Conceiving disaster management from the "sky"

Aircraft required in disasters

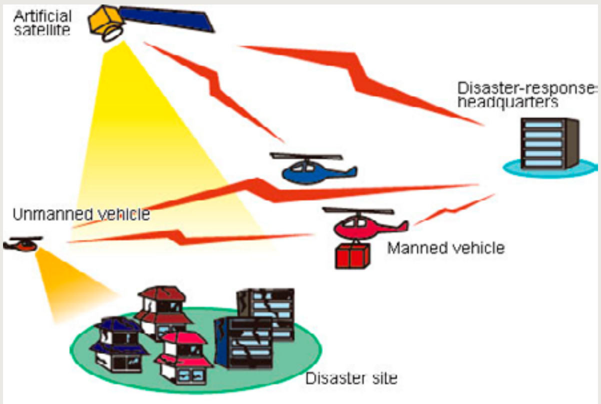
The first step when a disaster occurs is to "assess the situation" of the disaster site. Quickly and accurately understanding the site conditions is linked to determining the appropriate observations to be performed immediately after the disaster occurs. Since ground transportation systems may be paralyzed after a large-scale disaster, information gathering from the "sky" with artificial satellites and aircraft is effective in quickly assessing the situation. Aircraft are also an effective tool for providing later "search and rescue" and "transporting relief supplies" . Helicopters from many organizations such as the fire department, police and Self-Defense Forces were active in many situations during the Tohoku earthquake.

Existing manned aircraft must run at capacity during a large-scale disaster. If unmanned aircraft (including unmanned helicopters) could be used for information gathering tasks, the overall relief effort could be implemented more efficiently by having the limited number of manned vehicles conduct the more delicate information gathering as well as tasks other than information gathering, such as rescue/emergency aid or transportation of personnel/supplies (fig. 1). Unmanned vehicles have the advantage of easily being introduced even by small municipalities since they have lower procurement and operation costs compared with those of manned vehicles. Currently, various universities and research agencies, including JAXA, are tackling research and development aimed at the practical application of unmanned vehicles for disaster relief.

Necessity for a "manned vehicle/unmanned vehicle cooperation system"

Unmanned vehicles are already being used for information gathering at disaster sites that cannot be reached by people, such as near volcano eruptions or nuclear disasters. When nuclear power plants constructed along the coast of Fukushima prefecture suffered catastrophic damage from the tsunami during the Tohoku earthquake, private and American military unmanned vehicles were used to assess the situation.

Unmanned vehicles have already demonstrated their usefulness; however, there are some issues that must be resolved when considering flying them together with manned vehicles, especially in some critical operations



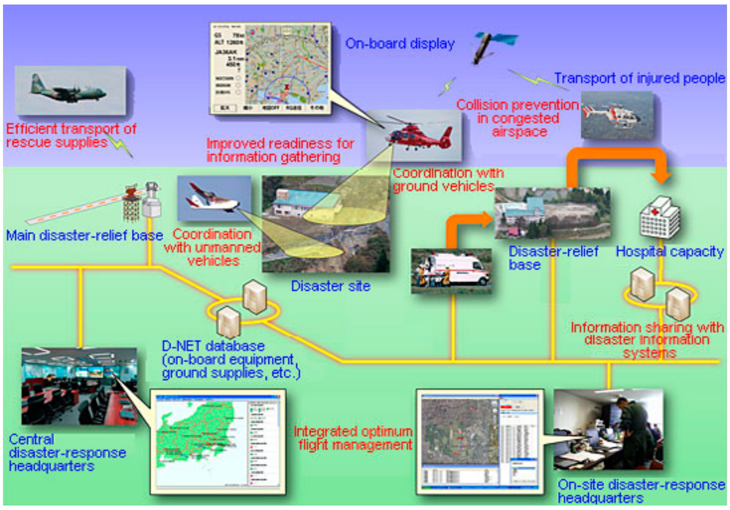
Because of the fear that ground transportation systems will become paralyzed during a large-scale disaster, measures from the "sky" , using artificial satellites and aircraft, are extremely important. As one method of conducting rescue operations more efficiently, a plan is being considered where unmanned vehicles assume the role of information gathering.

