HITACHI REVIEW
Volume 62 Number 3 April 2013

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Social Infrastructure Security Technology

HITACHI REVIEW Carried on the Web
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Preface to Social Infrastructure Security Technology

Atsushi Takita
President & CEO
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THE criteria for assessing the safety and security of social infrastructure systems are changing a lot. Different threats with various forms are happening in the 21st century such as natural disasters, pandemics, and other accidents that could endanger our life on a global scale; terrorist or cross-border military attacks; and cyber-attacks on information systems. The need to protect systems from these threats and ensure that the systems can maintain their operations and services is growing.

However, social infrastructure systems are becoming more complex and the threats we face are more diverse. It is very difficult to anticipate when, what, and how these threats are attacking us, and to take proper measures against all possible threats. We have to make preparations against events or accidents that might exceed what we have experienced and anticipated. One of the important things for this is how to link actions during normal times with those during an emergency seamlessly. In other words, this means conducting regular exercises to imagine and simulate emergency situations, and taking appropriate crisis response actions by integrating command and control with accurate situation assessment capabilities. The success of the Japan Self-Defense Forces in the Great East Japan Earthquake is a good example of how exercises conducted in normal times can lead to accurate decision-making in the field.

Hitachi has experience and expertise in the construction, maintenance, and operation of social infrastructure systems. This issue of Hitachi Review describes Hitachi technologies, products, and solutions that ensure the safety and security of our social infrastructure systems. The articles include explanations on how to adopt defense sector concepts in crisis management in order to make a flexible response to unanticipated events, and on how to make the best use of regular exercises in an emergency.

Numerous factors are involved in the safety and security of social infrastructure systems. The articles in this issue focus on topics from Hitachi's activities in recent years.

These include: (1) crisis management systems that protect the public from events such as natural disasters or terrorist activity, (2) cyberspace security for preventing attacks on networks and other information systems, (3) global environmental protection and the securing of energy supplies to resolve energy problems while also protecting the global environment, and (4) special systems that support the activities of people in harsh environments.

I hope that this issue will provide you with a more concrete understanding of the safety and security initiatives advocated by Hitachi, and help with safety in your business and the world.

Technotalk

Repurposing of Advanced Technology for Enhancing National Security

Takashi Shiraishi President, National Graduate Institute for Policy Studies
Takashi Saito Consultant, Hitachi, Ltd.
Kunizo Sakai President and CEO, Defense Systems Company, Hitachi, Ltd.*

With modern society facing a variety of threats to the safety and security of daily life, including natural disasters, physical and cyber terrorism, and energy problems, the concept of national security has taken on a wider meaning and has grown in importance. As Hitachi accelerates the global expansion of its Social Innovation Business that seeks to use information technology (IT) to supply advanced social infrastructure, it is also taking the security technology it has built up through many years of experience in the defense industry and applying it to the social infrastructure sector. Hitachi intends to contribute to the safety and security of social infrastructure through security solutions that are supported by highly reliable and advanced technology.

"Black Swans" and "National Security"

Sakai: Considering various recent developments in Japan and elsewhere, it seems as if the desire for safety and security is greater now than in the past. Debate on the subject of safety and security is particularly intense in Japan where the Great East Japan Earthquake (in March 2011) caused considerable damage to social infrastructure and continues to have a severe impact on the life of those affected. Mr. Shiraishi, could you please tell us how you view these developments.

Shiraishi: From 2010 to 2011, during the collation of the 4th Science and Technology Basic Plan of Japan, I chaired the committee producing the draft document. Safety and security were included among a number of different shared concerns during that time. While we lump safety and security together, "safety" is something that can be expressed in scientific and probabilistic terms, whereas "security" (in the sense of "peace of mind"), because it is a question of feeling, is a matter in which there is scope for human judgment. I believe it is important to make this distinction.

Another term that has risen to prominence since the earthquake is "black swans." While modern civilization is very advanced, it also incorporates a mix of complex technologies. Although there is no such thing as 100% safety, we acted as if such a thing were possible. This may be why the idea of black swans has achieved currency. The term can also be interpreted as meaning, not "unknown unknowns," but rather, "known unknowns." In other words, black swans are things that we might have foreseen if we had thought about it, but in fact we did not.

Sakai: That is a big difference.

* At the time of the interview.

Takashi Shiraishi

President, National Graduate Institute for Policy Studies

Graduated from the College of Arts and Sciences and completed a master's degree at the Graduate School of Arts and Sciences, both at The University of Tokyo. Completed a doctorate at the Cornell University Graduate School. After appointments that included professor at the Department of History at Cornell University and professor at the Center for Southeast Asian Studies at Kyoto University, he took up his current appointment in 2011. Professor emeritus at Kyoto University. President (non-executive) of the Institute of Developing Economies of the Japan External Trade Organization. Member (non-executive) of the Council for Science and Technology Policy. Doctor of History
Publications include "Government and Politics in Indonesia," (Libroport) in Japanese.

