Special feature

Commencement of DREAMS project

For maintaining air safety

Against a backdrop of increased demand for air transportation, air traffic management systems are changing greatly. The necessary technology development is being tackled globally so that satellite navigation and dramatically expanded information communication technology can be utilized to update the system with a new one that can anticipate future air traffic. In 2012, JAXA is focused on beginning the DREAMS (Distributed and Revolutionarily Efficient Air-traffic Management System) project to develop five key technologies which are necessary for realizing a new air traffic management system and which are to be contributed as international standards. We were given a summary of the project by the project manager, Masatoshi Harigae.

Flexibly adapting flight to the ever-changing conditions

— How is the air traffic management system about to change?

Harigae　From concerns that the current air traffic management system may not be able to respond to future air traffic demands, ICAO (International Civil Aviation Organization) proposed the "Global ATM (Air Traffic Management) Operational Concept" in 2003 with the aim of transforming the air traffic management system with new technologies. Simply put: "If the number of flights increases with the current system, the number of accidents may increase or more delays may occur. We actually don't know the number of aircraft that will be able to fly. To resolve this problem, we should flexibly control traffic according to the situation by sharing information and using it efficiently to dynamically change airspace or flight routes or change aircraft intervals." In order to respond to this, the program NextGen has begun in the United States, and SESAR in Europe. In Japan, the Civil Aviation Bureau has assembled its long-term vision CARATS (Collaborative Actions for Renovation of Air Traffic Systems) and prepared 46 measures in order to realize ICAO's proposal. From those, JAXA selected the ones that can be tackled with technologies that are its specialties, and established five research and development areas to be addressed by DREAMS. With application of the new air traffic management system set to begin in 2025, we are coordinating with various countries and tackling development of a new method for better managing air traffic.

Masatoshi Harigae
DREAMS project manager

— What technologies are specialties of JAXA?

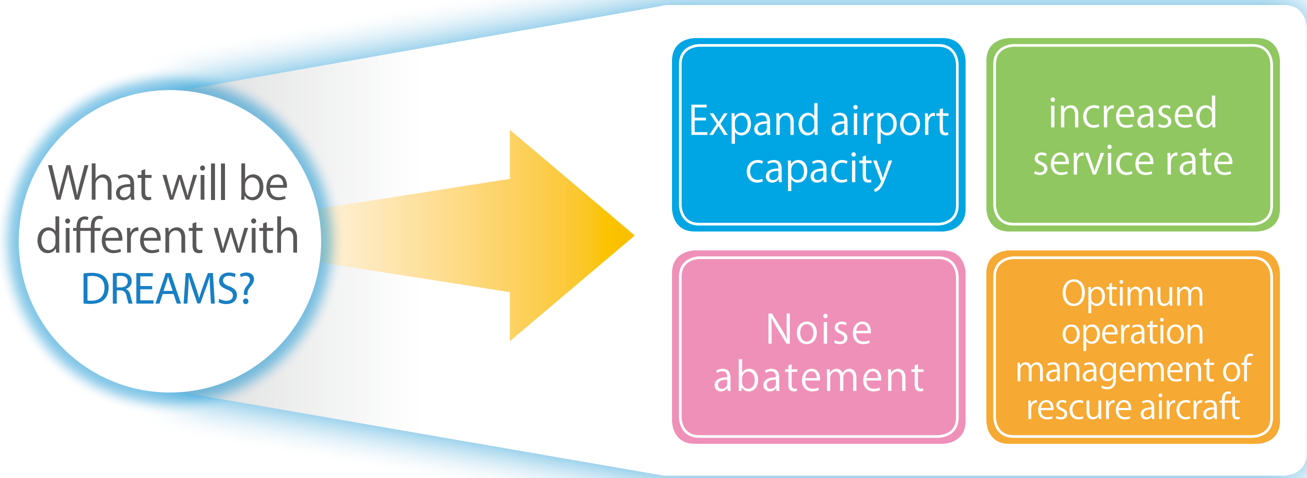
Harigae　Aircraft technologies (guidance and navigation/control/aircraft dynamics) in addition to helicopter application technologies.

