Imaging Solutions for Search & Rescue Operations

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Abstract

Over the past few years, Japan has once again been reminded of nature's devastating power to inflict damage and destruction on people and property. In order to respond effectively to such disasters, accurate evaluation of the nature of the emergency, together with immediate implementation of targeted search and rescue operations, is critical. Statistically, the survival rate of victims trapped in collapsed buildings and other structures drops rapidly once 72 hours have elapsed from the time the disaster struck, literally making it a race against time. This paper discusses various imaging solutions offered by NEC that have been specifically designed to facilitate faster and more effective emergency response - from determining the scale and nature of the disaster to implementing search and rescue operations.

Keywords

synthetic aperture radar (SAR), AEROEYE III, hyperspectral sensor (HSS), pole-mounted infrared imager, helmet camera, starlight scope

1. Introduction

Over the past few years, extreme weather conditions in parts of Japan have led to unusually heavy rain, resulting in severe flooding and massive landslides. As events such as these pose a serious threat to the lives and safety of the local population, state and municipal governments are ramping up their capabilities to respond promptly and accurately should a disaster occur. This paper will examine the wide range of solutions offered by NEC's Radio Application, Guidance and Electro-Optics Division that facilitate rapid damage assessment when a disaster occurs, allowing search and rescue operations to determine where help is needed and quickly locate and assist victims.

2. Processes and until Rescue of Victims

When the Great East Japan Earthquake rocked Japan's eastern coast on March 11, 2011, it touched off a whole host of associated disasters. A tsunami swept in from the Pacific, battering coastal regions, while fires spread through urban centers and landslides ravaged mountainous regions. To top it all off, the nuclear power plant at Fukushima sustained so much damage from the earthquake and tsunami. In the confusion that followed, it took authorities a long time to get a comprehensive picture of the nature and extent of the damage, and they were unable to respond as quickly and effectively as necessary. Drawing on the lessons learned from the Great East Japan Earthquake, we identified three main types of rescue operation: wide-area search, narrow-area search, and pinpoint search, as shown in **Fig. 1**. For each type of rescue operation, we propose a solution that best matches the process.

2.1 Wide-area Search

A wide-area search should be performed immediately after a disaster occurs with the aim of grasping the overall scale of the disaster. It should clarify the scale of the damage, as well as assessing general conditions in disaster-stricken areas. NEC's airborne synthetic aperture radar (SAR) features a swath width of about 5 kilometers, making it an ideal tool for a wide-area search. The main specifications of the SAR are shown in **Fig. 2**.

NEC's SAR uses an imaging radar that enables it to detect three-dimensional contours and artificial structures on the ground surface and visualize them. As it uses microwaves to illuminate a target scene and build up an image, it can oper-

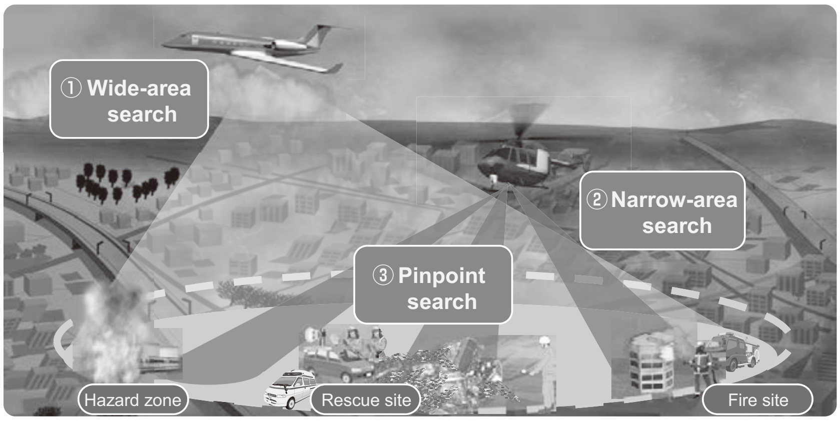


Fig. 1 Three main types of rescue operation in a disaster.

ate day or night and is not affected by weather conditions or smoke from fires or volcanos. Thus, it can reliably detect any changes that may have impacted the landscape of the disaster-stricken area, including landslides and building collapses. It also makes it possible to obtain information on the status of routes to the target area, ensuring that response teams can travel to the scene using the fastest possible route.