Takashi Saito

Consultant, Hitachi, Ltd.

After graduating from the National Defense Academy of Japan, joined the Japan Maritime Self-Defense Force. His appointments have included Commanding Officer of the Hamashio and Setoshio submarines, Commander of Escort Division 22, Commandant of the Maizuru District and Yokosuka District, 27th Chief of Staff, JMSDF, and 2nd Chief of Staff, the Joint Staff. He was appointed to his current position in 2009.

Shiraishi: Preparing for both known and unknown unknowns in a way that takes full account of this difference, and being prepared to expect the unexpected, is the second of these shared concerns.

The third concern is national security. In the 4th Science and Technology Basic Plan, the section previously entitled "Key Technology of National Importance" was renamed "National Security and Key Technology," this being the first time the term "anzen hosho" (national security) was used in the Science and Technology Basic Plan. Against this background, defense and civilian technologies are not clearly demarcated fields as there is a need to consider dual use, and the term "national security" has expanded in meaning considerably over the more than 20 years since the end of the Cold War. I believe these are things we need to take into account.

Saito: That's right. Speaking in terms of safety and security, while safety can be guaranteed in a probabilistic sense, trying to guarantee something like security that is a state of mind would likely turn out to be a never-ending task.

Shiraishi: It ultimately comes down to a question of cost. As with black swans, when one considers the uncertainties, many real-world phenomena follow a power distribution. The size and distribution of earthquakes is one example. This means there is a need to decide where to draw the line on the balance between costs and benefits because the cost of safety and security cannot expand indefinitely.

While where to draw this line in a way that receives public approval is a political question, I believe that we also need to determine the optimum cost of national security from a technological perspective.

Post-earthquake Leadership on Safety and Security

Sakai: Japan is an earthquake-prone country, and there is no doubt that structures that comply with Japanese safety standards are extremely robust. However, this makes them more expensive. As products are increasingly rolled out in overseas markets, this may also result in their being over-specced in countries where earthquakes are less common. Specifications need to be changed to suit the circumstances in each country, and I believe it is also necessary to categorize them into different grades.

Saito: Deciding on the balance between achieving the objectives and respect for human life is an important facet of system design, including in the case of equipment and other products for the Japan Ministry of Defense. It was mentioned earlier that 100% reliability is unrealistic, and the trade-off between safety and cost will become an increasingly serious problem in the future, including from a technical perspective.

Shiraishi: Looking at international trends, meanwhile, there is a growing appreciation of the fact that protecting human life increases costs to some extent and it seems likely that the world will move toward Japanese standards over the long term. Japan is already well-known for the safety and punctuality of the Shinkansen, and one gets a sense that the world's trust and expectations for Japanese nuclear power generation technology may have actually increased after the accident at the Fukushima Daiichi Nuclear Power Station. A considerable number of nuclear power plants are planned for construction around the world, particularly in emerging economies. Is it not Japan's responsibility to the world to effectively incorporate the lessons from this accident into its safety measures and build nuclear power generation systems that are even more reliable?

Sakai: We live in an era when large disasters or accidents prompt global cooperation. Hitachi is active in the fields of disaster prevention management solutions, nuclear incident response, and nuclear security, and it may be that some forms of standardization or other rules will be needed, including in the field of national security.

Japan's technology did not start out at the level it is today, and was achieved through a process of trial and error. It may be that taking a leading role in safety or security in the post-earthquake period will be our mission for the future.

Kunizo Sakai

President and CEO, Defense Systems Company, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1975. His appointments have included Senior Manager of the Defense & Social Systems Design Department, General Manager of the Engineering Division, General Manager of the Command Control Systems Division, Defense Systems Group, Director of Hitachi Information & Control Systems, Inc. (now Hitachi Information & Control Solutions, Ltd.), and General Manager and CEO of Defense Systems Group. He was appointed to his current position in 2009.

Importance of Conducting Simulations

Sakai: The threat of terrorism is something that cannot be ignored when considering national security.

Shiraishi: After the 9/11 terrorist attacks in the USA, the US government conducted a variety of simulations of attacks on nuclear power plants and introduced new safety standards. While this is a government responsibility, I believe that ideas like this are also needed in Japan.

Saito: When something happens, I become acutely aware of how little use Japan makes of simulation. A fundamental problem is that Japan has comparatively few organizations involved in crisis management and information is often not shared because of their silo-like organizational structures.

Establishing these sorts of organizations and frameworks is crucial, but before that it is important that there are more opportunities for conducting simulations, even if only simple ones. Even if people understand in principle what they are meant to do, it does not mean that they will behave this way when a crisis actually strikes. Products supplied by Hitachi include equipment for the map-based exercises used to study tactics in the defense sector, and I believe that these could also be used as simulation tools.

