

Reduce helicopter noise by controlling the trajectory of the vortex generated at the tip of the blade!

Helicopters are very useful and convenient as a mode of transportation for everyday life. Any flat surface can accommodate the takeoff and landing of a helicopter, as long as the horizontal clearance is sufficient. At times of disaster, this can include the rooftops of buildings or hospitals, or schoolyards or road surfaces. Yet the noise of helicopters may cause disturbances in urban areas. This problem has prompted authorities to limit the number of takeoffs or landings permitted in municipalities throughout the country. JAXA believes that noise reduction will increase opportunities for the use of helicopters, as well as the purposes for which helicopters are used. To make this possible, the agency is researching technologies to reduce helicopter noise.

The active roles helicopters are playing in various fields

The helicopter, a rotary-wing aircraft, plays an active role in fields such as rescue work for disaster management, emergency medical service, firefighting, disaster prevention, material handling, and news reporting. The helicopter can hover in mid-air or fly in various

directions, such as backwards and forwards, from side to side, or up and down. It can take off or land in narrow spaces using small “helipads” instead of long “runways.” These features are ideal for the transport of people and cargo, and they explain the active use of helicopters in various fields.

One of the disadvantages of the helicopter is noise.

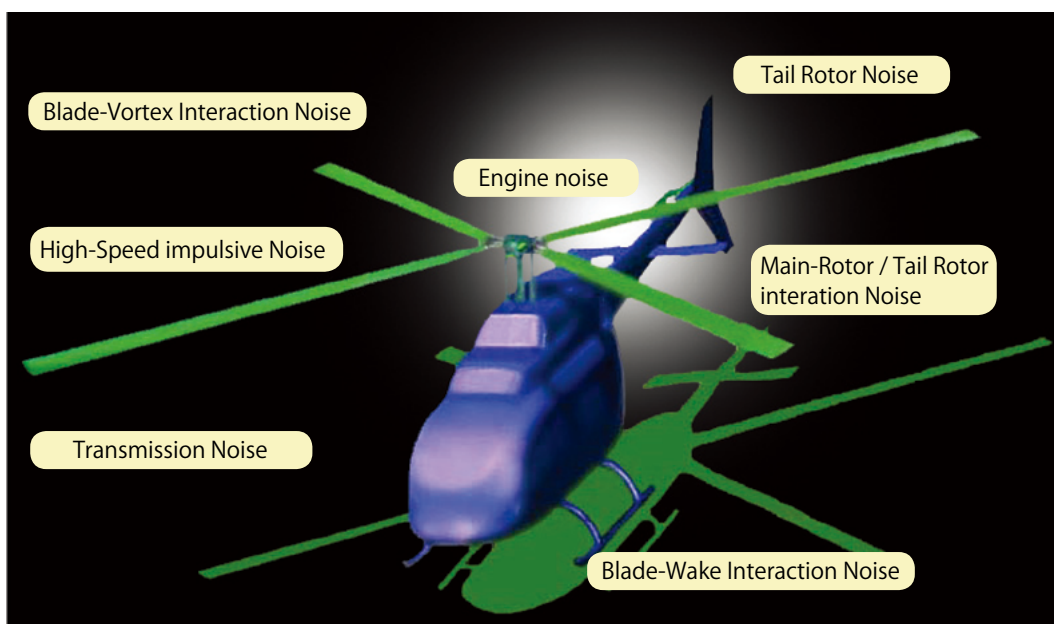


Fig.1 Major sources of noise generated by a helicopter



Fig. 2. Tip vortices generated by the blade

Research is underway to reduce helicopter noise. With successful techniques to accomplish this, the helicopter will play an even more active role in human activities.

What noise comes from where?

We will begin here by showing readers which noise components come from the various parts of a helicopter (Figure 1). A helicopter generates ascending force (lift) by rotating a rotor fitted with two to six blades, at the top of the helicopter body. This is the major source of helicopter noise. The other two important sources are the engine and the tail rotor of the helicopter.

Especially unsettling, among the various helicopter noises generated, are the thunderous roars of the helicopter when it flies at high speeds or descends slowly in an approach for landing. JAXA's Operation and Safety Technology Team is researching ways to reduce the noise generated when a helicopter makes its landing approach.

