Small Unmanned Aerial Vehicle System for Advanced Information-gathering

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OVERVIEW: Hitachi is working on the development of a small UAV system that can be used by a small number of people. Technological features include (1) autonomous flight control, (2) an aerial mesh network, and (3) the automation and visualization of information analysis. In February 2011, Hitachi delivered its first model, the JUXS-S1 (short-distance) UAV, as equipment to the Japan Ground Self-Defense Force. The need for UAVs will continue increasing in fields other than defense as well, and it is expected that the market will expand. By offering a varied lineup of small UAVs, Hitachi will continue to provide systems for any situation while contributing to the achievement of a safe and secure society.

INTRODUCTION

THE need for information gathering from the air at sites of natural disasters and accidents has increased in recent years. In particular, unmanned aerial vehicles (UAVs) have been attracting a great deal of attention as a safe and efficient means of acquiring information in regions that are difficult for people to access, such as the sites of disaster or conflict. UAVs were used to ascertain the status of damage to the Fukushima Daiichi Nuclear Power Station after the Great East Japan Earthquake of March 2011.

In broad terms, UAVs are categorized into large UAVs such as the RQ-4 Global Hawks of the US military that flew over from Guam after the Great East Japan Earthquake, and small UAVs with an airframe mass of 100 kg or less. Large UAVs include a wide range of sensors (cameras, radar, etc.), navigational devices, and communication equipment, an airframe that is capable of long-range and high-altitude flight, and the large-scale ground equipment and dedicated organization required to run them.

On the other hand, as the technology used in mobile phones, personal computers (PCs), cameras, and other electronic devices has been advancing at a spectacular rate recently, the same or higher levels of functionality and performance are now achievable in a smaller and lighter form. Hitachi has been developing a small UAV system that aggressively incorporates

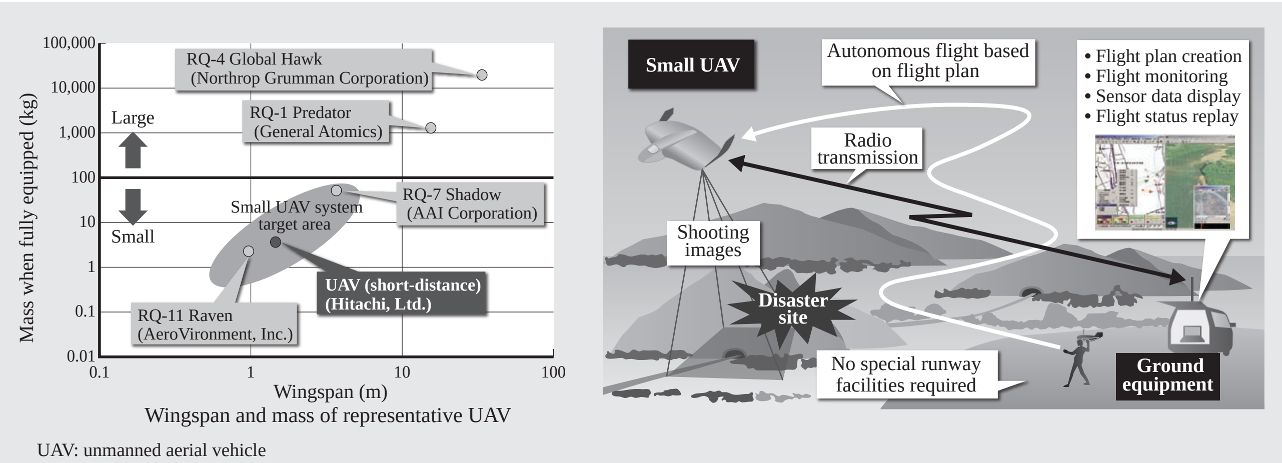

Fig. 1—Target Areas of World Trends in Small UAV Systems and Operation.
As a wide variety of UAVs are being developed around the world, Hitachi has developed a small UAV system with an airframe mass of less than 100 kg that can be used by a small number of operators, in order to gather information on-site from the air in areas such as those affected by disaster or conflict.

