vision of electric aircraft all about?

What is an electric aircraft?

An electric aircraft is one that flies on an electric motor instead of an internal-combustion engine. The first electric aircraft capable of flying passengers was developed in the United States in the 1980s. Using a solar cell for its power source, the aircraft was a single-seat plane with a low-output motor. Later, in the mid-1990s, German researchers came out with an electric motor glider that featured a nickel-cadmium battery. The motor glider would take off on its own power and cut its engines in the air, allowing it to glide through the sky.

After the turn of the century, electric aircraft performance improved dramatically with the spread of high-energy-density lithium-ion batteries and powerful permanent-magnet synchronous motors using



The propulsion system (electric motor system) developed by JAXA

neodymium magnets. A lithium ion battery-powered high-performance motor glider obtained type certificate in Germany in 2006, and Boeing conducted flight demonstration tests on a fuel cell-powered electric aircraft in 2008.

JAXA also began elemental research in 2004, aiming to establish basic technologies for electric aircraft that people could pilot.

In FY2014, JAXA is set to perform manned flight demonstration tests on a motor glider with a 60-kW electric propulsion system through its FEATHER (Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution) program.

Electric aircraft: Advantages and issues

Electric aircraft boast several advantages over aircraft with reciprocating engines. One of the biggest differences is in the aircraft's energy conversion efficiency: whereas a reciprocating engine has an efficiency of around 20%, an electric motor can reach an efficiency level of over 90%. Compared to traditional aviation gasoline, electricity has lower unit energy costs, making it a great way to cut overall energy costs. A simple structure also makes for easy

maintenance and eliminates the need for the periodic overhauls that reciprocating engines require (legal maintenance is mandatory). By significantly cutting energy costs and maintenance costs, electric aircraft bring total costs down by 40% compared to reciprocating engine aircraft.

Electric aircraft are also advantageous for the manufacturing field, too, as they do not need the oil systems that conventional reciprocating engines require and also have extremely simple piping. These differences allow for easier, lower-cost production. At mass production volumes, electric aircraft are also capable of enabling major price cuts. Moreover, electric aircraft in flight emit no CO2 whatsoever and produce only minimal noise and vibration, which makes them extremely comfortable, environmentally friendly planes.

Despite their numerous benefits and advantages, electric aircraft have many challenges to overcome. Their flight endurance levels, for example, are short because lithium-ion batteries have less energy capacity per unit of weight than fossil fuels do—and attempting to lengthen flight endurance by installing more batteries ends up making the aircraft too heavy to fly. Electric aircraft also take time to charge and require relatively expensive

batteries.

For these reasons, the only electric aircraft currently feasible have only a handful of seats. The right technological innovations could help electric aircraft evolve into small planes with a seating capacity of around 20, but even two or three decades might still not be enough time to develop larger electric passenger aircraft.

FEATHER's electric motor glider

FEATHER plans to conduct flight demonstration tests at the Japan Air Self-Defense Force's Gifu Air Base and other locations in FY2014.

The tests will replace the reciprocating engine from the prototype HK36TTC-ECO, a two-seat motor glider from Diamond Aircraft, with a JAXA-developed electric propulsion system.

Driven by a lithium-ion battery (75 Ah, 128 V, 32 series), the aircraft's powerful permanent-magnet synchronous motor will have a maximum output of 60 kW (approximately 82 horsepower). The aircraft will also feature an IGBT inverter and use torque control to control the electric motor output, which, just like a reciprocating engine, can be controlled with a throttle lever.

The reciprocating engine in the prototype aircraft can generate a maximum output of 60 kW to 86 kW (depending on the series), so the electric motor will be producing the same amount of power. As the motor can also reach up to 8,000 rpm, reduction gears will regulate the propeller rotations. The propeller is a variable pitch propeller, but JAXA will be flying the aircraft at a fixed pitch propeller for the tests.