Sakai: Equipment for map-based exercises supplied to the Japan Maritime Self-Defense Force Staff College has been in use for 17 years, and I understand it has recently been used for disaster response simulation.

The problem of silos may well apply not only to organizations but also to the spread of technology. Because there have been so many examples in which the use of computers and other technology outside their immediate fields (repurposing) has led to social progress, this idea is important.

The Type 92 floating bridge that we supplied to the Japan Ministry of Defense was utilized in the Great East Japan Earthquake, and Hitachi's anti-personnel landmine clearing machines are helping bring safety and security to conflict-torn regions. Hitachi's corporate credo is to contribute to society through technology, and in the security field as elsewhere, I believe we can offer even better systems through the repurposing of existing products, and through their integration with other technology.

Saito: Measures for countering cyber-terrorism are also important for the safety of social infrastructure. A recent cyber-attack by the hacker group Anonymous has attracted attention, and even before that, the safety of information has been under threat from cyber-attacks against companies and public agencies in Japan. What has the government been doing to about this?

Shiraishi: Awareness of the importance of cyber-security is growing within the government, particularly at the Japan Ministry of Defense and Cabinet Secretariat. Because cyber-security is a field that demands close cooperation between government and the private sector, transcending the military/civilian divide, I would like to encourage the government to expedite the establishment of structures and systems for cyber-security. As it is companies who possess the advanced technology in the information and communication technology (ICT) field, I am also looking to you for action.

Saito: With the greater fusion of information and control, there is pressure to adopt countermeasures, such as the identification of security vulnerabilities in the control systems of factory production machinery, for example. This is another area where simulation should prove effective, and I see a need for both the public and private sectors to utilize such techniques to strengthen risk awareness.

Sakai: Infrastructure control is one area that definitely needs protection. We are working on technology developments that include cyber-security and encryption software, and in the case of cyber-security, I believe it is possible to deliver systems that protect what needs protecting at an appropriate cost by adjusting the level of security based on the importance of the data.

Utilization of Technology that Transcends Military/Civilian Divide

Shiraishi: Regarding the repurposing of technology that transcends the military/civilian divide, I also have hopes for satellite technology. Combining satellite imaging with geospatial information systems (GIS) is likely to prove valuable in activities such as disaster relief. Similarly, environmental and meteorological monitoring can help with disaster countermeasures, not only in Japan, but also in nearby Asian countries.

Sakai: Hitachi also develops solutions that contribute to forest and ecosystem conservation and the global environment by using satellite imaging to monitor illegal felling of forests, for example. We want to use satellite technology to pursue a variety of different forms of added value, such as its use in resource exploration.

Saito: To digress slightly from today's discussion, battery technology is growing in importance for defense products, particularly advanced personal equipment. This offers the potential for using civilian technology in defense, rather than the other way around, and in this sense it represents another opportunity for utilizing Hitachi technology.

Sakai: We are also conducting research into the long-term storage of energy with the aim of achieving a sustainable society. I believe that the way we need to proceed is to consider both the overall future direction for energy technology and also how batteries and other advanced technology can be applied in the defense sector.

Shiraishi: Because you are active in a wide range of businesses and technologies, my expectations for Hitachi extend across many different facets. I hope you can draw on your extensive strengths to also take a leading role in the national security sector.

Sakai: While the defense of social infrastructure has in the past considered different equipment separately, the modern post-9/11 and post-3/11 (Great East Japan Earthquake) era demands security that covers the infrastructure of society in its entirety. As Hitachi expands its Social Innovation Business globally, we hope to be able to utilize the national security technology we have built up through our defense business to respond to threats to the social infrastructure, such as natural disasters, physical and cyber-terrorism, and energy problems. We will continue to strive to develop and apply technology to help create a safe and secure society.

Thank you very much for your participation today.

Technology for Safety and Security from Underwater to Outer Space and Cyberspace

Hajime Morito
Kentaro Kashiwa
Takeshi Hiroki
Kazuhiko Tanimura

GROWTH IN IMPORTANCE OF SAFETY AND SECURITY FOR SOCIAL INFRASTRUCTURE

OUR perceptions of safety and security were changed drastically by the September 11, 2001 terrorist attacks in the USA and the Great East Japan Earthquake that struck on March 11, 2011. In the case of the Great East Japan Earthquake, interruptions to essential services caused by damage to or loss of social infrastructure systems, such as electric power, gas, water, sewage, transportation, logistics, and communications, extended over a wide area, including places not directly affected by the disaster. In addition to reinforcing how essential these social infrastructure functions that people take for granted in normal times are to their way of life, this provided an opportunity to identify some of the vulnerabilities of this infrastructure.