Fig.1 : Example of a highly efficient application from the "sky" during a large-scale disaster

such as search and rescue. Since a "minimum safe altitude" is established for manned vehicles and they are prohibited from flying below that altitude without permission, except for take-off and landing, there is no danger of a collision if unmanned vehicles fly below the minimum safe altitude. However, when manned vehicles are conducting search and rescue operations, they are permitted to fly below the minimum safe altitude. Since unmanned vehicles are small and difficult to be seen by pilots of manned vehicles, the danger of a collision results if a manned vehicle drops its altitude to one where an unmanned vehicle is flying. In order for manned and unmanned vehicles to operate in collaboration safely and efficiently, information must be shared between manned and unmanned vehicles. Therefore, we are proposing a "manned vehicle/ unmanned vehicle cooperation system for disaster relief operations" .

Communication issues that must first be resolved

When a disaster occurs, the disaster-response headquarters is set up. Information is transmitted between aircraft and the disaster-response headquarters mainly using "aviation radio" , which is one-on-one voice communication. However, since hundreds of aircraft from all over the country gather at a disaster area after a large-scale disaster occurs, it is difficult to transmit information quickly and accurately to each aircraft by aviation radio. To resolve this issue, we are hoping to introduce a communication system that uses digital data. Within Japan, many data communication systems that can exchange helicopter flight information and disaster-related information are being developed; however, the lack of data compatibility is a factor in preventing progress since each system is being developed independently. As a national agency, JAXA is proposing standardization with the “Disaster Relief Aircraft Information Sharing Network” (D-NET) (fig. 2), which can provide data compatibility between systems created with different standards.



Via D-NET, data can be exchanged between systems created with different standards, allowing information to be communicated reliably and efficiently during disasters.

Fig. 2: Basic concept of the Disaster Relief Aircraft Information Sharing Network (D-NET)

Demonstration testing of the “manned vehicle/unmanned vehicle cooperation

We are focusing on the development of a manned vehicle/unmanned vehicle coordination system using D-NET and its standardization. The following are considered the main functions of this system.

- Dynamically manage the allocated airspace and positions of unmanned vehicles, and show that information to the pilots of manned vehicles.
- Provide a warning to manned vehicles when an unmanned vehicle has deviated from their allocated airspace or when a malfunction is detected on the unmanned vehicle system.
- When an unmanned vehicle discovers a survivor in need of help, that information is sent to a manned vehicle via the disaster-response headquarters and shown in the vehicle’ s display.
- If it is necessary for a manned vehicle to fly into an unmanned vehicle’ s allocated airspace in order to rescue a survivor in need of help, orders are sent to the unmanned vehicle to withdraw from the airspace.

Survivors in need of help were discovered by video cameras mounted on unmanned vehicles, and information was sent to the disaster-response headquarters.

Rescue order was sent from the disaster-response headquarters to manned vehicles, and site information as well as the flight status of the unmanned vehicle were shown in the display.

Unmanned vehicle arrived at the site, on-board emergency medical personnel provided first-aid treatment to victims, and then that data was sent to the hospital where optimal preparations were performed.

Manned vehicles transported victims to the hospital, where full-scale treatment was performed after arrival.

Fig.3 : Demonstration test

With these functions, manned and unmanned vehicles can coordinate safely and efficiently in the search and rescue operation. In December 2012, we conducted a demonstration test to confirm the validity of this system' s functions (fig. 3). The test was conducted assuming a situation where survivors must be searched for over a wide area due to the tsunami damage that would be caused by the Tokai earthquake. After unmanned vehicles discovered the victims, manned vehicles arrived at the site based on that information, then transported the victims to the emergency hospital after first-aid treatment was provided. The unmanned vehicle used was an unmanned commercial helicopter manufactured by Yamaha Motor Co., Ltd., and the manned vehicle used was JAXA' s research helicopter. In addition, as the transport destination for victims, we received cooperation from Shizuoka General Hospital, which is assumed to be the base hospital if the Tokai earthquake occurs. The development and demonstration of technology assuming cooperation between manned and unmanned vehicles in the civil operation is a globally pioneering example.