— What improvements can be expected with DREAMS?

Harigae　"Increased airport capacity (more aircraft than now will be able to take off and land)", "improved service rates", "noise abatement" and "optimal operation management of rescue aircraft"

— Specifically, what are the five technologies?

Harigae　The objective of the first, weather information technology, is to reduce the effects of weather on flights. During takeoff and landing, there is an interval of at least 2 minutes with the preceding aircraft in order to ensure safety at airports. Why 2 minutes, you may ask. This is to wait for the wake turbulence left by the aircraft that has taken off to dissipate. These are vortices generated by the wings, and they are dangerous should a subsequent aircraft enter them. For example, when there is no wind, vortices remain in place until they dissipate, but when there is wind, it is not always necessary to wait 2 minutes. With DREAMS, we are developing technology to predict the behavior of wake turbulence, which varies with wind movement, then calculate the optimum interval for the subsequent aircraft, which is utilized for control. By changing the interval accordingly, more aircraft takeoffs and landings than now may be possible. In addition, the abrupt airflow changes(*)



that can occur on the runway because of low-level wind disturbances may be dangerous when they cause aircraft turbulence. Therefore, using observation data from LIDAR (optical radar) and a high-resolution radar set up at the airport, we are developing a system to predict incidences of aircraft operation failures that low-level wind disturbances will cause, so that the pilot can be warned of the danger in advance. This aids in determining the optimum approach timing, which is connected to increased service rates.

(*) Sudden wind changes if there are buildings or topographical formations around the airport

— What is the second one, noise abatement technology?

Harigae If the traffic volume increased 1.5 times, the number of people who would feel that it is noisy on the ground would increase by that much. So that this can be prevented, the objective of noise abatement technology is to minimize the effects of noise exposure. Sound also flows together with the wind, and the way in which it is transmitted changes depending on the temperature. By changing the aircraft approach route depending on the weather conditions, we can prevent the effects of noise exposure from surpassing current levels. With DREAMS, we are continuing development of technology that can predict noise exposure according to the weather conditions during flight and that can derive a route that can minimize those effects.

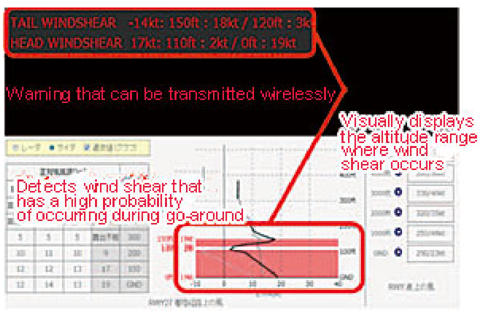
Contributing JAXA's own technologies to realize a global ATM

Harigae The third one, high-accuracy satellite navigation technology, is technology for increasing the reliability of satellite navigation during approach and landing. With DREAMS, we are aiming at developing a navigation system that combines INS (inertial navigation system) with GPS. High-accuracy position information is more necessary during approach and landing than during flight at a high altitude. We are developing essential technology where INS provides a complement through backup data so that approach and landing can proceed even if signals from satellites can no longer used.

Five key technologies of the DREAMS project

1 Weather information technology

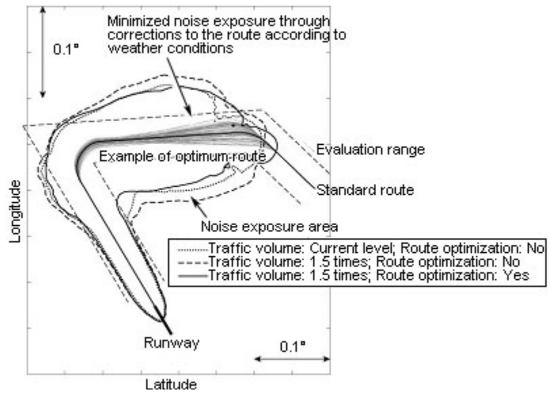
⇒ Predicts aircraft movements with regard to wind and determines takeoff/landing timing



Sample information, displayed in the operation controller's screen, warning of the danger of low-level wind disturbances