This article describes what Hitachi is doing to ensure the safety and security of social infrastructure, and updates the latest situation with reference to the lessons learned from the Great East Japan Earthquake.

EXPANSION OF SOCIAL INFRASTRUCTURE AND GROWTH IN POTENTIAL THREATS

Social infrastructure provides systems that are essential to our way of life. These include both industrial infrastructure, such as transportation, energy, finance, and communications, and lifestyle infrastructure, such as water, food, healthcare, and education. As in the past, these systems need to deliver reliable services and be kept in operation to underpin the public's way of life. Now, however, prompted by incidents such as terrorism or major earthquakes, major changes are taking place in the criteria by which the safety and security of social infrastructure are judged, resulting in these requirements becoming even more severe.

Fig. 1 shows the expansion of social infrastructure and growth in potential threats. Traditionally, social infrastructure has meant the equipment and other facilities used to support human activity. In recent years, however, the rapid emergence of the Internet and other networks has given the communication networks that carry information an essential role in social activity. Moreover, environmental conservation for the entire planet has become important now that problems such as global warming are becoming more severe, and it is no exaggeration to say that our destiny depends on the global environment.

Meanwhile, looking at the changing nature of the threats to social infrastructure, these consisted in the past of problems with system operation, such as dealing with accidents, faults, or human operational error. Now new threats have emerged, including deliberate attacks such as physical military strikes or cyber-attacks on information systems or information assets. Looking at the threats to the global environment, global warming caused by the emission of carbon dioxide (CO_2) has become a major issue along with natural disasters such as earthquakes and typhoons. Yet another threat to be concerned about is that of pandemics, in which an infectious disease impacts the population on a global scale.

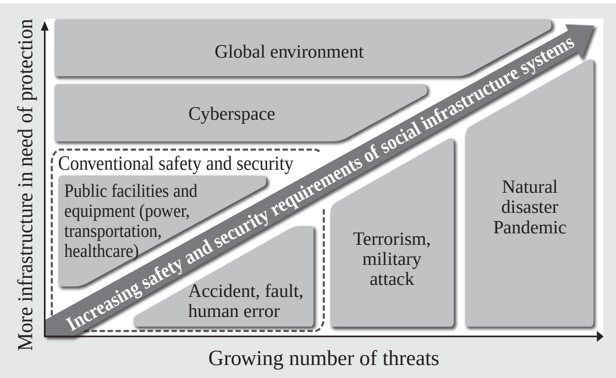

Fig. 1—Expansion of Social Infrastructure and Growth in Potential Threats.
While more and more social infrastructure is in need of protection, the corresponding threats are becoming more diverse.

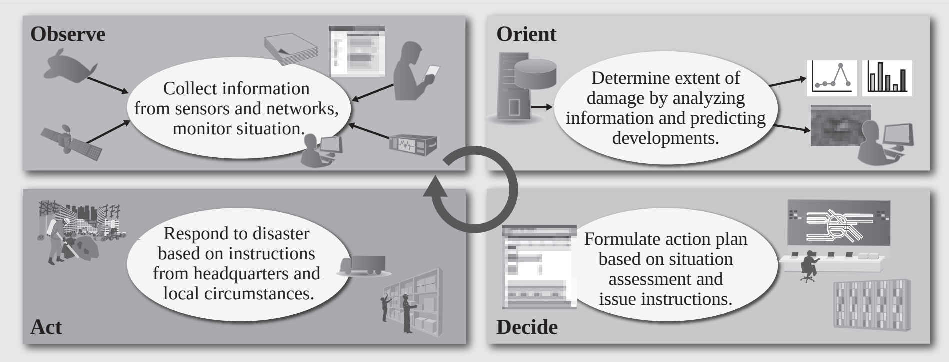

Fig. 2—Crisis Management System Using OODA Loop.
The figure shows the basic concepts of crisis management incorporating the OODA loop methodology used in the defense sector.

As this indicates, the background factors affecting social infrastructure are becoming more difficult, making the provision of safety and security solutions that can protect people's way of life an extremely important topic.

THREAT RESPONSE STRATEGIES

With more and more social infrastructure in need of protection, as described above, considering all possible situations in advance and preparing countermeasures to each one is all but impossible. Given these circumstances, Hitachi is seeking to apply concepts from the defense sector to respond to crisis situations. Fig. 2 shows the basic concepts of crisis management.

The OODA loop[(a)] for rapid decision making and situation response is an effective concept to adopt in a crisis. The OODA loop consists of four phases: (1) Collect and monitor information (observation phase), (2) Analyze collected information to assess the situation (orientation phase), (3) Formulate an action plan based on the situation assessment and issue instructions (decision phase), and (4) Act based on instructions from headquarters and local circumstances (action phase). Repeatedly working through this cycle helps achieve rapid decision making and situation response. The OODA loop concept is suitable for use in disasters or other emergencies in which the situation is changing rapidly and there is a confused mix of different information.