The battery, which weighs around 120 kg, will be



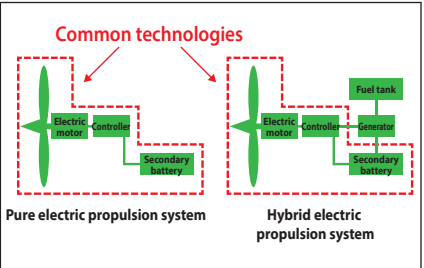
The motor glider (prototype) slated for flight demonstration tests

housed in a pod under the main wing.

For the flight demonstration tests, the aircraft will make its takeoff climb at full power for 1 to 2 minutes, circle the airfield (on a traffic pattern) at an elevation of approximately 300 m and around 20 to 30 kW of power, and then land.

The cruising speed will range from 100 to 150 km/h. A single full battery charge will be enough to get the aircraft through its 15-minute program (takeoff, cruising, and landing), even if the pilot applies full power for around 2 minutes during takeoff. Having completed a 5- to 6-minute trip through the traffic pattern and landed, the aircraft will be fully recharged and sent into the air again.

JAXA plans to conduct the flight demonstration tests on a long runway so that the aircraft can glide and return to the ground safely in the event that it experiences a loss of power during takeoff.



The configuration of the electric aircraft system

The potential for electric aircraft

JAXA is also pushing beyond FEATHER and exploring the possibilities of a hybrid propulsion system, which could make it possible to get past the problems of short flight endurance that limited battery performance creates and open doors to larger aircraft. In a hybrid car, an engine and an electric motor are often installed in a parallel fashion to power the vehicle simultaneously. In the hybrid propulsion system that JAXA is now looking into, however, a fuel-cell hybrid gas turbine generator sends power to the electric motor and turns the fan.

Although it will be some time before developers will

be able to create mid-size and large electric aircraft, we are now starting to see real business potential in small electric aircraft. Akira Nishizawa, FEATHER Team Leader in the Technology Demonstration Research Office, says, "It's our job to create the technologies at the core of the electric aircraft that the world will be needing in the future. I want to keep demonstrating technologies that will put Japanese manufacturers in prime position to capture the market."

Electric aircraft represent one of the biggest innovations in the history of aircraft development. Unlike reciprocating engines, electric motors are wonderfully compatible with digital technologies and offer a market accessible to appliance manufacturers, material manufacturers, and a host of other industries. "Individual use grows as mobility increases," Team Leader Nishizawa says. "Aircraft could be the last form of personal mobility after the car. That's what makes them such an incredible source of business opportunities."

Electric aircraft will have a massive ripple effect on industry and society as a whole. If small electric aircraft follow the path blazed by cars and eventually become low-cost, carefree mobility options, our lifestyles will undergo enormous change.



Akira Nishizawa  
FEATHER Team Leader  
Technology Demonstration Research Office



# The Multi-axis Vibration Evaluating System (MaVES): Measuring three-dimensional vibration characteristics of any object

Every aircraft or spacecraft structure needs to be designed to prevent flutter. Meeting that requirement requires numerical analyses based on ground vibration tests, but the Multi-axis Vibration Evaluating System (MaVES) designed by JAXA makes the job much easier. What is MaVES, exactly, and how does it aid in the anti-flutter effort?

“Flutter” is self-excited oscillation that an object experiences due to the effects of airflow. Imagine a flag flapping in the wind—that movement is a representative example of flutter. The flutter phenomenon can occur in the main wing of an aircraft and, depending on the oscillation properties involved, grow to an amplitude that ultimately causes wing damage. When engineers develop a space rocket, they also have to take the flutter properties of the rocket’s fuselage panels into account.

Actual aircraft and spacecraft in operation are designed to prevent flutter. The Multi-axis Vibration Evaluating System (MaVES) can become a powerful design tool for preventing flutter.

MaVES, a system equipped with laser beams to measure an object’s vibration characteristics in three dimensions, applies vibration to a testing material and analyzes how the object vibrates in response. The process of vibrating an aircraft in a stationary state (not exposed to airflow), making precise measurements of the resulting

vibrations, and analyzing the natural vibration characteristics is vital to estimating how the aircraft will vibrate in flight.