2 Noise abatement technology

⇒ Optimizes the approach route so that noise is not diffused



If an instrument landing system (ILS) is installed at the airport, landing is possible even if there is poor visibility due to weather. However, runways that allow an instrument approach are limited to begin with, and more than half of Japan's airports can only be entered from one direction. With the ILS method, there is a limitation: the minimum 5 km straight section before landing on a runway cannot be ensured if there are mountains or densely populated areas around the airport, and ILS cannot be set up in those directions. Depending on the wind direction, a pilot must approach and land by sight from a direction where ILS is not set up. As a result, poor visibility is a factor accounting for 1/4 of flight cancellations. To resolve this, the fourth one, trajectory control technology, converts the conventional ILS, which is installed on the ground, to GBAS (ground-based augmentation system), which uses GPS, allowing the approach route to be flexibly established and allowing approach in bad weather. With DREAMS, we are conducting research and development of technology that transforms the straight section into a 2 km curved approach route and allows the route to be followed on autopilot. By combining navigation and control technologies, service rates can be improved.

— What about the last one, disaster-relief/small aircraft operation technology?

Harigae　With the same basic idea as the other four, information has become important. This is technology that allows necessary information to be shared between rescue aircraft and emergency-response headquarters during a disaster so that rescue missions can be accomplished safely and efficiently. DREAMS has led to the proposal of the Disaster Relief Aircraft Information Sharing Network (D-NET). We are continuing research on technology that consolidates management of information (for example, which rescue aircraft are currently where, where are people who are receiving help and which hospitals are open), reduces wasted time (waiting for task assignments, waiting for takeoff/landing, waiting for refueling, etc.) and aircraft near-misses as well as enables optimum operation management.

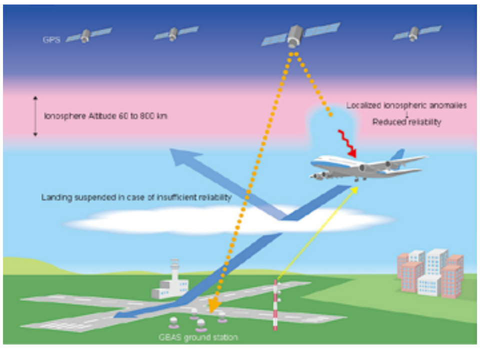
These five technologies may seem disconnected and unrelated, but the basic concept of all these technologies is that, by gathering necessary information and better chaging aircraft movements according to it, many aircraft can be flown safely and efficiently. The information includes “turbulence”, “weather”, “position”, “sound” and “rescue aircraft capabilities”, and the necessary information differs depending on the objective; however, the underlying idea is the same for all of them. JAXA will try to realize the policy created based on ICAO's concept of “flying not in a fixed way, but flying flexibly according to the situation”.

— What form will these technologies finally take?

Harigae　What we are basically making with all of them is software. The hardware necessary to run this includes on-board receivers/communication equipment for satellite navigation as well as satellite

3 High-accuracy satellite navigation technology

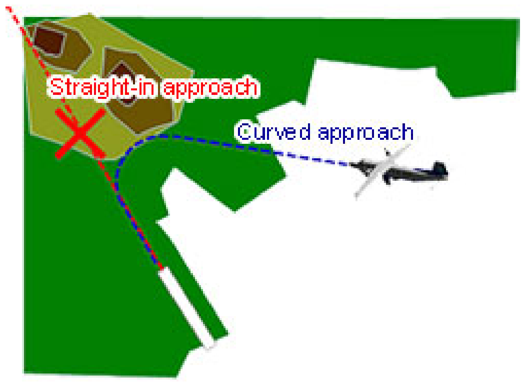
⇒ Reliably obtains position information for a safe approach and landing



