Feature story

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

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.

The Safety Technology for Aviation and Disaster-Relief Program (STAR) 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.

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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) 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.

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.
The International Civil Aviation Organization (ICAO) released its “Global ATM Operational Concept” in 2001. The document predicted that the operating aircraft would double in number by 2023. 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 CHARTS 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 risk 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 inside area medical/transportation drill and the Iwate Prefecture disaster drill used D-NET to give JAXA valuable demonstration testing opportunities. (For more on how the Iwate Prefecture disaster drill used D-NET, see page 10-11.)

D-NET makes it possible to share information between aircraft and disaster-response headquarters, which can then 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 landing 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 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 airborne safety?

We launched research into airborne 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 see and appreciate: lower incident rates through SafeAvio, better rescue rates through D-NET2, and more.
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.

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 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.

Sugiyama: 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

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?

Muraoka: 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.

Sugiura: 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 1,100°C at Mach 5, so we’re researching a way to use -25°C liquid hydrogen to cool the air before it enters the engine.

Taguchi: 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 median 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 it’s true that supersonic aircraft might come 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.

Moderator: The Concorde was designed to carry passengers faster than conventional airplanes, but it’s still in service today. How do you see the development of supersonic aircraft heading in the future?

Muraoka: As far as the Concorde aircraft itself is concerned, it was produced at the end of the cold war; it seems to me that the aircraft industry is now working toward more regional applications. The supersonic aircraft we’re thinking about has the potential to serve as a regional flagship, bringing time-critical patients from hospitals more quickly than ever. For example, in the future, an aircraft like this might be used to transport patients from the island of Okinawa to a hospital in Tokyo. As a result, the aircraft is designed such that it can make supersonic flights without producing any sonic booms. I think new aircraft will create unprecedented new value.

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

—Taguchi

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

—Kanda

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.
Protecting passengers and crew members from turbulence

How SafeAvio detects turbulence in advance to help reduce shaking

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 air in the atmosphere. There are two basic types of 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. 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.

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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 nemeses of airlines

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°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°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°C 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 blades, the hinge parts of the ailerons 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 can cut lift by 50% and elevate 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 and trigger a response that produces relatively spherical droplets. To mitigate the effects of icing on overall flight operations, aircraft have anti-icing systems, which serve to prevent icing from occurring, and de-icing systems, which remove ice from surfaces.

More than that, icing can impair visibility. For example, icing can cause the windshield of a cockpit to obscure the pilot’s view. Icing is also dangerous—it can enter the air intake vents of the jet engines and cause vibrations. On jet aircraft, meanwhile, icing is extremely dangerous—it can enter the air intake vents of the jet and trigger a response that produces relatively spherical droplets.

Icing on the propellers of a propeller aircraft can also, in some cases, cause the propellers to fail. On jet aircraft, meanwhile, icing is extremely dangerous—it can enter the air intake vents of the jet and trigger a response that produces relatively spherical droplets.

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New anti-icing technology

Many people have seen machine sprays 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. Sometimes, our human senses can detect this treatment on the road surface, and determine whether the substance on the wing surface is water or ice and how much icing has occurred. The ability to gauge the possibility of safe takeoff in real time and, by applying solutions optimally. As water and ice absorb infrared rays differently, JAXA is attempting to develop an icing sensor that identifies 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 icing has occurred. The ability to gauge 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.

Superhydrophobic coating technology may have 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 adapt solutions optimally. As water and ice absorb infrared rays differently, JAXA is attempting to develop an icing sensor that identifies 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 icing has occurred. The ability to gauge 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 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 1960s. 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 coast 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 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 40-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 26%, an electric motor can reach an efficiency level of over 90%. Compared to traditional aviation gasoline, electricity has lowerunit 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 MEA-SFC-20 with a two-seat motor glider from Diamond Aircraft, with 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 62 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 600 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 for the tests.

The battery, which weighs around 120 kg, will be 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 110 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 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. We 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. “Individuals who grow up as mobility enthusiasts,” Team Leader Nishizawa says, “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.

The configuration of the electric aircraft system.

Common technologies

Pure electric propulsion system

Hybrid electric propulsion system

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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, give rise 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) makes 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 arm, the laser sensors can move into virtually any configuration imaginable and rotate 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 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 Structural 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.”

### 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 vibrations 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 generates 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.

Numerical Simulation Research Group, researchers work on methods of determining how the sound from a rocket engine propagates into the rocket’s fairing and developing tools for applying these 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 (1 Hz or below) 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 analyses 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 bodies—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 (FEM-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 University Leuven in Belgium to create and validate tools for using FEM-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.

Takusho Takahashi, a leader in the Acoustics 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.”
Researchers measure noise sources on the “Hisho” experimental aircraft at Noto Airport

In September 2013, JAXA conducted five noise measurement tests with the “Hisho” experimental aircraft at Noto Airport. The noise measurements were carried out to validate the system’s unique noise reduction devices.

As a preliminary step in refining noise reduction techniques through series of flight tests planned for the “Hisho,” the noise measurements were performed without applying any special noise reduction devices. The purpose of the noise measurement tests was to identify noise sources and establish a measurement system at Noto Airport.