The system consists of a six-axis industrial robot, three laser sensors on the end of the robot arm, integration software that processes vibration data from the controller and sensors, and modal analysis software that analyzes the vibration characteristics.

By irradiating a target object with lasers and measuring the reflected light with its laser sensors, MaVES can determine the object’s vibration velocity. Each laser sensor measures vibrations in one direction, which means that the system’s set of three laser sensors enables users to capture vibrations in three dimensions. Laser technology enhances functionality in many other ways, too: unlike accelerometers and other conventional vibration sensors, which have to be placed directly on the target object, MaVES can measure vibration properties without ever touching the object—or affecting vibration properties—and evaluate the vibrations of objects with complex shapes, objects with high temperatures, and other objects that have traditionally presented challenges. Located on the ends of the MaVES robot’s arm, the laser sensors can move into virtually any configuration imaginable and irradiate the entire object. As a result, MaVES makes it possible to measure the vibration characteristics of the entire object.

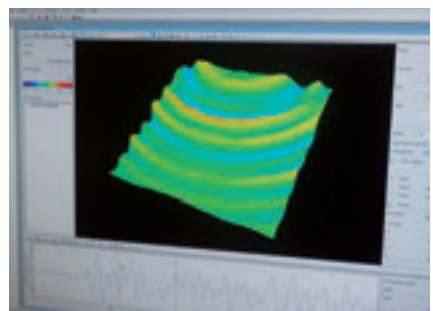
The laser sensors also feature built-in CCD cameras. Users can bring up the images from these CCD cameras on computer screens to determine the optimal measurement locations and make quick adjustments accordingly. Once the measurement locations are set, the system can coordinate with the robot to perform automatic measurements.

The vibration data collected by the system is then analyzed by the integration software and displayed in an animated, graphical form. The modal analysis software resolves the vibrations of the specimen into a natural mode of vibration, called an “eigenmode,” which lets the

user perform more detailed analyses of frequency, attenuation rate, and mode shape characteristics.

MaVES can measure vibration frequencies of up to 5.12 MHz. That leaves more than enough room for aircraft flutter, which normally tends to occur at low frequencies of under 100 Hz. The system also has a measurable spatial resolution of 1 mm or less, enabling highly detailed measurements.

Understanding flutter characteristics is just one of the many applications of vibration measurement technology. One of applications is nondestructive testing because evaluating differences in vibration propagation gives engineers the ability to determine the nature of damage to an object. In the field of consumer electronics, as well, accurate vibration measurements are vital because vibrations have a sizable impact on the sound and feel of a given product. The functionality and versatility of the MaVES system cut across so many industrial lines that JAXA has already started receiving measurement requests from organizations outside the aerospace domain. Atsushi Kanda, Structural Functionality Section Leader in the Structures Research Group, has a clear goal for MaVES. “We’re going to make MaVES as user-friendly as possible to open vibration measurement technology to more usage scenarios,” Kanda says, “and push ahead with research and development on non-contacting excitation to help obtain more precise vibration data.”