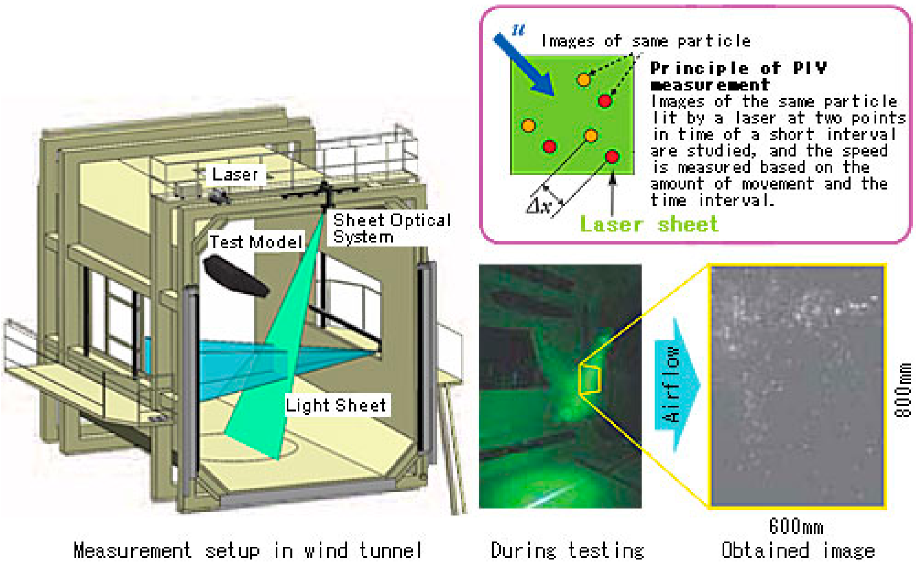
By offering to industrial communities such as "Japan UAV Association" (JUAV) the results obtained from these demonstration tests as information communication standards for disaster-relief unmanned vehicles, we hope to develop as well as propagate a domestic standard for the communication protocol in manned/unmanned vehicle coordination.

Fig.4 : Illustration of firefighting amphibian
(provided by ShinMaywa Industries, Ltd.)

Firefighting aircraft

Earthquakes, thunderbolts, fires, fathers. Until a few decades ago, these four were synonymous with things that are feared. Nowadays, fathers are probably not feared in many homes, but earthquakes, lightning and fires are still scary enough. Fire is particularly problematic since it can also occur as a secondary disaster to earthquakes or lightning. In particular, wildfires that occur even though there is no blaze are often deep in the mountains, impenetrable by fire engines, and tend to be large in scale. Firefighting aircraft are active in some countries around the world to extinguish wildfires. The majority are compact helicopters in Japan, fixed-wing aircraft, requiring a runway, in the United States, and "amphibians" (refer to page 6) in Europe, for example, in France and Italy.

Amphibians are aircraft that can take off from and land on the ground and water. Since it can take water up

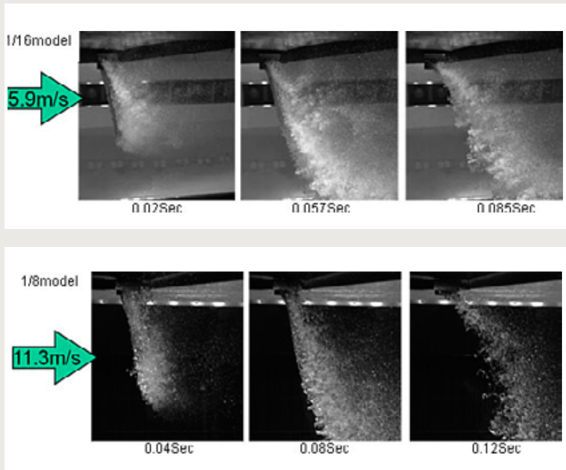


PIV, which is used to measure airflow in wind tunnel tests, is applied to evaluate the dispersal speed of water droplets in a water drop.
Fig. 5: Dropping speed measurement of water droplets using particle image velocimetry (PIV)

into its fuselage by gliding along the water surface, it can efficiently scoop water if a lake is near the fire site. However, there is the problem that water easily disperses due to the fast flight speed during water drops with existing aircraft. There is also the issue of operating safety if the aircraft dives toward the fire, drops the water, then quickly ascends to fly away in order to suppress this dispersal by dropping the water at a low altitude. In order to resolve these issues to realize safe and effective aerial firefighting, JAXA, in collaboration with ShinMaywa Industries, Ltd. and the Japan Aircraft Development Corporation, is researching the technology necessary for developing a large-scale firefighting amphibian. (Fig. 4).