BVI noise is the culprit.

When a rotor rotates, the attached blade produces an air eddy (Figure 2). The tip of the blade produces a strong vortex called the blade tip vortex. When the blade tip

vortex produced by the leading blade hits or passes by the succeeding blade, the event generates an impulsive noise. The noise generated by the interference of the blade with the blade tip vortex is called Blade-Vortex Interaction (BVI) noise. This is the recognizable "flapping" noise of a helicopter. BVI noise is most noticeable when the helicopter descends gently to land.

The blade tip vortex moves downward during normal flight. But during an approach to landing, it stays near the rotor because the aircraft itself is descending. This generates a strong interference with the blade. The noise is bigger when the blade tip vortex is parallel to the blade than when it hits the blade perpendicularly (Figure 3).

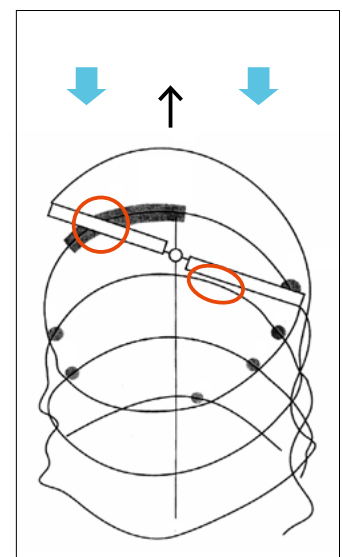


Fig. 3. Trajectory of the blade tip vortex

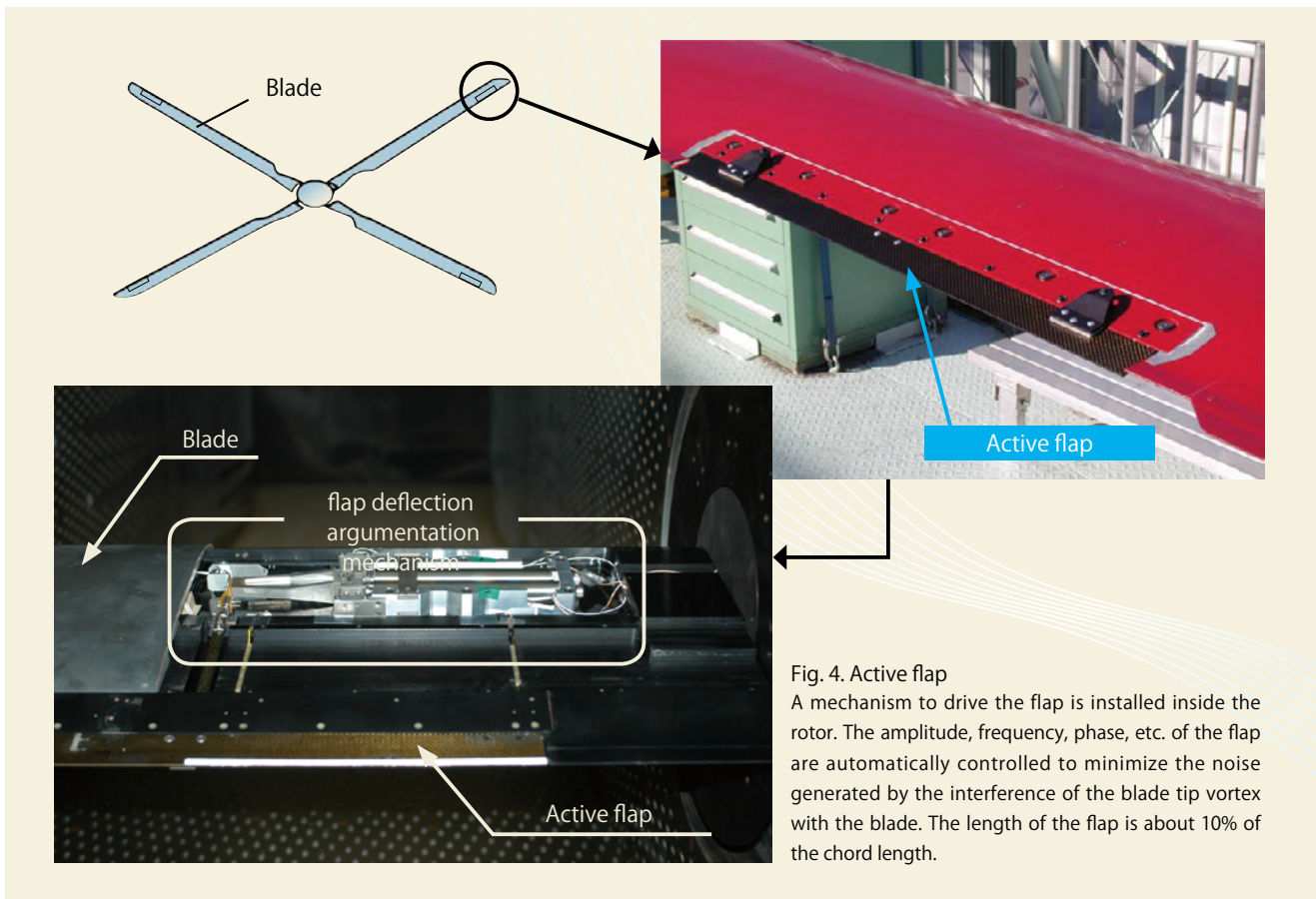


Fig. 4. Active flap
 A mechanism to drive the flap is installed inside the rotor. The amplitude, frequency, phase, etc. of the flap are automatically controlled to minimize the noise generated by the interference of the blade tip vortex with the blade. The length of the flap is about 10% of the chord length.

Controlling the blade tip vortex

The BVI noise can be reduced by controlling the behavior of the BVI with a device to actively drive a flap installed on the blade. Our team is trying to develop a device, what we call an “active flap,” for this purpose (Figure 4). By actively driving the flap installed on the blade (Figure 5), the active flap changes the trajectory of the generated blade tip vortex up and down. The level of interference of the blade with the blade tip vortex can be changed to reduce BVI noise.

Through years of research on helicopter noise reduction, JAXA has clarified the noise-generation mechanism using Computational Fluid Dynamics (CFD) and wind-tunnel testing. Analyses and evaluations in wind-tunnel tests have shown that the active flap developed by our team can reduce noise by as much as 6 dB.