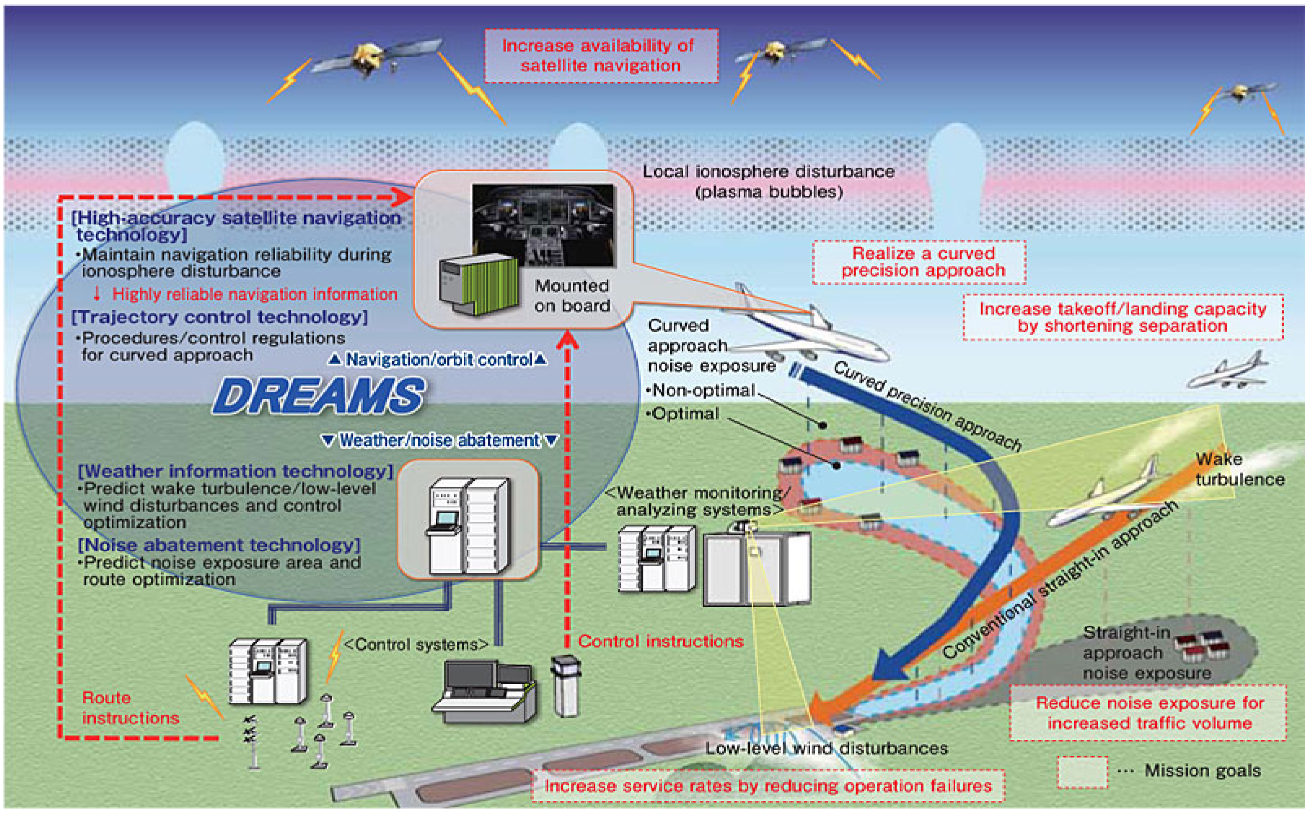
If there are local ionosphere disturbances, the satellite signal may be interrupted. This covers such an emergency case.

4 Trajectory control technology

⇒ Flexibly generates approach routes



If mountains are nearby, a curved approach makes landing possible, even on a runway where a straight approach is not possible.



Basic concept of DREAMS (excluding disaster-relief/small aircraft operation technology)

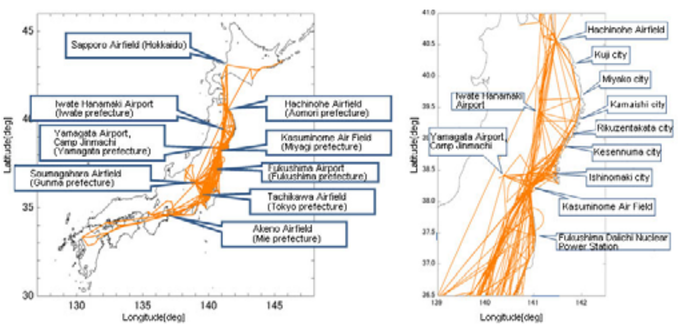
navigation equipment, weather monitoring systems and control systems on the ground. It would become fully functional once the necessary equipment is installed on the aircraft and on the ground. At this time, all hardware is not in place, but I'm assuming that their development is continuing in preparation for 2025.