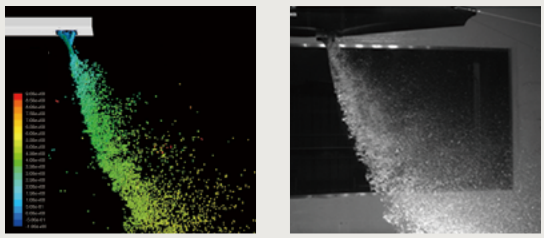
Thorough checking of water-dropping conditions through wind tunnel testing

Success in extinguishing a fire is determined by the size of the water particles dropped from the amphibian, the water-drop area as well as the density of water that reaches the ground. Since water dispersal varies depending on the airframe scale, water volume that is dropped, aircraft speed and wind direction, it is imperative that the relationship between flight conditions and water drop be studied to establish a prediction analysis method for effectively extinguishing fires. At JAXA, we have developed “particle image velocimetry” (PIV), which measures airflow velocity in a wind tunnel, and have applied this measurement method to obtain detailed measurements of water droplet dispersal (fig. 5). JAXA's 6.5 m × 5.5 m low-speed wind tunnel is being used for this test. In addition, photos were taken with a high-speed camera (fig. 6) and the water dropped in the wind tunnel was measured using a graduated cylinder (fig.



A large water mass is divided by the flow of the wind, allowing us to investigate how it gradually changes into finer particles.

Fig. 6: Measurement results of water drop using a high-speed camera



Analysis results (Provided by ShinMaywa Industries, Ltd.)

Experimental results

The actual water-dropping conditions can be thoroughly analyzed.

Fig. 8: Water-dropping conditions through numerical analysis

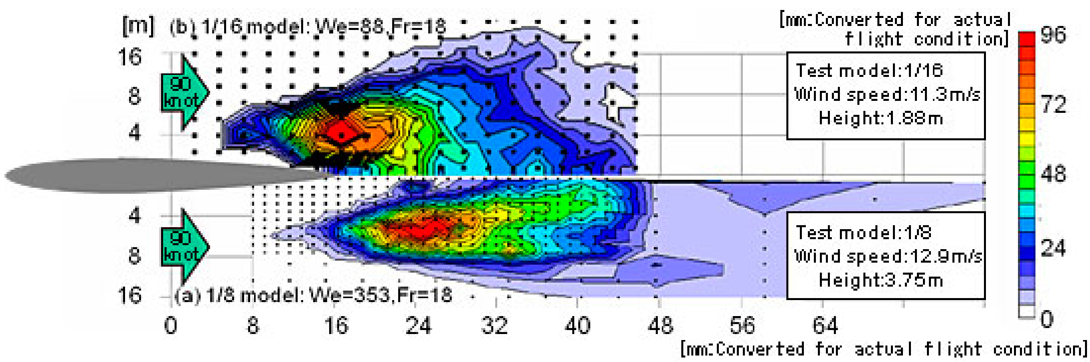


Fig. 7: Measurement results of dropped water volume using a graduated cylinder

Fig.9: Verification of pilot support tool using the flight simulator

7). The results obtained in this test will, through numerical analysis (fig. 8), be used as data for determining dispersal of an actual water drop.

Research on instrument display system for firefighting

If a pilot in a mission with a firefighting amphibian can be shown a suitable flight path and water-drop location, the firefighting mission can be conducted more safely and reliably. In collaboration with Shimadzu Corporation, JAXA is researching a system for providing the pilot with necessary flight information and, in collaboration with ShinMaywa Industries, Ltd., we are continuing development of “pilot assistance systems for firefighting” that will employ this system.