Testing with a full-scaled low-noise blade fitted with an active flap

As part of the effort to put the active flap into practical use, JAXA has started a joint research project with National Aeronautics and Space Administration (NASA) in February 2009. Researchers will collect and share data from tests on the performance of JAXA’s original active flap installed on a full-scale blade (40 cm chord length x 5.8 meter radius) in a huge wind tunnel owned by NASA. The test section of the tunnel alone measures 12 meters high and 24 meters wide. These dimensions are sufficient to accommodate a full-scale helicopter in its entirety. The size of the tunnel is truly surprising. By comparison, the test section of the largest wind tunnel at JAXA measures only 6.5 m x 5.5 m.

The test will be conducted in another five years. JAXA is now designing the blade with the active flap. Though technically a simulation, the flight environment for the testing with the full-scale model (as opposed to a



miniature) will be extremely similar to the actual flight environment. It may safely be said that this will be the most advanced wind-tunnel test ever to be performed. Using only test data collected from miniature models, it is difficult to estimate the characteristics of noise that will be generated by the full-scale model. For this reason, much is expected of the test to be conducted in five years.

Before the actual wind-tunnel test, NASA and JAXA will be using the agencies' respective CFD technologies to analyze and weigh the performance based on the specifications of the low-noise blade provided with JAXA's active flap. As mentioned above, these two agencies seek to enhance the accuracy and reliability of their CFD technologies by weighing the performance analysis results. Joint research on a similar CFD technology is also being conducted with the Office National d'Etudes et de Recherches Aérospatiales (ONERA). Joint projects of this type are helping to improve the CFD analysis technologies of the two agencies.