Conducting training exercises beforehand and making use of the information they provide is also important. Use of the OODA loop concept is not limited only to emergencies. To be able to respond to situations that exceed expectations, regular training exercises need to be performed, and all of the lessons learned incorporated into actual practices. Using the OODA loop in exercises provides a reliable way to incorporate the results of these exercises into emergency scenario manuals or other materials used at times of emergency. Examples of results include checking command and control systems and improvised responses.

Scenarios and simulations are important aspects of this activity. To conduct a training exercise, the participants first need to be told a scenario based on the training objectives. The exercise then proceeds by running a simulation based on their response to this scenario and using this to generate a new scenario. Fig. 3 shows the concept behind training exercises.

(a) OODA loop
A decision making methodology proposed by U.S. Air Force Colonel John Boyd based on experience from the Korean War. OODA stands for "observe, orient, decide, and act," and it is a model for achieving fast and accurate decision making by repeatedly working through this cycle. The OODA loop is not only in widespread use throughout the US military, it has also been adopted as a decision making process in business.

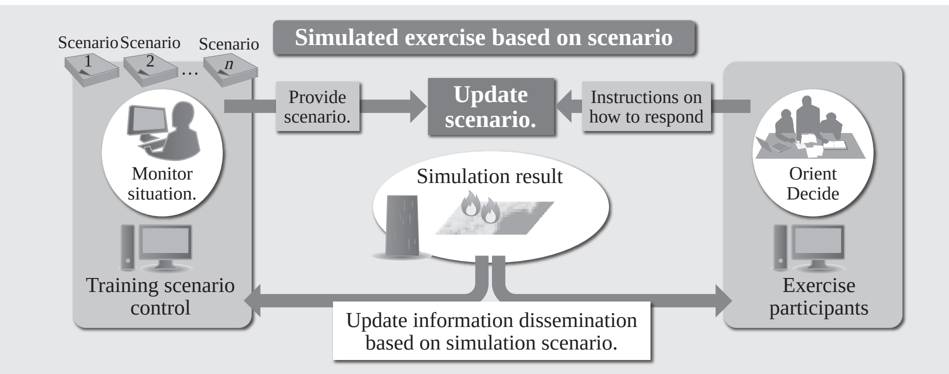

Fig. 3—Concepts behind Training Exercises.
Training exercises involve providing the participants with a scenario based on the training objectives, running a simulation based on their response to this scenario, and using this to provide a new scenario.

OODA loops also need to be established in cyberspace. The response to a cyber-attack can use the same concepts as the (real world) emergency situations or (virtual) training exercises described above. Simulation is particularly effective in cyberspace where staging exercises using the actual systems is difficult.

Incorporating the concepts described above makes it possible to respond flexibly to situations that could not be anticipated in advance, and that have been difficult to deal with in the past.

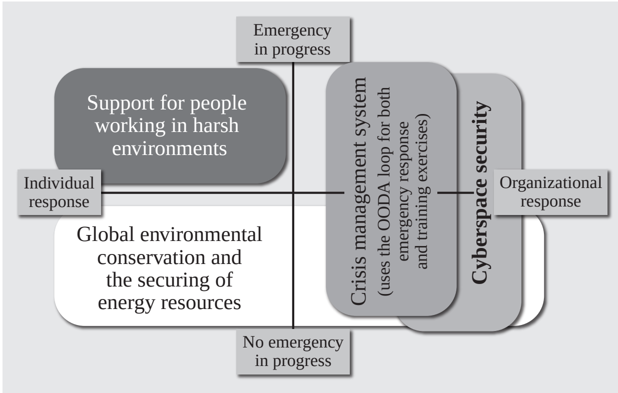

Fig. 4—Technologies Covered in this Issue, and their Scope.
This issue contains articles on subjects that have been of growing importance in recent years, including crisis management systems, cyberspace security, global environmental conservation, the securing of energy resources, and support for activities in harsh environments.

HITACHI'S ACTIVITIES

Hitachi has for many years been developing, delivering, maintaining, and operating products and solutions for many different types of social infrastructure. This issue of Hitachi Review contains articles on subjects that has been of growing importance in recent years, including crisis management systems, cyberspace security, global environmental conservation, the securing of energy resources, and support for activities in harsh environments (see Fig. 4).

Crisis management systems and cyberspace security provide typical examples of the use of the OODA concept, both for training exercises and the actual response in an emergency. Global environmental conservation mainly concerns the use of the OODA concept to support data gathering (observation) and situation assessment (orientation) during times when there is no emergency. Support for work in harsh environments involves solutions that help with the "act" phase when dealing with emergency situations.