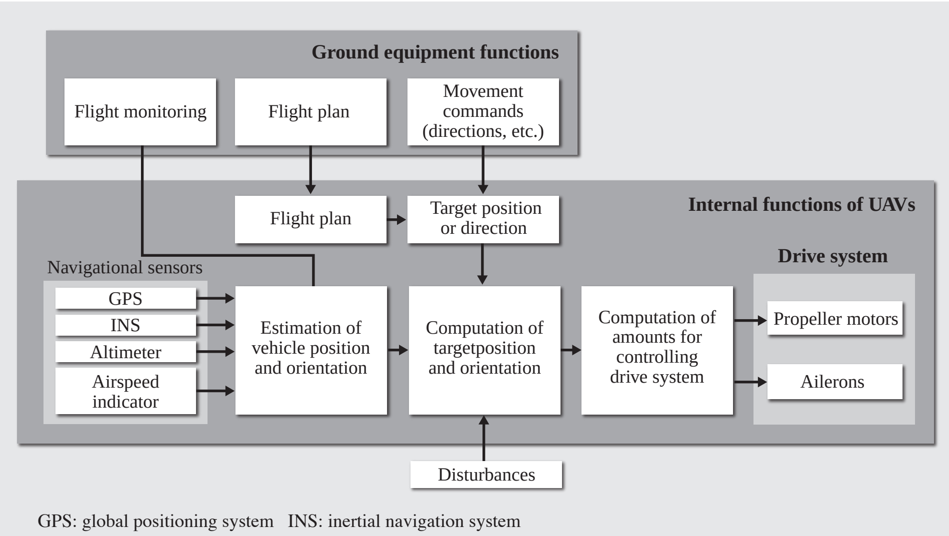

Fig. 2—Basic Autonomous Flight Control Method.
This figure shows the autonomous flight control system used with small UAVs. A vehicle uses its on-board navigational sensors to determine its own position and orientation, and controls its drive system in order to arrive at the next flight pass point.

these cutting-edge technologies, and which can be easily operated by a small number of people on-site for disaster monitoring or defense purposes (see Fig. 1).

This article discusses the features offered by Hitachi's small UAV system, Hitachi's delivery track record, and efforts for the future.

FEATURES OF SMALL UAV SYSTEM

The small UAV system is supported by a wide range of technologies. Key technologies are discussed below, including autonomous flight control, aerial mesh networks, and the automation and visualization of information analysis.

Autonomous Flight Control

When they first appeared, UAVs were flown by human pilots using radio control. In other words, the operations of the pilot were wirelessly transmitted to the UAV, which was then controlled accordingly. For this reason, the control of UAVs greatly depended on the skill of the pilot.

Nowadays, autonomous flight control is widely used in order to make flying both easy and safe. Autonomous flight control means that the navigational devices inside the UAV are used to control the vehicle so that it autonomously flies according to a predetermined flight plan. The emergence of navigational sensors that are high-performance, small, lightweight, and low-cost [such as global positioning systems (GPS), inertial navigation systems (INS), altimeters, and airspeed indicators] as well as processors are behind the spread of UAVs with autonomous flight control capabilities.

The method for implementing autonomous flight control in a small UAV system is as follows. First, ground equipment is used to create a flight plan in advance of flight (a plan made up of multiple flight pass points), and to set that flight plan in the UAV's system. As the UAV flies, it will periodically check the data acquired by its navigational sensors to compute the vehicle's own position and orientation. This process is executed in realtime so that it can handle any sudden disturbances, and the drive system powering the flight (propeller motors and ailerons) are controlled so that the vehicle arrives at the predetermined flight pass points (see Fig. 2).