Visualization of vibration measured by MaVES

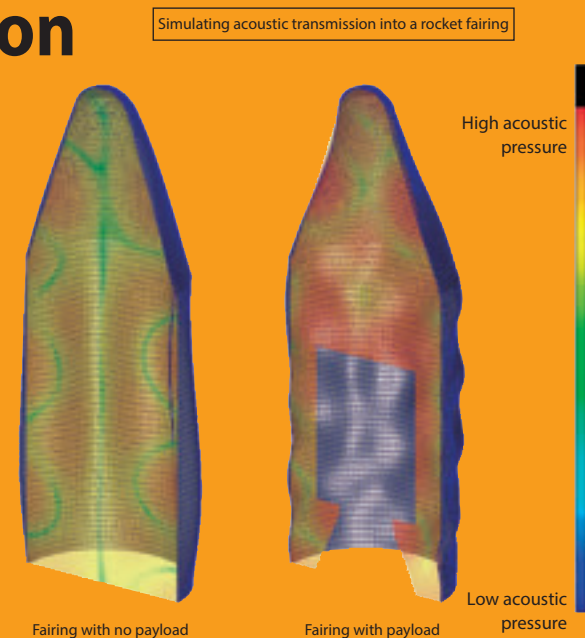


# MaVES

Multi-axis Vibration Evaluating System

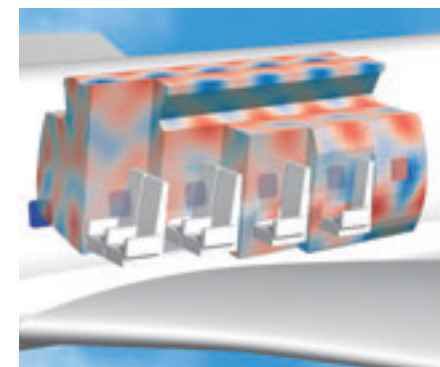
# Analyzing acoustic vibration in rockets and aircraft

The roar of a rocket launch creates vibrations that travel all the way to the satellite inside the fairing at the tip of the rocket. In order to safeguard these meticulously assembled satellites, engineers need to find ways to prevent unnecessary vibrations from affecting launch procedures. The same principle applies to aircraft, as well: keeping the cabin quiet requires a reduction in the sound generated by vibrations. JAXA’s Numerical Simulation Research Group studies methods of using computers to analyze sound-induced vibrations in structures and the transmission of sound into structures.



## What is acoustic vibration?

Sounds are the small changes in air pressure created by a noise source, with small sounds coming from small pressure fluctuations and loud sounds emerging from big fluctuations. These pressure fluctuations can also produce vibrations, or “acoustic vibrations,” that vary in specific frequency based on the size (mass or stiffness, etc.) of the object involved. Just as a short pendulum swings faster than a long pendulum does, short objects have faster vibration frequencies than longer objects do. Applying vibrations that approach an object’s specific frequency makes the object shake with more intensity and, at worst, break. Take a rocket launch, for example. The propulsion of a rocket engine creates massive sounds. If these sounds travel through the rocket fairing and reach the satellite inside, the satellite might shake and could potentially suffer damage. Thus, engineers need to understand the characteristics of vibrations in an object and take steps to keep the amplitude of the vibrations below the right threshold. Computer-based numerical simulation is what makes this crucial preparatory step possible. In the



Simulating an acoustic environment inside an aircraft cabin

Numerical Simulation Research Group, researchers work on methods of determining how the sound from a rocket engine propagates into the rocket’s fairing and develop tools for applying those methods in a computer environment.

## A new method for analyzing mid-frequencies

Sounds include components of many different wavelengths, some of which have a hard time propagating all the way to a fairing, while others are easily propagated. Numerical simulations thus have to look at a wide range of frequencies. Researchers already have the tools to study low-frequency (long-wavelength) sounds with the finite element method (FEM), which breaks analysis targets into small elements, and high-frequency (short-wavelength) sounds through statistical energy analysis (SEA). However, there is no established method for performing precise analyses of frequencies between these two extremes. Of all the different proposals for mid-frequency analysis methods, JAXA is concentrating on the wave based method (WBM). An approach that represents solutions by superimposing wave functions, WBM makes it possible to analyze a wide range of acoustic vibration with high precision—from low frequencies to mid-frequencies. One of the unique characteristics of WBM is that, to be a viable method for analysis, the target space needs to be broken down into subdomains that have convex bulges—an impossibility for the concave interior of a fairing containing a satellite. To make WBM more widely applicable, JAXA is thus researching a hybrid finite element-wave based method (HF-WBM) that divides the fairing interior into

subdomains, applies WBM to the simple convex areas, and uses FEM for the more complex domains around the satellite. JAXA has drawn on a proposal by researchers at the Katholieke Universiteit Leuven in Belgium to create and validate tools for using HF-WBM in the acoustic analysis of rockets.