— What are the plans for future?

Harigae This year we are in the system development phase, and next year we will conduct technology demonstration and evaluation. Then, the technologies will be proposed as international standards from 2014. We are participating as an adviser to the committee that determines international regulations, so some proposal activities have already begun. Since disaster-related technologies are put to practical use domestically, we have started trial operations with disaster-related agencies.

5 Disaster-relief/small aircraft operation technology

⇒ Enables optimum operation management during a disaster through information sharing



Flight trajectories of rescue aircraft for the Tohoku earthquake (March 12)

	Accomplished missions (times/machine)	Wasted time (hr/machine)			Near misses (occurrences/machine)
		Waiting for task assignments	Air alert (waiting for takeoff /landing, etc.)	Ground alert (waiting for refueling, etc.)	
Without D-NET	3.0	5.29	0.24	1.25	6.8
With D-NET	4.4	3.42	0.09	0.19	3.0
Effect of implementation	+46%	-35%	-62%	-85%	-57%
		Total -45%			

46% increase in rescue rate with D-NET (simulation)

Research Report

From the research field

Developing a fixed-wing small unmanned aerial system for radiation monitoring

Unmanned Aircraft Systems Applications Technology Team

In June 2012, the Japan Atomic Energy Agency (JAEA) and JAXA began collaborative research on development of a radiation monitoring system using sUAS (small Unmanned Aerial System). The system will be developed integrating JAXA's sUAS technologies and JAEA's radiation spectrometer technologies to be applied for the autonomous radiation monitoring in the area around F1 (Fukushima Daiichi) Nuclear Power Station. The collaborative research is scheduled until March 2015. We interviewed section leader Koji Muraoka, who leads sUAS development at JAXA, about the program.

A device to accomplish the task safely and reliably

— Helicopter UAVs have already been applied to part of radiation monitoring missions. What are the differences in using fixed-wing UAVs, and what are the advantages in using JAXA's sUAS technology?

Muraoka First of all, using UAVs for radiation monitoring makes operation costs lower than with manned aircraft. Among UAVs, helicopters and fixed-wings each have their own advantages. Helicopter UAVs can hover and fly slowly at lower altitudes, making close and detailed observation of radiation possible. However, since current flight missions are performed by remote control pilots within their visual ranges, there are limitations on the flight range and mission hours. The range is restricted to within about 1 km in diameter, and the mission duration is limited to about 90 minutes. In contrast, JAXA's fixed-wing sUAS can fly over a wider area using its auto-flight capabilities over a certain amount of time. So, quicker observation of a wider area is possible using the fixed-wing sUAS. In previous research, we have accomplished flight demonstration of 20-hour endurance with auto-flight (program flight) systems. In the course of the present research program, we will upgrade onboard system components such as a long range communication system, add an auto-flight mode for the monitoring mission maneuvers, and integrate a radiation spectrometer as a payload.

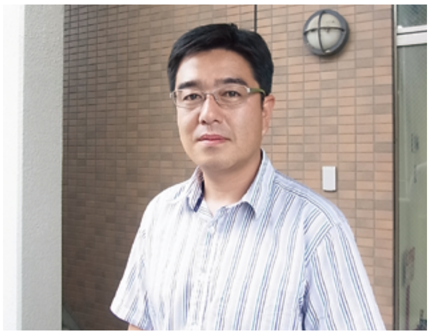
— Why is a system component upgrade required?

Muraoka To enhance safety and reliability of the sUAS. The sUAS is going to fly above the F1 restriction zone beyond the isolated flight test area, and we need to further enhance sUAS's safety and reliability. Our previous sUAS has demonstrated high levels of endurance in the flight test, but the

Existing JAXA fixed-wing sUAS
(The sUAS for radiation monitoring will be developed based on this vehicle.)