Researchers set up a phased array with 155 microphones next to the Noto Airport runway to capture the noise at an altitude of 60 to 120 m to measure the noise in terms of power density in various configurations. The data collected was used to identify noise sources and establish a measurement system at Noto Airport.

Flight tests at Taki Aerospace Research Field to evaluate the flight controller for Quiet Tilt Wing VTOL UAV

From October 7 to October 12, flight tests for a Quiet Tilt Wing VTOL UAV named LeART were conducted at Taki Aerospace Research Field in Taki, Hokkaido. The main objective of this project is to develop a flight controller for VTOL aircraft, and the tests demonstrated that the attitude controller works properly at variable flight speeds.

The flight tests confirmed the feasibility of the Quiet Tilt Wing VTOL concept, achieving a flight speed of 1.6 m/s, a range of 4.6 m, and a noise level below 60 dB. The tests also revealed that the flight controller is effective in maintaining an appropriate flight altitude.

JAXA tests the performance of the FEATHER electric propulsion system

As part of the Flight Demonstration of Electric Aircraft Technology for Harmonized (FEATHER) project, JAXA conducted performance confirmation tests on electric propulsion systems for aircraft and attained stable performance by approximating 150 km/h.

For the tests, researchers installed an aircraft motor system developed by JAXA in a 6.5 m long and 2.2 m wide fuselage equipped with a 3.5 kW electric motor. The performance of the motor system was measured under various conditions, including the necessary durability and cooling performance levels, for flight applications.

Researchers have also validated the unique technologies for improving electric motor efficiency and reliability, demonstrating smooth performance.

STELLAR 150 powered by WPT is ready for flight tests

An actual FOSTER-copilot device was developed in Japan, and testing was carried out to verify the actual electric aircraft on a test aircraft. The demonstration of the FOSTER-copilot system was supported by Weathernews-JAXA and JAXA-JATSU joint research programs.

Westerhout and D-NET launch a collaborative research program

In January 2014, Weathernews Inc., Weathernews and JAXA launched a collaborative research program to develop a system that ensures prompt and safe operation of large-scale disaster-affected aircraft.

JAXA has been working on the research and development of “Disaster Aircraft Information Networking” (D-NET), which transmits and shares operations, aircraft, and task assignment information among various aircraft and ground stations. Weathernews, on the other hand, has developed a portable aircraft tracking system called FOSTER-copilot, an easy-to-implement solution that is already in use at 45 stations.

The goal of the Weathernews-FOSTER-copilot joint research program is to enable the integrated management of system software and operation data related to D-NET, including real-time situation awareness, collaboration, and coordination by sharing information between the two systems.

This collaborative research is expected to contribute to prompt rescue and ad hoc operations, particularly in large-scale disasters requiring large numbers of aircraft, through matchless cooperation among on-the-ground disaster response headquarters and operation bases, and through the use of flight operations for disaster relief for medical evacuation and rescue operations.

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JAXA Aeronautics Magazine

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

The JAXA Institute of Aviation Technology will take part in the European Union’s “EM-EASED” project, which will showcase the exchange of human resources between Europe, Japan, and South Korea.

As part of the European Union’s “EM-EASED” project, the JAXA Institute of Aviation Technology will participate in two specialized programs, “Japanese Wind Tunnel Testing (JetFTB)” and “Japanese Aircraft Testing Facility (JATF).” Through these programs, researchers will have the opportunity to exchange human resources with counterparts in Europe and Japan.

The project aims to foster exchanges of European, Japanese, and South Korean human resources in the field of aviation technology, focusing on the exchange of human resources between Europe, Japan, and South Korea.

JAXA conducts flight operation tests on a small turboprop engine featuring parts created with a 3D printer

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JAXA tests on its Unmanned Aerial Radiation Monitoring System in Fukushima

JAXA conducted flight tests on its Unmanned Aerial Radiation Monitoring System (URMS), a joint research project with the Japanese National Atomic Agency (JAEA) in Japan, to demonstrate the feasibility of using drones to monitor radiation levels in areas affected by nuclear disasters. The flight tests were performed over the Fukushima Daiichi Nuclear Power Plant, where radiation levels are elevated.

The URMS system consists of a drone equipped with a radiation monitor and a GPS navigation system. The drone is capable of flying at a speed of 50 km/h and a altitude of 1000 m, and can stay in the air for up to 2 hours.

The flight tests were successful, and the URMS system was able to collect radiation data from the Fukushima Daiichi Nuclear Power Plant and other areas affected by the nuclear disaster. The data collected will be used to improve the accuracy of radiation monitoring in areas affected by nuclear disasters.

JAXA tests on a new VTOL aircraft using a 3D-printed engine

JAXA has been working on the development of a new VTOL aircraft that can be used in disaster relief operations. The aircraft is equipped with a 3D-printed engine, which is capable of producing 40 kW of power.

The engine is made using a 3D printer and is connected to the aircraft’s fuselage. The engine is controlled using a control system developed by JAXA, which allows for precise control of the engine’s output.

The JAXA-FOSTER-copilot joint research program is expected to contribute to the development of a new VTOL aircraft that can be used in disaster relief operations.

Weathernews-JAXA joint research program.

JAXA and Weathernews-JAXA joint research program.

weathernews-jaxa joint research program.

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