Rockets keep evolving. JAXA will continue to extend its method to ensure compatibility with the components of future rockets, including fairings made of different materials, fairings with various structures, and acoustic absorption materials.

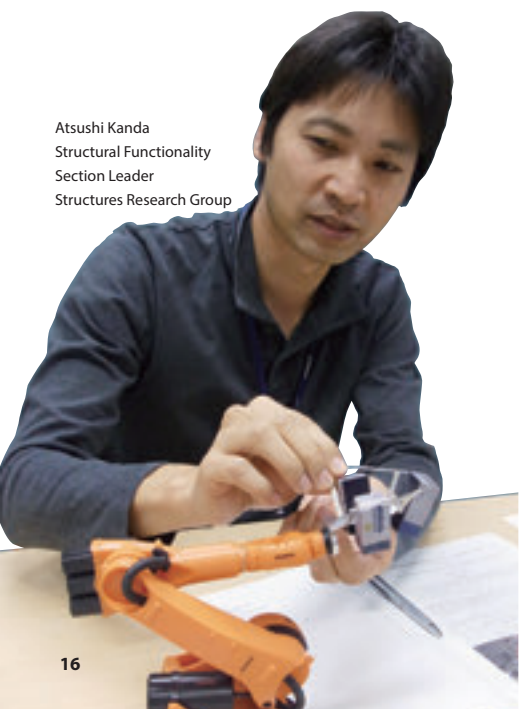
## Creating versatile tools

Acoustic vibration is a problem for more than just rockets—it also affects aircraft cabins, cars, railways, and virtually every other context where loud sounds affect objects. JAXA’s tools are a promising resource for application in a diverse range of fields. Takashi Takahashi, a leader in the Aeroacoustics and Vibration Section, is motivated to make the new solution a valuable one. “We want to get our acoustic analysis method up to practical processing speed in workstation settings,” he says, “and provide it as an intuitive tool that you don’t have to be a numerical analyst to be able to use.”



Takashi Takahashi  
Section Leader  
Aeroacoustics and Vibration

Atsushi Kanda  
Structural Functionality  
Section Leader  
Structures Research Group





# Flight Path Topics

## JAXA participates in the "EM-EASED" project to foster exchanges of European, Japanese, and South Korean human resources

The JAXA Institute of Aeronautical Technology will take part in the Euro-Asian Sustainable Energy Development (EM-EASED) program, which serves to promote the exchange of human resources from Europe, Japan, and South Korea.

Part of the European Union's "Erasmus Mundus Program," the new EM-EASED program aims to encourage exchanges of European, Japanese, and South Korean human resources in higher education settings. The 16 participating universities and research institutions will swap students and researchers, primarily those engaged in the renewable energy field, to form strong international ties. On the Japan side, JAXA joins member universities Okayama University, Keio University, Waseda University, and the Tokyo Institute of Technology as an "Associate institution." Through the program, the Institute of Aeronautical Technology plans to accept one or two researchers and/or students from Europe in aviation energy-related fields like fuel consumption-reducing technology and alternative fuels.

Accepting highly skilled European researchers through EM-EASED will not only help the Institute contribute to international human resource development but also invigorate JAXA's research activities overall. The new tie with European universities will also help forge new bonds, which will lay a more robust foundation for future international collaboration. The Institute is committed to making this new program a dynamic force in facilitating international teamwork through human resource exchanges. The first exchange between participating institutions in Europe, Japan, and South Korea will start in early summer of this year.

## Researchers measure noise sources on the "Hisho" experimental aircraft at Noto Airport

In September 2013, JAXA conducted fly-over noise measurements with its Jet Flying Test Bed (JetFTB), "Hisho," at Noto Airport as part of the "Flight demonstration of quiet technology to reduce noise from high-lift configurations (FQUROH)" mission.