2.2 Narrow-area Search

The purpose of the narrow-area search is to gather detailed information on the disaster site identified in the wide-area search. Especially effective in this type of search are NEC's AEROEYE III and hyperspectral sensor (HSS). These are aircraft-mounted systems with a narrow observation width of a few hundred meters suitable for higher resolution visualization of a specific area.

1) **AEROEYE III**
Equipped with a high-image-quality infrared camera and visible-light camera, the AEROEYE III makes it possible to collect detailed video information about the target site. An infrared camera is a camera that visualizes the thermal differences of temperatures emitted by objects, thereby making it possible to obtain clear images whether it is day or night.
Since this device features temperature measurement capability (pseudo-color display), it makes it easy to specify the origin of a fire, detect residual fires, and search for victims. The main specifications of the AEROEYE III are shown in **Fig. 3.**

2) **Hyperspectral sensor (HSS)**
The HSS features high wavelength resolution, allowing it to measure the reflected spectral intensity from the subject with the number of available observation bands ranging from a few dozen to a few hundred, mainly in the range from visible light to infrared light.
Conventional visible-light cameras identify the subject

Item		Specifications
Max. dimensions		SAR main unit : W200×H300×D500 mm Antenna unit : W400 mm
Weight		Approx. 100 kg (total weight including antenna unit)
Main performance	Frequency band / Resolution	X band / 0.3 m
	Swath width	5 km or more (when mounted on fixed wing aircraft, at altitude of 10,000 ft)
	Transmission output	Approx. 1 kW
	Power consumption	Approx. 1.8 kW
Main features		・Real-time processing on board ・Wide range of observation modes (Strip Map, Spot Light, Full Polarimetry, 3D InSAR, Moving Body Detection, ISAR)

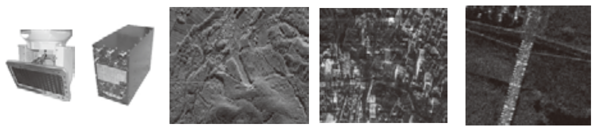
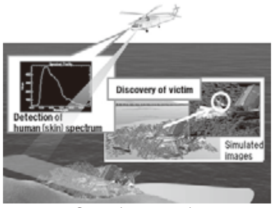


Fig. 2 SAR main specifications.

Item		Specifications
Max. dimensions		Φ320×370 mm
Weight		Approx. 30 kg
Main performance	Resolution	640×480 (infrared camera), 2million pixels (visible-light camera)
	Detectable wavelength range	8 to 14μm (infrared camera)
	Max. field of view	40°(infrared camera, visible-light camera)
Main features		・Entirely made in Japan ・Site measurement function ・Temperature measurement function ・Automatic target extraction/tracking function

Fig. 3 AEROEYE III main specifications.

Item		Specifications
Max. dimensions		W63×H81×D132 mm (sensor main unit)
Weight		Approx. 700 g (sensor main unit)
Main performance	Used frequencies	40 to 1,000 nm
	Number of bands	60 bands
	Detection range	1 km (target: human)
Main features		・Simultaneous visible-light and hyperspectral imaging ・Real-time target extraction



Operation example

Fig. 4 HSS main specifications.

based on its shape. An HSS camera, on the other hand, identifies the subject by collating the obtained spectral intensity with an existing spectral database. The spectral intensity can be obtained on a per-pixel basis. By applying this property, the HSS can detect distant victims at an early stage or victims buried in the rubble of a building or beneath a landslide, provided that part of the victim is exposed - something which is difficult to do with a visible-light camera.

To improve HSS identification accuracy, different spectral databases can be prepared to suit different disaster scenarios. The main specifications of the HSS are shown in **Fig. 4**.

2.3 Pinpoint Search

Once a search site has been identified with narrow-area search, rescue teams will need to physically access the site in order to rescue the victim or victims. NEC offers a wide range of equipment to support rescue efforts, including pole-mounted infrared imager, helmet cameras, and starlight scopes. NEC's pole-mounted infrared imager features the world's smallest 12-µm infrared imager, which has made it possible to achieve an extremely compact and lightweight design.