Crisis Management Systems

In crisis situations that cause major damage over a widespread area, such as large disasters or terrorist attacks, there is a need to respond to a rapidly changing situation, with central government, public agencies, local government, and the general public working together to minimize the damage and accomplish the subsequent recovery and reconstruction. This requires preparing for disaster by fully implementing the OODA loop described above before the disaster strikes, and by establishing reliable means for data gathering and command and control during the disaster.

(1) Hitachi supplies a comprehensive disaster prevention management solution for dealing with large-scale disasters (see Fig. 5). This solution improves the awareness of personnel and tests command and control functions by conducting training exercises beforehand, and supplies information analysis functions that provide support during the disaster for data gathering and fast decision making by public agencies and local authorities (see p. 160).

(2) A nuclear incident response solution designed specifically for the nuclear power industry supplies enhanced security for nuclear power facilities and associated fields, applications that require especially strong incident response functions (see p. 168).

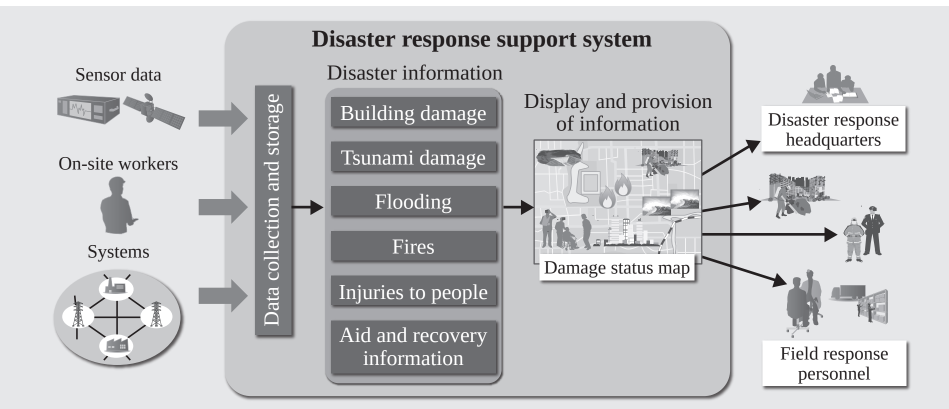

Fig. 5—Example Disaster Prevention Management Solution.
This solution improves the readiness of personnel and tests command and control functions by conducting training exercises, and supplies information analysis functions that provide support during the disaster for data gathering and rapid decision making by public agencies and local government.

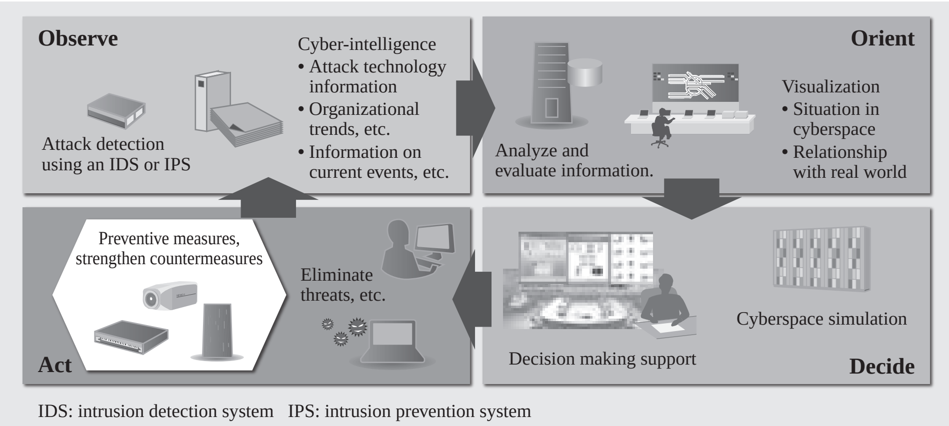

Fig. 6—Example of Cyberspace Security.
The OODA loop is used as a basis for enhancing counter cyber-attack capabilities.

This solution strengthens nuclear incident response functions for dealing with severe accidents, and implements the new recommendations stipulated by the International Atomic Energy Agency (IAEA).

(3) Hitachi supplies a wide-area communication system that coordinates the different communication systems used by government ministries and agencies during a major disaster to provide dynamic information sharing and interconnection between various communication systems (see p. 174).

Cyberspace Security

It is no exaggeration to say that many types of social infrastructure could not function without information systems. This means there is a need to implement the OODA loop in cyberspace to prevent information leaks, cyber-attacks, and other threats.

(1) Hitachi supplies solutions for national security with functions for enhancing counter cyber-attack capabilities based on the OODA loop (see Fig. 6 and p. 180).

(2) A solution designed specifically for defending against information leaks helps keep information assets safe, particularly through the use of information encryption and strengthening measures for preventing the reverse engineering[(b)] of software (see p. 185).