Flight plans generally specify flight pass points and other information that is comprised of latitude, longitude, and altitude settings. A flight plan previously loaded into an UAV can be modified in flight by wirelessly resetting the plan. It is also possible to use ground equipment to issue movement directives to UAVs in realtime (including changes in direction, altitude, and speed).

Aerial Mesh Network

The main objective of a small UAV system is to capture images and other information, and to enable the even more effective utilization of this information, images and other data must be transmitted in realtime. In general, when wireless communication is used to transmit images or other large amounts of data, a wide bandwidth must be used in the high frequency range. Signals in the high frequency range are subject to a large amount of propagation loss, however, and communication is difficult over the horizon. Visibility is often difficult to secure at the altitudes small

UAVs fly, due to the effects of terrain and terrestrial objects. This small UAV system is given an automatic communication relay function as a means of solving this type of problem, using ad hoc network technology. By flying small relay UAVs in addition to the small UAVs taking images, it is possible to acquire the status of UAVs on the other side of mountains in realtime, even where direct communication is not possible. Also, since the radios use the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) protocol, which is a wireless local area network (LAN) technology, by combining this with ad hoc network technology, a flexible network is implemented without the need for complicated settings. These technologies make it easy to build an aerial mesh network in which multiple small UAVs and ground equipment can coexist. Furthermore, a simultaneous transmission (multicasting) function exists that allows for the sharing of information with multiple devices on the ground (see Fig. 3).

In the future, Hitachi will work to use technologies such as ultrahigh-resolution images and even more advanced image and video compression/decompression technology in order to achieve even higher quality information sharing while using narrower frequency bands.

Automation and Visualization of Information Analysis

The aerial acquisition of information originally involved the manual identification of targets and other forms of information analysis. In recent years, however, there has been a need for automatic information analysis that can reduce the burden placed on users caused by the need to analyze huge amounts of acquired images.

Taking defense applications as an example, images shot of a target are not very meaningful by themselves. It is also necessary to know precisely where and when the images of the target were taken. This small UAV system simultaneously transmits a variety of different types of information together with its images, including shooting time, shooting position, airframe orientation, and camera tilt. Since a digital map with ground surface altitude data is implemented on the ground equipment side, it is possible to compute the area shot by the camera and the position of the target (see Fig. 4). The more accurate and the faster the computation of this position, the more efficiently the next mission can be executed.

In the field of environment measurement, on the other hand, the need for visualizing measured information is also high. Fig. 5 shows the visualization of radiation dose rate and other environmental sensors placed on small UAVs. The effective visualization of measured information makes it easy to grasp acquired information.

In addition, Hitachi is currently developing mosaicing technology for sequentially pasting multiple images on a map to create the most recent image of a wide area, as well as automatic moving target detection technology that can automatically detect a target as it moves between continuously shot images while computing the target's position, movement direction, and speed. Hitachi is promoting the development of information analysis automation and visualization technologies, which are expected to advance particularly rapidly.

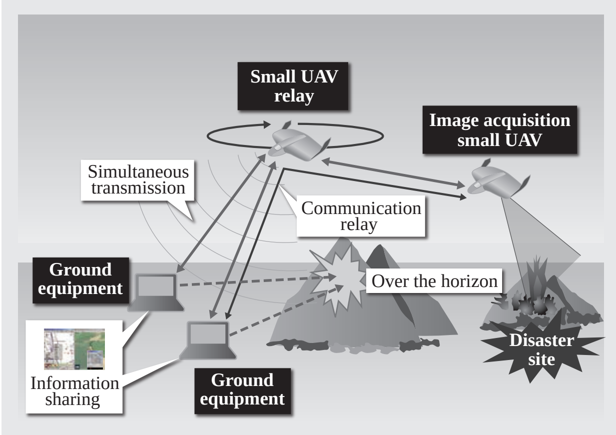

Fig. 3—Aerial Mesh Network Overview.
Multiple devices create a flexible network. By flying small UAVs as relays, it becomes possible to communicate in realtime with other small UAVs that are over the horizon.