Specifications of the existing UAS

Dimensions	Length: 2.6 m; Span: 4.2 m
Max. take-off weight (payload weight)	50 kg (3 to 10 kg)
Propulsion	Single engine (reciprocated)
Flight time	Maximum 20 hrs
Airspeed	25 to 30 m/sec (90 to 108 km/h)
Flight altitude	Less than 250 m
Flight control	Take off and land: Remote manual control Cruise: Auto-flight (programmed flight)



sUAS Section
Section Leader
Koji Muraoka

test area was isolated from residential areas. Flight was conducted within our visual range, and circling above the ground station for 20 hours was performed. This was simply because we did not aim to demonstrate long-range capabilities, but just aimed to demonstrate system endurance technologies and to maintain test safety easily. In the present research, long-range communication will be added so that we can monitor the system status and send a flight abort (return-to-base) command in case of failure or sudden weather deterioration. Also, we will perform hazard analysis in much more detail and review the architecture of the system. We might replace a system component and might add redundancy to the system.

— What is the auto-flight mode for more accurate radiation monitoring?

Muraoka It is a terrain-following flight mode that controls an airplane to fly at a constant distance from the ground. JAEA's spectrometer can estimate radiation levels at 1 meter above the ground using the spectrometer data and position data obtained at the UAS's flight altitude. The current auto-flight mode only has a function to maintain pressure altitude or GPS altitude, which maintains altitude above sea level. Flying at a constant altitude above the ground will help make the estimation more accurate.

Radiation monitoring using sUAS (concept image)

— Can you explain the schedule of the development?

Muraoka We have already started system review and preliminary design of the upgraded sUAS. The prototype will be constructed by the end of this year, and flight testing will be started from early next year. The first stage of the test will be performed within the test area to evaluate basic system functions and to confirm system reliability. Then, we will conduct a series of field tests and demonstrations in the restriction zone from the middle of FY2013. Our eventual goal is to release the system so that it will be used for regular radiation monitoring around the F1 restriction zone.

Mission scenario

- Mission area: Within Fukushima restriction zone around the F1 power plant
- Take off and land by remote manual control from a base station located close to the restriction zone
- Automatic flight to the mission area and start radiation monitoring
- Downlink the radiation data to the ground station
- After completion of the monitoring, automatic flight return to the base station
- Data download and detailed analysis of radiation distribution around the area

The day when unmanned aircraft fly through the sky on a daily basis

— Finally, what is your future aspiration?

Muraoka Currently, UAV technologies are growing fast, but the application area is still limited to crop dusting, university research or science observations, etc., in restricted areas. I believe UAV technologies have a potential to become very common infrastructure to help our society. To make the UAV technologies widely acceptable to our society, the vehicle must fly more safely, and we will need to establish processes of vehicle design, manufacturing, operation, maintenance, etc., as with manned aircraft. This research is being tackled with that in mind.

Research Report

From the research field

Research and Development of Vortex Generators for Higher-Performance, Safer Passenger Aircraft

Environmentally Compatible Airframe Technology Team, Aviation Program Group
Wind Tunnel Technology Center, Aerospace Research and Development Directorate

What is a Vortex Generator?

Have you ever seen small vanes aligned near the wing leading edge of a jet passenger aircraft? These are called Vortex Generators (VGs) and are one of the aerodynamic devices for increasing the performance and safety of aircraft. Many passenger aircraft have the VGs on their wings to increase the cruise speed and to allow more flight maneuvers without sacrificing its performance and safety.