Global Environmental Conservation and Securing of Energy Resources

Securing reliable energy supplies is essential to industrial progress and a civilized lifestyle. On the other hand, indiscriminate exploitation of energy resources results in damage to the global environment and poses a threat to the long-term existence of humanity. Hitachi is taking on the challenge of combining global environmental conservation with a reliable supply of energy.

(1) The carbon-hydride energy storage system is intended for the long-term storage and transportation of hydrogen, a form of energy that is otherwise difficult to handle, by storing it in the form of methylcyclohexane (MCH), a stable liquid (see Fig. 7). The system can

(b) Reverse engineering
The analysis of hardware or software, or the observation and interpretation of its operation, to determine information such as its specifications, design, manufacturing methods, component parts, specific technologies, or source code.

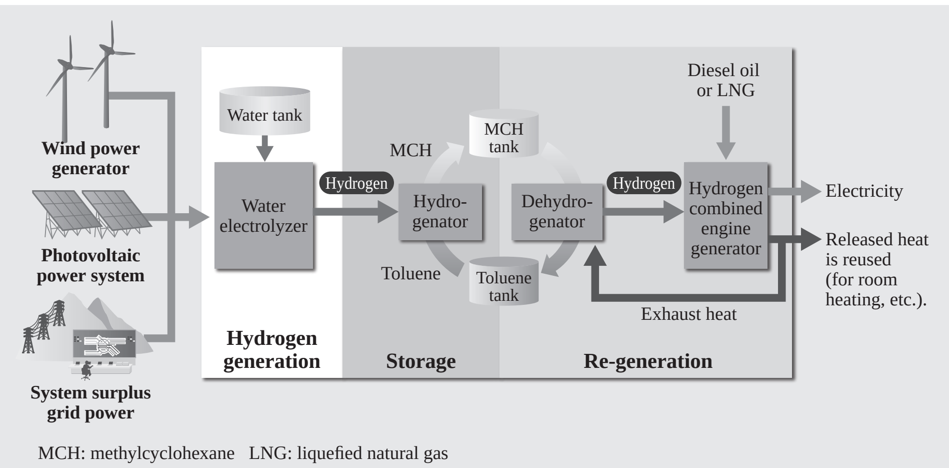

Fig. 7—Overview of Carbon-hydride Energy Storage System.
Renewable energy is stored in the form of MCH and converted to electric power when needed.

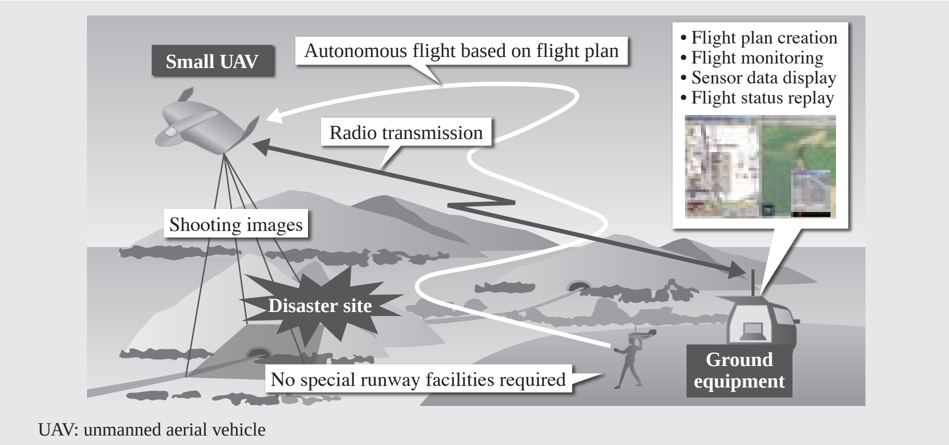

Fig. 8—Example Unmanned Aerial Vehicle System.
UAVs are tools for automatic aerial data gathering that can be used with a small number of people and require only a short takeoff and landing distance.

help achieve a stable supply of renewable forms of energy, such as wind power, that have a fluctuating output, and it can assist in situations where providing energy supplies is a challenge, including remote islands, Japan Ministry of Defense personnel on overseas missions, or places that have become isolated due to a disaster (see p. 192).

(2) Water resource cycle simulation assists with water resource management and countermeasures against flood damage. Hitachi's system includes functions for simulating the combined effects of both surface and ground water (something that was difficult in the past), and functions that provide an intuitive view of the simulation results. This helps solve the various problems associated with water. For example, it can facilitate faster decision making by allowing the current status of water resources or inundation damage to be determined and predictions made about the future (see p. 199).

(3) The satellite imagery solution enables quantitative evaluations to be made of conservation activities by using time-series data that extends into the past and was acquired through the use of satellite images for monitoring. It can support forest conservation by applying imagery analysis and interpretation techniques that Hitachi has built up over time to calculate carbon stock amounts. It can also contribute to the conservation of marine ecosystems through the analysis of ocean images (see p. 204).