Towards an actual flight demonstration

After completing the wind-tunnel test at the NASA facilities, JAXA plans to conduct a flight test under the research cooperation with the Air System Research Center of the Japanese Ministry of Defense. We are planning to test the aerodynamic performance and noise-reduction performance of a low-noise blade on a full-scale active flap installed on an MOD-owned helicopter.

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JAXA is also researching the following:

- a technology to reduce a high-speed impulsive blade noise by modifying and designing the tip shape of

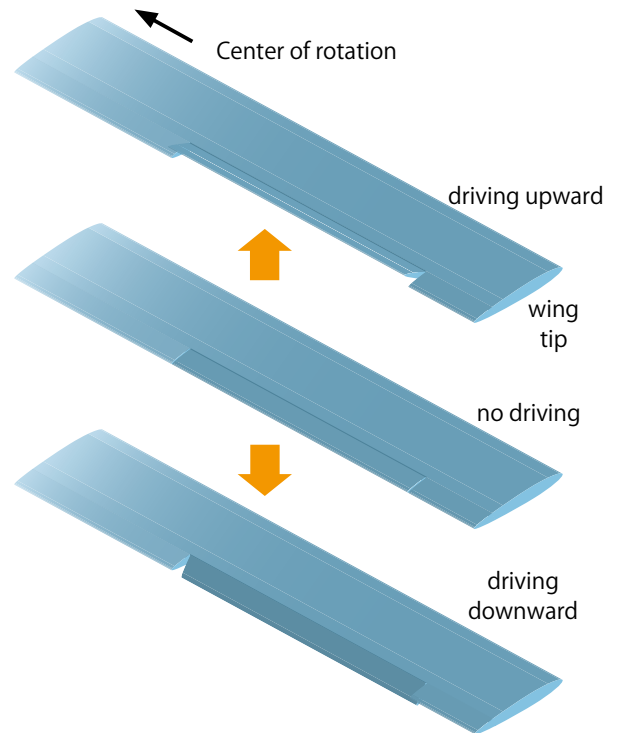


Fig. 5. Example of the flap being driven
Drive the flap and deflect a flap installed at the trailing edge of a blade. The length of the flap is about 10% of the chord length. Install the flap at a position about 75% radius of the rotor.

the blade;

- an optimal flight path (route) search technology to calculate optimal low-noise flight paths for minimal noise during approaches to helipads (heliports);
- a navigation technology for Instrument Flight Rules (IFR) using GPS to safely fly helicopters between two points.

References:

"Welcome to the Helicopter World," Tomoari Nagashima,



Unmanned aircraft to promptly collect information on disaster-stricken areas

— Research and development of the unmanned aircraft system for disasters monitoring

Unmanned and Innovative Aircraft Team

A UAV system to promptly obtain information on disaster-stricken areas

To quickly collect information with a flying camera (See Special Feature No. 9 of this report), our team is studying a quick-response, disaster-monitoring system made up of a new generation of “small electrically unmanned aerial vehicles (UAVs).” These UAVs have quick-start capabilities, fly at high speeds, are highly portable, and are easily maintained. If a UAV crashes or collides with another aircraft, the damage to the aircraft will be less severe if the UAV is small and lightweight. To avoid interference with manned rescue helicopters, the UAV must fly at a low altitude below the flight paths of the helicopters when the helicopters rush to the disaster-stricken area. There are both pros and cons to flying at low altitudes. A UAV can collect image information at higher resolutions with less interference from clouds in the atmosphere at a low altitude, but the scope of the image field is also narrower. To gather wide-area information in a short time with the UAV system, the operators must deploy two or more UAVs at the same time from plural takeoff points. To reduce the number of operators, the UAVs fly automatically from takeoff to recovery.



Fig. 1 Flight route along a valley road.

Technical problems likely to arise in operation scenarios

In the event of fallen rocks or collapses of terrain, roads will be closed to ambulances, fire engines, and other rescue vehicles on the ground. To collect information on important rescue roads as quickly as possible, the pre-programmed flight routes for UAVs are set above these roads. When UAVs are mobilized after a disaster strikes, they automatically take off from narrow places (takeoff and recovery stations) such as the roofs of buildings or athletic fields, fly automatically along their flight routes, collect the surveillance information, and return to their takeoff points as quickly as possible.