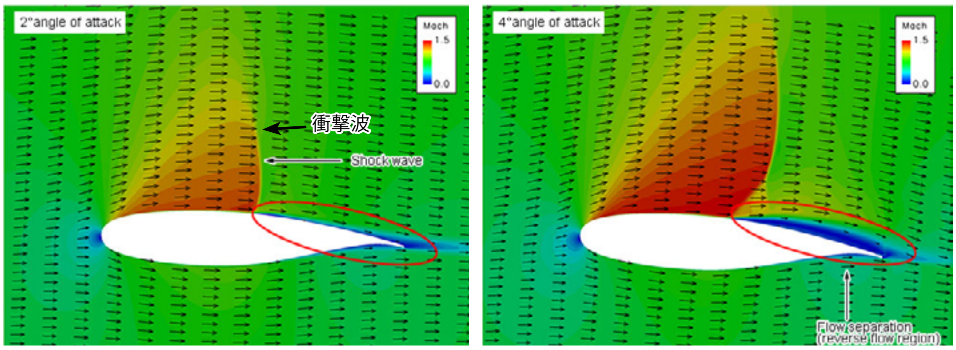
Although VGs have been used for aircraft for a long time, their basic physics has not still been fully understood. Higher-performance VGs may be created if their effects are physically clarified. Therefore, JAXA has been studying VGs since last year to understand the physics of the VG effects, and to acquire guidelines on optimal design and placement of VGs on aircraft wings. To efficiently meet the goals, both wind tunnel tests and Computational Fluid Dynamics (CFD) simulations have been conducted. In June, the first round of wind tunnel tests was conducted with a two-dimensional wing model to evaluate the effect of VGs on the performance of the wing, and to validate our CFD simulation techniques.

Vortex generators on Boeing 777 main wing
Small VGs are shining due to the sunlight. The one at the far left is a navigation light.

Device for Suppressing Flow Separation

The wing is the most important element of an aircraft and it greatly influences the performance of the aircraft. For a transonic aircraft, the shape of its wing is carefully designed so that shock waves appeared on the upper surface of the wing in cruise is weakened as much as possible and that the lift is generated efficiently at the same time. However, a reverse flow region, the so-called flow separation, can appear on the upper surface of the wing when the aircraft attitude or speed is suddenly changed in emergency situations, for example, to avoid a collision with another aircraft. In these cases, the shock waves on the wing can be stronger if the angle between the passenger aircraft and the air flow (angle of attack) becomes larger or the flow speed is increased. This can result in large flow separation, which significantly decreases the lift generated by the wing, can create strong vibration, the so-called buffeting, and can stall the passenger aircraft due to pitch-up motion. Pilots cannot control the aircraft safely under such conditions, which determine the flight envelope of speed and attitude of the aircraft.

To avoid flow separation, it is known that air flow should have a little disturbance. The VGs are used to create disturbance as small vortices in boundary layers (thin layers of low-speed air) on the wing. The low-speed air is effectively mixed with high-speed air outside of the boundary layers, and this suppresses the flow separation. With the VGs, passenger aircraft can be maneuvered with larger flight envelopes.



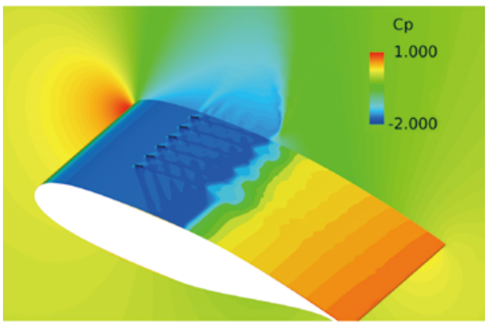
Flow separation induced by shock wave (no VGs, Mach number distribution through CFD analysis)
Air flows faster on the upper surface of the wing (this means lower pressure) and slower on the lower surface (higher pressure). A force is generated from the larger pressure to the smaller, which corresponds to the lift generated by the wing. The cruise speed of typical jet passenger aircraft is around Mach 0.8. However, there is usually a region on the upper surface of the wing where the air speed locally exceeds Mach 1, followed by a shock wave, where air speed is abruptly decreased and pressure is increased. The larger the angle of attack is, the faster the air flows on the upper surface of the wing. When the local air speed is much larger than Mach 1, the shock wave becomes stronger and the pressure increase is so sudden that a large reverse flow region behind the shock wave is created. The wing can no longer generate enough lift. This kind of flow separation is called shock stall, and usually causes a sudden pitch-up motion and strong vibration called buffeting. The shock stall is one of the important factors to determine the flight envelope of an aircraft.