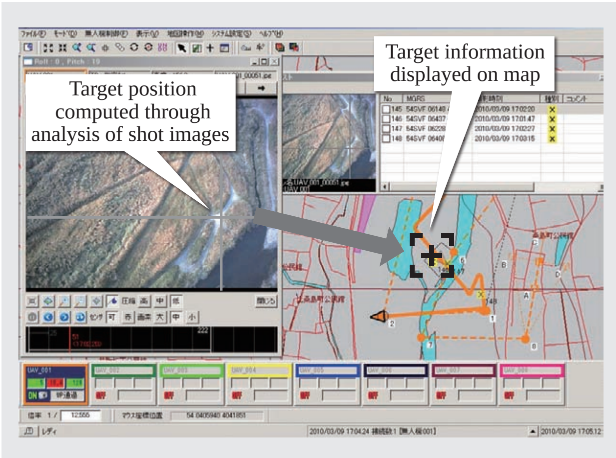

Fig. 4—Example of Target Position Computation.
Shot images are used to compute the position coordinates of the specified target, and the target information is displayed on the map.

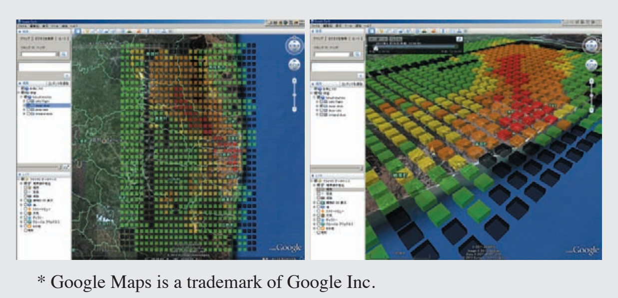

Fig. 5—Example of Visualizing Environmental Information.
This is an example of measured radiation data visualized using Google Maps. Visualization makes it possible to grasp information visually.*

DELIVERY TRACK RECORD

Hitachi delivered its first JUXS-S1 short-distance UAV as equipment for the Japan Ground Self-Defense Force in February 2011. As of June 2012, 16 UAVs have been delivered.

The JUXS-S1 short-distance UAV system is comprised of the small UAV itself as well as ground equipment. Major features of the UAV include user-friendliness and the ability to be carried around and run by just two operators.

The small UAV has a wingspan of approximately 1.5 m, and is lightweight with a mass of approximately 4 kg. This makes thrown takeoff and landing in a small area possible, so no special devices or facilities are required for those activities (see Fig. 6). The UAV can be split into parts for carrying, and can be stored in a compact space. Sensors for information acquisition, cameras for visualization, and other types of equipment are also provided.

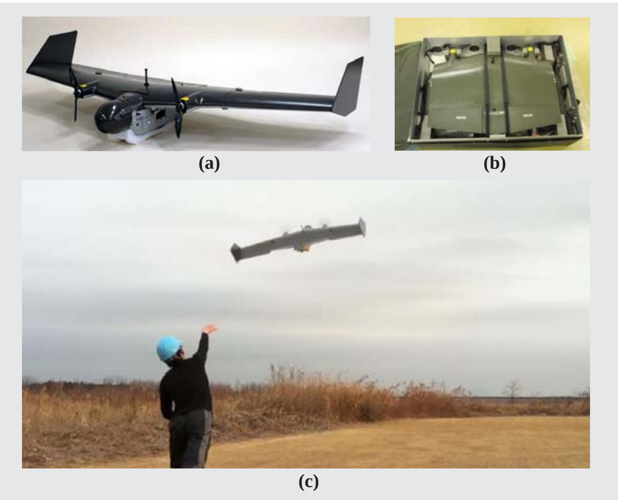

Fig. 6—Exterior of UAV (Short-distance) JUXS-S1 and Thrown Takeoff.
Due to the small and light airframe, this UAV can be easily carried and operated by a small number of people. (a) shows the UAV after assembly, and (b) shows it packed. A thrown takeoff (c) has also become possible, and no special devices or facilities are required for takeoff or landing.