The flight routes are predetermined to avoid collisions against mountains or buildings (Figure 1). Yet there is still a chance that the disaster-monitoring missions of the UAVs will be hindered by unexpected obstacles, such as rescue helicopters forced to take emergency landings or newly built towers which are yet to be mapped. When there are obstacles of this sort, the UAVs must automatically avoid them to prevent collision and continue their missions. And when a UAV needs to return to a recovery point immediately because of a technical problem, a new request, or a sudden change in an area to be monitored, the revised mission instructions and flight route must be set automatically.

The low-altitude flight of a small aircraft is susceptible to topographic wind. This makes it necessary not only to avoid collisions, but also to stabilize the airframe attitude in order to preserve the quality of the recorded images.

As mentioned above, our team is clarifying technical problems based on assumed operation scenarios and studying how to solve the problems.

Technical problems likely to arise in operation scenarios

Researchers in the UAV System Engineering Section
(From left) Midori Maki, Kazutoshi Ishikawa, Nobuhiko Kaneko,
and Shigeichi Takeda

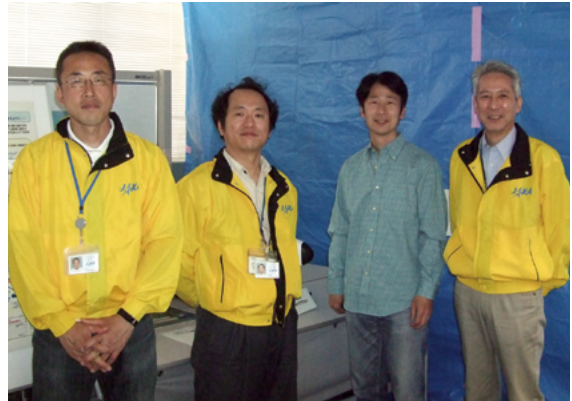


Fig. 2 Test model airplane to evaluate automatic flight techniques (left). Test model airplane to evaluate short-distance takeoff/recovery techniques (right).



Fig. 3 Flight test to evaluate a low-speed, high-descent-angle approach.

Critical technical problems of this UAV system must be checked to confirm the viability of the initial designs before moving onto the more detailed design of the final system. Technical evaluations of the problems will have to be carried out not only with computer simulations and ground tests in test facilities, but also in actual flight tests with experimental flight models (Figure 2). Here we briefly present the results of demonstration flights performed last December and this February at the Makurazaki Airport in Kagoshima Prefecture.

We fabricated an airframe that can stably fly at low speeds for takeoff and recovery in a narrow place. We verified that the aircraft can fly stably even if it descends at a steep angle and at low speed (Figure 3).

To verify obstacle avoidance-technologies realizable with only limited ability sensors and computers small enough to load on the UAVs, we carried out test flights with a sounding balloon as a dummy obstacle. The UAV successfully detected the dummy obstacle with a small-laser-range measurement unit and a set of guidance and



Fig. 4 Flight test to evaluate the obstacle-avoidance technique (image taken from the onboard camera)

control algorithms for obstacle avoidance, then flew back along its flight route to the next setting point (Figure 4).

We want to solve technical problems encountered in anticipated operations. By doing so, we can ensure that UAV will serve actively and fruitfully at disaster sites.

(Kazutoshi Ishikawa)

Research and development for a high-precision navigation system

Operation and Safety Technology Team

Safe and efficient flight operations by satellite navigation

Navigation technology is a technology to keep track of the position and speed of an aircraft. To avoid collisions with other aircraft and make safe and accurate flights to destinations, an aircraft must have exact real-time information on where and how it is flying. Up to now, aircraft navigation systems have generally determined positions in airspace using radio waves transmitted from ground stations. Satellite navigation via radio waves from the Global Positioning System (GPS), a technology familiar to everyone in car navigation systems, has come into service more recently.