VG research team members
In front of the wind tunnel where VG tests were conducted

Studying VG Effects with Wind Tunnel Testing and CFD

Our ultimate goal is to maximize the VG effects without increasing total drag of actual passenger aircraft. So our objectives are to clarify the mechanism of the VG effects, and to establish the guidelines on how the shape of the VGs should be determined and how they should be placed on the wing. Two approaches have been used to better achieve these objectives: wind tunnel tests with air flowing around scaled models, and CFD simulations.

The wind tunnel tests are highly reliable because actual air flow is used, while they are limited by variety of VG models and measurement techniques for capturing the VG effects. CFD simulations easily enable to compare many VG models in different locations, and visualize detailed flow phenomena around the VGs. Computational results, however, must be validated with the wind tunnel tests to see if they represent the actual air flow well. The essence of the VG effects can be revealed if both approaches are used effectively. Either of them has advantages and disadvantages, but they complement each other.



Pressure distribution on VG-equipped wing (CFD analysis results)

Acquisition of Competitive Technologies

In the first round of the wind tunnel tests, a simplified wing model was used with and without VGs. Flow phenomena around the VGs and their effects were evaluated by pressure distributions obtained on the wing and flow visualizations using the Schlieren method. Wind tunnel testing techniques required for the VG tests has been constructed, such as a special adhesion method for accurately attaching extremely small VGs to certain places and for allowing VGs to be easily attached and removed while ensuring adequate strength. CFD simulation results were also compared with the wind tunnel test data, and it was turned out that the CFD analyses needed to be slightly adjusted to this kind of simulations. Compared with the wing, vortices generated from the VGs were extremely small, but they dominated the flow field on the upper surface of the wing in high angles of attack. Properly capturing those vortices was essential to evaluate the VG effects.

In the near future, we plan to conduct wind tunnel tests under conditions closer to actual flight and wind tunnel tests with an entire scaled aircraft model to obtain more detailed data. At the same time, our wind tunnel testing techniques and CFD simulation techniques continue to be improved to clarify the physics of the VG effect, and to improve the aircraft performance by VGs.

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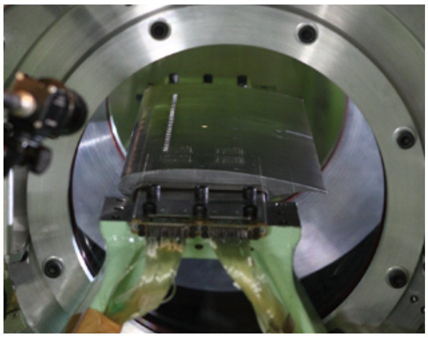
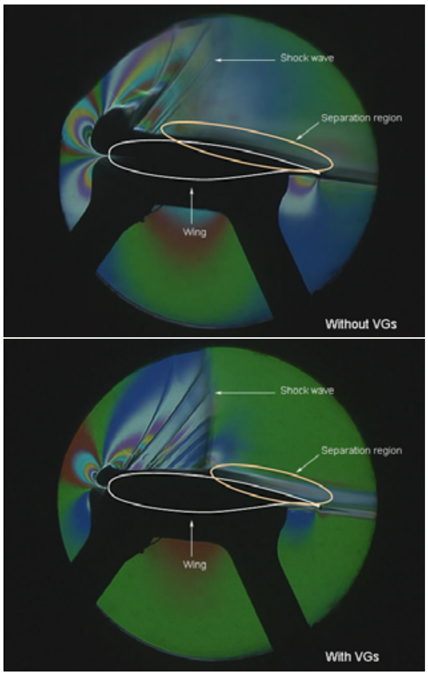
With the current steady progress in the domestic development of passenger aircraft and aircraft for Ministry of Defense, the spirit in the aviation industry is rising up. We have been working on research and development of aeronautical technologies directly related to the development of the current and future aircraft.



VG-equipped wing model set up in wind tunnel



Flow visualization using the Schlieren method
With no VGs, air flow separates near the leading edge of the wing in a high angle of attack. Separation can be suppressed by installing VGs.