1) **Pole-mounted infrared imager**

The tip (camera section) of the imager is flexible, allowing it to bend as required and allowing conditions under the rubble of a building to be observed by inserting the tip through a gap in the rubble. With a visible-light camera, it is impossible to see if anyone is buried under the rubble unless the greater part of their body is exposed. With the infrared imager, however, only a small part of the victim's body need be exposed - just enough so that the temperature difference from the surrounding rubble can be clearly visualized. With this technology, the chances of missing someone buried in the rubble are greatly reduced. The main specifications of the imager are shown in **Fig. 5**.

2) **Helmet camera**

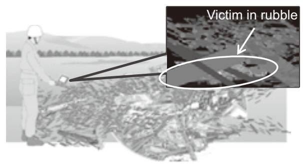
Because an infrared camera is mounted on the helmet and images are shown on a head-mounted display, the rescuer's hands are free to perform other activities such as digging out victims with a shovel, operating other equipment, supporting a rescued victim, and so on.

3) **Starlight scope**

Unlike the infrared camera, the starlight scope visualizes images by amplifying faint light. Even at night with a new moon, visibility sufficient for a rescue operation can be obtained as long as there is starlight. This is

Item		Specifications
Dimensions		When stored : Approx. 1,100 When extended : Approx. 2,500
Weight		Approx. 7.5 kg
Main performance	Effective number of pixels	640 (H)×480 (V)
	Field of view	Approx. 50°
	Recording time	More than 11hours
Main features		・Incorporation of a 12µm infrared imager with the world's smallest pixel pitch. ・3-step telescopic pole design that can be fixed at required length


imager



Application example

Fig. 5 Imager main specifications.

Item		Specifications
Max. dimensions		W60×H70×D102 (excluding protrusion)
Weight		Approx. 280 g
Main performance	Field of view	Approx. 40°
	Magnification	Approx. 1.0x
	Power consumption	0.3 VA or less
Main features		・Monocular starlight scope ・High visibility under starlight


Starlight scope

Image example

Fig. 6 Starlight scope main specifications.

especially useful when a rescue operation has to be performed during a power outage caused by a disaster or in a mountainous region at night. This device is sensitive across the bandwidth range from visible light to near infrared and outputs images equivalent to what we would see under normal lighting, so users won't find themselves struggling to adapt. The main specifications of the starlight scope are shown in **Fig. 6**.

3. Future Tasks

There are three main issues we have to solve in the future.

1) **Compact design of the devices**
All the devices introduced in Chapter 2 need to be compact and lightweight. Once the SAR has been made sufficiently compact and lightweight, it can be installed on small airplanes and helicopters, making it possible to use it in more operations. Similarly, once the AEROEYE III and HSS have been made compact and lightweight, the deadweight of the helicopter can be reduced, which will allow it to carry more rescued victims. When the imager, helmet camera, and starlight scope are made compact and lightweight, the load on rescue team members can be reduced, likely increasing the efficiency of search and rescue operations.

2) **Provision of high-quality images**
By increasing the S/N ratios of the image sensors, clearer images can be delivered, further enhancing the ability of rescues to observe, assess, and identify disaster conditions and more easily locate and rescue victims. The achievement of clearer images will require intensive efforts and collaboration with the NEC Research Laboratories.

3) **Improvement of target extraction technology against a complex background**
It is sometimes difficult to detect a disaster victim with a single sensor alone against a complex background. Even when a victim is detected, it may prove difficult to accurately assess the conditions around the victim. In such situations, the effectiveness of rescue operations can be improved by combining sensors with different characteristics that complement each other.
Of critical importance in this regard is the development of technology that can overlay images from an infrared camera over the images from a visible-light camera; the former facilitates detection of victims and the latter clarifies the conditions around the victims.

4. Conclusion

NEC offers a wide range of image solutions tailored to the needs of search and rescue operations and specifically designed to reduce the time it takes to gather vital information from immediately after a disaster occurs to the rescue of victims. In the future, we will continue to refine and improve these products to further enhance search and rescue capabilities and improve response to disasters and accidents.

5. Acknowledgment

This paper is the result of research and development conducted as part of a project called "The Research and Development of High Resolution SAR for Light Aircraft (FY2012-2014)" commissioned by the Ministry of Internal Affairs and Communications. We would like to express our gratitude here.

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Vol.9 No.1 Special Issue on Solutions for Society - Creating a Safer and More Secure Society

Vol.9 No.1
January, 2015

Special Issue TOP