In choosing a flight route to a destination, a radio navigation system must base the choice on the positions of the ground stations. Satellite navigation systems are free from this restriction, and thus can choose more efficient flight routes for an aircraft. This improvement can shorten flight times, save fuel, reduce environmental loads, and improve efficiency in allocating airspace. Satellite navigation is therefore expected to be of great help in coping with future increases in air traffic demand.

Augmentation system for satellite navigation

The current GPS was never intended for aircraft navigation. As such, it lacks sufficient reliability for this purpose in its present form. When a GPS satellite accidentally transmits erroneous signal, GPS devices can easily output positioning information several hundred kilometers out of position. When a driver notices a difference between the information displayed by his/her on-board navigation system and the actual road before his/her eyes, he/she quickly knows there is a problem and can even stop the car if he/she senses danger. But a pilot flying in the clouds has no visual cues to alert him/her to any discrepancies between the actual flight route and the route indicated by the satellite navigation system. If the aircraft continues flying, it may collide with another aircraft or a mountain.

SBAS (Satellite-Based Augmentation System) and GBAS (Ground-Based Augmentation System) are systems which enhance the accuracy and reliability of satellite navigation. SBAS, the former, provides extensive augmentation information to improve the accuracy and reliability of satellite navigation via geostationary satellites. GBAS, meanwhile, provides more accurate augmentation information by limiting the scope of information provided to areas surrounding airports. The combined use of these systems with GPS will enable efficient flight operations using satellite navigation.

Enhancing the accuracy and reliability by the GPS/INS integrated navigation system

JAXA conducts research and development to further enhance the reliability of satellite navigation.

Because GPS signals are weak, radio shielding due to changes in aircraft attitude or radio interference from other radio sources may disable GPS when SBAS and GBAS function properly.

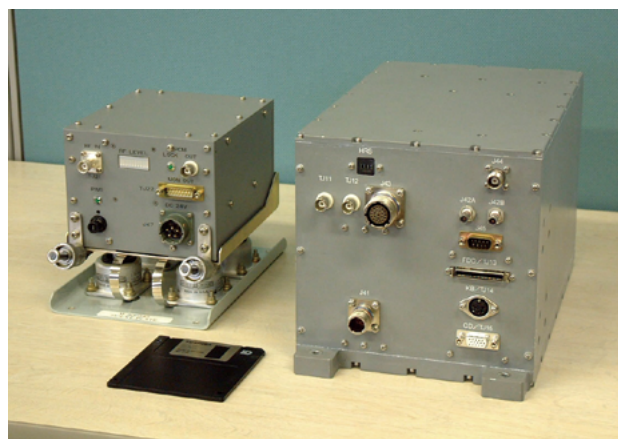


Fig. 1. GPS-aided inertial navigation avionics "GAIA"

A GPS/INS integrated navigation system developed for the High-Speed Flight Demonstration (HSFD) project. The main unit (on the right in the photo) has a mass of about 10 kg.

Navigation Technology Section
(From left) Yoshimitsu Suganuma, Toshiaki Tsujii, Takeshi Fujiwara,
Hiroshi Tomita



Fig. 2. Vehicle for High-Speed Flight Demonstration (HSFD) Phase I

Unmanned experimental vehicle to demonstrate approach and landing systems and accumulate autonomous flight technology for the development of a Japanese-version space shuttle. The experimental vehicle has completed three successful flight tests on Christmas Island of the Republic of Kiribati.

To compensate for the weakness of the GPS signal, JAXA has developed a GPS/INS integrated navigation system by combining GPS with the Inertial Navigation System (INS). The INS conducts inertial navigation with accelerometers and gyros for measuring the angular velocity. The system is never affected by radio disturbance, as it requires no external radio signals. Yet problematically, navigation errors can gradually corrupt the INS. The combination of INS and GPS will enable continuous navigation with high accuracy. When GPS is available, the combined system estimates INS errors and compensates for the errors with GPS positioning information. When a temporary GPS outage occurs, the system automatically switches to inertial navigation by INS. A prototype of the integrated navigation system has also been used for automatic flights of an experimental unmanned aircraft (Figures 1 and 2).