In 2010, we used our flight simulator to verify the pilot assistance system being developed. (Fig. 9) With the simulator, we assigned various flight altitudes and crosswind conditions to simulate a series of flights, from approaching a fire occurring on level ground or in mountainous areas, dropping the water, then leaving. The data obtained from the tests described above were applied to the behavior of the water when it was dropped. Information considered effective in firefighting was shown in a helmet-mounted display (HMD) and a head-down display (HDD) for research at the front of the cockpit, and their validity was evaluated by five pilots (fig. 10). By resolving the issues made evident through these tests, we will focus on establishing technology for achieving more reliable water drops.

Our work consists of research and development of technology related to the sky (aviation and space). Sky-related technology is useful in various situations. As we hope that this technology can also be useful in disaster response, we have introduced some endeavors of the JAXA Aerospace Research and Development Directorate, focusing on how aviation fundamentals/basic technologies can be applied to disaster response. This article is the result of a compilation of conversations with section leader Okuno of this department’ s Flight Research Center, section leader Ito of the Wind Tunnel Technology Center and researcher Kobayashi of the Operation and Safety Technology Team of JAXA’ s Aviation Program Group. We hope that our research can provide even a small amount of help to your everyday life.

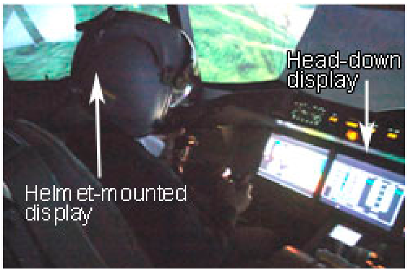


Fig.10 : Assessment testing of instrument display systems

Researcher Kobayashi, Section leader

Section leader Ito

Intermission Break

The Amphibians — Aircraft that soars from the water

■ Taking off from and landing on the surface of water

Runways are needed for airplanes to take off and land. The runway length differs depending on the aircraft type and distance of its service route. Generally, larger aircraft or aircraft with longer routes have longer runways.

However, there are some aircraft that do not require a runway. There are aircraft, called "seaplanes" or "amphibians", that take off from or land on the surface of water such as an ocean or lake. Seaplanes have landing gear called floats for taking off from and landing on water; they have the shape of a relatively small aircraft. In contrast, the amphibian is an "aircraft where the lower part of the fuselage is shaped like a boat". Because of this fuselage, floats are not necessary for it to float on water, and it has a larger shape. The wings and engines are typically mounted on the upper surface of the aircraft in order to avoid water splashing while it is gliding. It is also designed to float even if there is a hole in part of the bottom of the boat. There is also the amphibious type, which has landing gear stored in the fuselage allowing it to take off from or land on the ground.

■ History

The idea of aircraft flying from the surface of water is an old one. In March 1910, Henri Fabre (France) succeeded in the world's first take-off from the surface of water through powered flight. In January of the following year, Glenn Curtiss (USA) succeeded in flying a practical seaplane, designed based on a land plane, and in January 1912, successfully flew the world's first flying boat.

The first official flight of a seaplane in Japan was conducted by the Navy at Yokosuka Oihama in 1912. Ten years later, in 1922, using amphibians sold by the Navy, Nihon Koku Yusou Kenkyujyo ran scheduled flights for transporting newspapers and mail between Sakai and Tokushima as well as Sakai and Takahama. Even afterward, they were used for long-distance and transoceanic routes until around the Second World War. However, due to improved reliability, safety and convenience of land planes, there was a decreased need for operation that may require ocean landing (the special feature of amphibians), and their mission as a large-sized long-distance aircraft ended.

■ Working Amphibians

In modern Japan, "The Search Rescue Amphibian Aircraft" (fig.) are active in emergency situations such as natural disasters. Amphibians are indispensable as nearly the sole emergency transport method to islands with no airfields and that are too far to reach by helicopter, such as the Bonin Islands.

"Firefighting amphibians" are active in such places as Canada, the United States and Europe during large-scale wildfires. Since they are able to take up water by gliding over scattered lakes and reservoirs, they possess features suitable for extinguishing wildfires. At JAXA, in collaboration with ShinMaywa Industries, Ltd. and the Japan Aircraft Development Corporation, we are continuing research and development of the technology necessary to realize a domestically manufactured firefighting flying boat.

Fig.: STOL Search and Rescue Amphibian "US-2" (provided by ShinMaywa Industries, Ltd.)