The ground equipment can also be stored in a state that allows for carrying. By deploying the ground equipment while the small UAV is in flight, it is possible to display acquired information while processing information, including the detection of targets (see Fig. 7).

Since UAVs can be deployed into dangerous areas without the need to risk human lives, the unmanned vehicle industry is having a tremendous effect, not only in defense, but with the acceleration of adoption in a variety of other fields. Hitachi will continue focusing its efforts on the field of small UAVs, by playing its part in building a "smarter eye of the sky."

FUTURE EFFORTS

In addition to small UAVs, there are needs for higher levels of functionality and performance in a wide range of unmanned vehicles, and versatility is demanded.

In addition to its short-distance UAVs with a wingspan of 1.5 m, Hitachi is also developing UAVs with a wingspan of 4 m, tethered UAVs, and others.

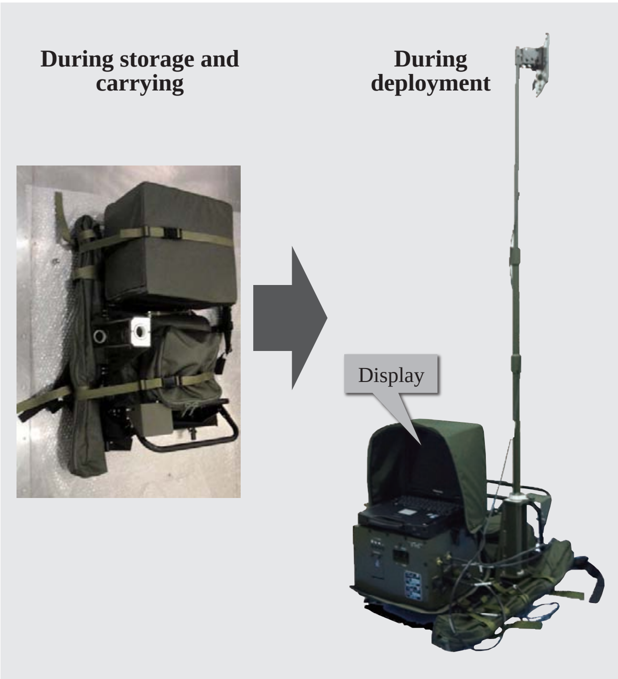

Fig. 7—Exterior of Ground Equipment during Storage, Carrying, and Deployment.
Ground equipment is small and lightweight, just like the fuselage. Information from the small UAV can be verified in the display.

The UAV with the wingspan of 4 m has a larger system than the one with a wingspan of 1.5 m, and flight time and mileage are also much longer. Situations where a larger UAV is applied include extremely remote and large areas that must be monitored and observed for an extended time, such as isolated islands and regions affected by a disaster at a nuclear power plant.

A tethered UAV is constantly connected to ground equipment, even during flight (both power and communication cables), and can therefore remain in the air for a long time. Situations where this type of UAV is applied include the provision of communication infrastructures in disaster regions, temporary base stations for various events, and the long-term monitoring of suspicious areas surrounded by tall obstructions.

Hitachi's diverse lineup of UAVs allows it to provide systems that are suited for each application.

CONCLUSIONS

This article discussed the features and delivery track record of Hitachi's small UAV system, as well as plans for future efforts.

The defense field is the main market at present, but demand is also increasing in other fields as well, and an expanding global market is predicted. Hitachi will continue mobilizing a wide range of cutting-edge technologies and operational know-how, including UAV, information sharing, and analysis technologies, as it works aggressively to develop next-generation small UAV systems in order to contribute to the achievement of a safe and secure society.

ABOUT THE AUTHORS

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