As a preparatory step in verifying noise reduction techniques through series of flight tests planned for the next few years, the noise measurements with the Jet FTB "Hisho" were performed without applying any special noise reduction devices. The purposes of the noise measurements were to identify noise sources from the flaps and landing gear of JetFTB, improve JAXA's noise measurement techniques, and establish a measurement system at Noto Airport.

Researchers set up a phased array with 195 microphones next to the Noto Airport runway. JetFTB flew over the array 90 times at an altitude of 60 to 120 meters to measure the noise levels of JetFTB in several configurations (different flap deflection angles/landing gear up or down), in various flight paths (level, descending, and climbing), and at a few engine thrust levels.



JetFTB "Hisho" flies over the phased array (circled)

## JAXA tests the performance of the FEATHER electric propulsion system

As part of the Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution (FEATHER) project, which completed its last set of tests in May, JAXA conducted performance confirmation tests on an electric propulsion system for small aircraft from October 15 to November 1.

The tests were designed to demonstrate the performance of electric propulsion systems for aircraft and obtain data on the performance required for flight.

For the tests, researchers installed an aircraft motor system designed by JAXA in a 6.5-m x 5.5-m low-speed wind tunnel and measured motor shaft power, motor efficiency, propeller thrust, the temperatures of various motor system parts, and other values.

The data showed that the system had a maximum motor output of 63 kW and motor efficiency levels of 94% or higher, indicating that the motor demonstrates sufficient performance for manned flight. Researchers were also able to confirm that the system fulfills the performance requirements, including the necessary durability and cooling performance levels, for flight at speeds equivalent to those in actual flying environments.

JAXA researchers have also validated the system's unique technologies for improving energy efficiency and reliability. Development is proceeding smoothly.



## Flight tests at Taiki Aerospace Research Field to evaluate the flight controller for Quad Tilt Wing (QTW) VTOL UAV

From October 7 to October 12, flight tests for a QTW VTOL UAV named McART3 were conducted at the JAXA Taiki Aerospace Research Field in Taiki, Hokkaido. The main objective was to evaluate the designed flight controller for McART3, and the tests demonstrated that the attitude controller works properly at propeller tilt angles\* ranging from 90 degrees (vertical) to 15 degrees.

The McART3, a small UAV demonstrator of the QTW VTOL concept, has a length of 1.1 m, a width of 1.4 m, and a weight of 4.6 kg. It also has four propellers, each of which is installed on a wing. By rotating its tilt wings, McART3 can smoothly shift between vertical takeoff/landing mode and airplane mode while keeping its body pitch attitude horizontal.

JAXA plans to evaluate the flight controller for all supposed tilt angles in the next flight experiment, scheduled for early 2014. Development on this VTOL flight control technology will lead to the development of both manned and unmanned QTW VTOL aircraft.



\* Tilt angle is referred to as the angle of the implemented wings. When the wings are set perpendicular to the ground surface, the tilt angle is referred to as 0 degrees; when the wings are set as even with the ground surface, the tilt angle is referred to as 90 degrees.

## JAXA tests on its Unmanned Aerial Radiation Monitoring System in Fukushima

JAXA conducted flight tests on its Unmanned Aerial Radiation Monitoring System (UARMS), a joint research project with the Japan Atomic Energy Agency (JAEA), in Namie, Fukushima Prefecture, on January 24. Past tests at the JAXA Taiki Aerospace Research Field and Shikabe Airport in Hokkaido evaluated the system's flight and monitoring performance. As flight testing was deemed safe near the Fukushima Daiichi Nuclear Power Plant, where radiation levels are elevated, JAXA decided to perform evaluation testing of the airframe system in Namie, a zone preparing to lift restrictions on residents' return.

For the tests, JAEA's radiation detector for unmanned aircraft was installed on JAXA's base unit prototype, which was then flown to an altitude of approximately 150 m and tested over an area of roughly 1 km<sup>2</sup>. The data and findings obtained through the flight tests in Namie will be incorporated into the functional improvement aircraft currently in development to lay the foundation for a more practical unmanned aerial radiation monitoring system.