Aiming at a safe, congestion-free sky

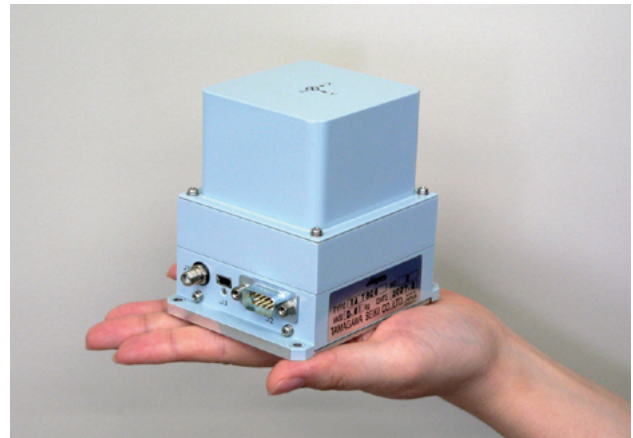


Fig. 3. Micro GPS/INS integrated navigation system "Micro-GAIA"

Navigation system with a small GPS receiver for portable electronic devices combined with several millimeter square MEMS gyros and MEMS accelerometers manufactured on tiny square chips. The system has a mass of about 600 g.

Demand for air traffic is predicted to increase from anywhere between 1.5 to 3 times the current level over the next 20 years. High-precision navigation technology will be indispensable to achieve safer and more efficient operations in the congested airspace of the future.

To meet diverse air traffic demand, it will also be important to apply a high-precision navigation system to small aircrafts as well as large ones. Towards this end, JAXA has been attempting to develop small, lightweight, low-cost Micro-GAIA using MEMS (Micro Electro Mechanical Systems) (Figure 3). Through research and development of these high-precision navigation systems, JAXA hopes to realize a sky where aircraft of many types can fly safely and efficiently together.

(Takeshi Fujiwara)



Interview

People who fly dreams
Vol.12

I want to develop an aircraft capable of smoothly crossing the border between sky and space.

Is outer space the next target for the supersonic aircraft?

Supersonic Transport Team
Masahisa Honda

✈ Though formerly employed by a manufacturing company, Masahisa Honda found himself working for JAXA. People with many different backgrounds get together at JAXA to conduct research. According to Honda, research on an aircraft is far more than just deskwork. The ultimate question is whether the aircraft will actually fly.

Demonstration in a flight experiment

✈ What does the Supersonic Transport Team research?

Honda Our team researches technology necessary to realize the flight of a supersonic transport for the first time in years. Our main theme, among others, is to half the sonic boom (a loud explosive noise caused by a tremendous shock wave). This is a challenge peculiar to supersonic transports. We research various airframe shapes (concept) to achieve this goal.

We are also working on several other technical challenges. Foremost among these are how to reduce the noise coming from the engine, how to make the airframe lighter, and how to fly the supersonic transport with less

fuel. Lastly, we research hypersonic transports that will be capable of flying at much higher speeds than today's SSTs. Our target for the new SST is Mach 5 or more.

✈ Could tell us about your own role on the team?

Honda Over the last fiscal year, I started designing the airframe for a silent supersonic transport. When complete, the aircraft will fly test flights to demonstrate a technology which sets out to reduce the sonic boom by half. I serve as a contact man for the internal and external people involved in the design. You can think of me as kind of a facilitator to smooth the flow of research and development.

✈ How does JAXA's supersonic transport technology rank in the world?

Honda I think JAXA's computer-aided sonic-boom-reduction technology is unrivalled. Sonic boom reduction is based on a computer-aided airflow-simulation technology called Computational Fluid Dynamics (CFD). CFD has been our forte since the days of NAL (National Aerospace Laboratory, the predecessor of JAXA).

Even if we present papers which prove the "mathematical shape of a quiet supersonic transport," people won't be convinced until we actually fly the supersonic transport. Calculations are for solving equations. We create an equation by building up a hypothesis. Real-world phenomena are extremely complicated. We can formulate equations to represent real-world phenomena by simplifying and disregarding various real-world effects. Yet many phenomena, such as the wind streams that make the air flow in whirls, cannot be easily expressed



A rendering of the Silent Supersonic Technology Demonstrator (S³TD), a system now being designed.

in equations. We are still incapable of perfectly expressing reality in equations. To prove that the expected results have been obtained, we have to actually fly the supersonic transport. People won't recognize how great the technology is until we prove it. We are preparing to prove the technology now.