The UARMS base unit before takeoff

## Weathernews and D-NET launch a collaborative research program

In January 2014, Weathernews Inc. (Weathernews) and JAXA launched a collaborative research program to build a system that ensures prompt and safe rescue operations when large numbers of disaster-relief aircraft need to respond to a major disaster.

JAXA has been working on the research and development of "Disaster Relief Aircraft Information Sharing Network" (D-NET), which transmits and shares operational, aircraft, and task assignment information among multiple aircraft and ground base stations. Weathernews, on the other hand, has developed a portable aircraft tracking system called FOSTER-copilot, an inexpensive, easily implementable solution that is already in use in 45 helicopters.

The goal of the Weathernews-JAXA joint research program is to enable the integrated management of disaster-relief aircraft equipped with FOSTER-copilot and D-NET, including medevac helicopters and firefighting helicopters, by sharing disaster information between the two systems. This collaborative research is expected to contribute to prompt rescue and aid operations, particularly in large-scale disasters requiring large numbers of aircraft, through much smoother cooperation among on-the-ground disaster-response headquarters and operation bases and through the safe and efficient flight operations of disaster-relief aircraft for medical transportation and rescue operations.



An actual FOSTER-copilot device

## Flight tests evaluate CFRP speed brakes produced via "out of autoclave" composite manufacturing methods

JAXA is currently researching and evaluating new curing methods for carbon fiber reinforced plastics (CFRP) by assessing the VaRTM (Vacuum assisted Resin Transfer Molding) and VPH (VaRTM Prepreg Hybrid) curing method, both of which are less expensive than the traditional autoclave manufacturing method. In November 2013, JAXA carried out flight test to evaluate actual aircraft structure parts which were fabricated by VaRTM and VPH curing methods. CFRP and original (Aluminum alloy) speed brakes of Sabreliner 65 twin-engine business jet were tested at Phoenix Goodyear Airport (USA).

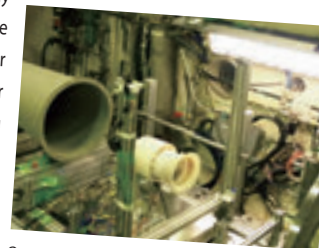
The flight tests showed that the brakes produced via the VaRTM and VPH curing methods were lighter than the aluminum alloy brakes (60% of the conventional type) but just as strong and functional.



A VPH composite speed brake during flight testing

## JAXA conducts engine operation tests on a small turbofan engine featuring parts created with a 3D printer

JAXA is currently developing an integrated tool that combines optimization algorithms, a morphing tool, and an analytical solver (for analyzing flow field) for use with turbofan engine nacelle (the outer case of the engine) designs. With spikes in fuel costs and increased attention to environment-friendliness spurring the development of high-bypass (a high ratio between the amount of air inflow used for combustion and the amount of air inflow that passes through the fan only) turbofan engines, there is a growing need for not only optimally designed engines but optimally designed nacelles—components that have gone essentially unchanged for many years. To evaluate its new optimized design tool, JAXA will create nacelle prototypes with a diverse array of configurations and test them with engines. JAXA is currently using a 3D printer to fabricate the nacelle and fan components for small turbofan engines, putting the prototypes on actual engine testing equipment, and running operational tests. Although a 3D printer might not create the most durable items, it makes it possible to improve the prototype engines quickly and inexpensively and also enables repeated testing. This fiscal year also saw the start of JAXA's research on engine controls using small turbofan engines, a project that created some engine parts with a 3D printer and tested the resulting engines at the Chofu Aerospace Center altitude test facility from October 2013 through February 2014. Through these efforts, JAXA successfully created a small turbofan engine simulation model and a filter (verification software) for estimating the corresponding engine performance.



Operation tests at the altitude test facility