✈ What was the happiest event in your career?

Honda It was our successful flight experiment with the small supersonic technology demonstrator (commonly called the rocket demonstrator) in 2005.

We developed a demonstrator without an engine and launched it with a rocket to demonstrate a design technology to reduce drag. I was on the crew dispatched to search for the demonstrator and recover it. As my colleagues shouted out in joy at the successful demonstration flight, I was searching for the demonstrator in a helicopter.

Having seen the landing point for the demonstrator in the flight data and in images sent from the ground, the site was fairly easy to locate. But finding the jettisoned rocket was another challenge altogether. Not having tracked the



Masahisa Honda
System Concept Section
Majored in aeronautic engineering as an undergraduate.



An ordinary commuting scene. In front of the main gate of the branch office of the airfield of JAXA's Chofu Aerospace Center.

jettisoned rocket via radio waves or images, we had to try to calculate the point of landing with the data alone. On the day of the experiment and the day after, I searched in vain for the wreckage of the demonstrator by helicopter. It seemed as if we would never find it. But then, about 10 days after the experiment, I drove to the landing point to do a cleanup and discovered the rocket. The joy of the achievement rushed through my veins. Why hadn't I been able to find it? Believe it or not, the rocket was stuck in the ground and completely buried. Having crashed against at a very high speed, the rocket had formed a big crater.

From a private company to JAXA

✈️ What do you do when you're not working?

Honda I used to play tennis as a student, but I gave it up after graduating. Then, about five or six years ago, I took it up again. I take lessons once a week and play at our tennis club at the workplace. I often watch overseas dramas on TV. My favorite is "Dark Angel." It's a near-future drama about genetically-engineered people with special military abilities. Too busy to watch it in real time, I record it on a disk and watch several episodes at a time later.

✈️ What led you to do the present job?

Honda I remember watching Apollo's lunar landing on TV as a child. I wanted to go to the moon, too. In the same broadcast, I saw a simultaneous

interpreter and was very impressed at his prowess in language. Fascinated by space, I began reading books on UFOs, and also the Blue Backs, a series of science books on space and physics. When I had to decide between faculties at the university, science or engineering, I chose the aeronautical department of the faculty of engineering. Because I had a more concrete image of the faculty of engineering. People there studied technology to develop and produce things. In those days, Concorde was just put into commission. The word supersonic inspired big dreams in me.

✈️ I hear you got into a company straight out of college.

Honda I designed rockets and reentry capsules^(*) for a manufacturer. In 2003, my employers had me take part in a flight experiment project for a rocket demonstrator the NAL (renamed JAXA in 2005) was then promoting. Through the experience, I came to know JAXA as an agency full of engineers enthusiastically researching supersonic transports. My student-day dream sprang to mind and awoke an ambition to help develop the supersonic transport. I was an employee on-loan at the beginning, but now I'm a regular staff member of JAXA. Thinking back,

I was delighted to be engaged in a space-related job, a job I had often longed for. But now I have returned to aviation, the starting point of my dream (laughs).

From a private company to JAXA

✈️ What do you want to achieve in JAXA?

Honda First, I want to make the planned flight experiment a success. With help from a wide range of JAXA's technologies in aviation and space, I want to research an aircraft that will be capable of flying not just around Earth, but also to Mars, Venus, and other planets.

✈️ In closing, do you have any encouraging words for those who aim to become researchers?

Honda You can never realize something unless you dream about it first. But a dream or idea alone isn't enough, either. You will never realize your idea unless you work at it. If you have something you want to accomplish, you will succeed most quickly if you devote all of your time to it.



The flight experiment in 2005 was conducted in Australia.

1. Rocket landing point. The rocket crashed against the ground at a speed of Mach 1.
2. Liftoff! Visit the Chofu Aerospace Center to see this test model in person.
3. A "Beware of kangaroos" sign is posted on the spacious grounds of the test site.