Support for Work in Harsh Environments

When an accident occurs, or in a disaster or other emergency, it is sometimes necessary to perform work in situations that are difficult for people to approach directly, such as contaminated land or places where hazardous materials are located. To deal with such situations, Hitachi supplies a range of equipment and systems that support data gathering and situation assessment during an emergency.

(1) Unmanned aerial vehicle (UAV) systems are tools for automatic aerial information gathering that can be used with a small number of people and require only short takeoff and landing distances. Hitachi can provide pilotless operation using autonomous flight control, realtime situation assessment via an aerial mesh network, automation of information analysis, and visualization enhancements (see Fig. 8 and p. 209).

(2) Hitachi is contributing to the security of maritime infrastructure in ways that include the construction of minesweepers that use sonar system technology[(c)] to remove mines so that vessels can travel in safety. Hitachi uses these technologies to supply underwater monitoring solutions for protecting important social infrastructure such as offshore airports and power plants or oil reserve facilities constructed on the shoreline (see Fig. 9 and p. 214).

(3) Japan's landscape is characterized by many rivers and ravines[(d)], and Hitachi supplies prefabricated supporting bridging systems for use in the event of breaks in the transportation infrastructure. The Japan Ministry of Defense uses Hitachi's prefabricated temporary floating bridges that are designed to float on a river and support vehicle traffic, and prefabricated temporary span bridges that can span rivers or ravines without requiring piers. In the Great East Japan Earthquake, a prefabricated temporary floating bridge helped with the recovery effort by ferrying

(c) Sonar system technology
Systems that use sound waves for purposes such as distance measurement and detecting the features of underwater organisms, objects, and topography. Some sonar systems emit their own sound waves and use the echoes to measure the distance and direction of objects. Others can detect and measure the sounds that objects emit themselves.

(d) Ravine
Used here to refer to any crevice or other gap in the earth's surface.

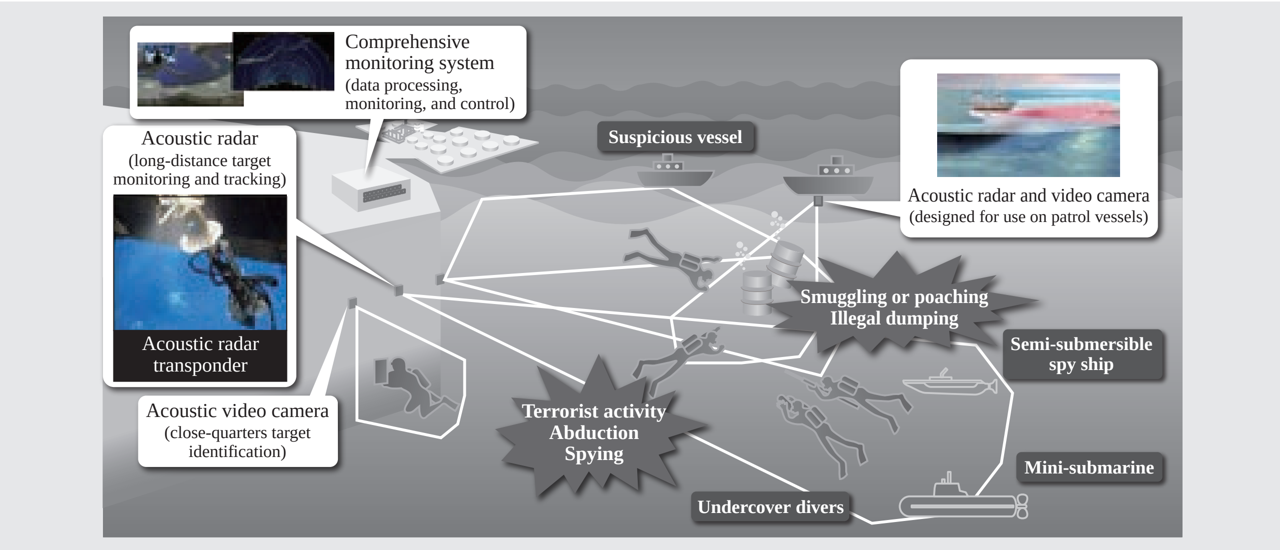

Fig. 9—Underwater Monitoring Solution.
The solution uses sonar system technology to protect important social infrastructure built on the shoreline.

construction machinery to an island that had become isolated due to a collapsed bridge (see p. 219).
(4) Hitachi is contributing to international peace by supplying demining equipment for clearing landmines left in the ground in overseas countries after civil wars or other conflicts. Hitachi is also developing a landmine clearance machine with a remote control function for clearing anti-tank mines (see p. 224).
(5) Hitachi supplied the electric propulsion system for the icebreaker Shirase that transports personnel and supplies to the Antarctic. The system supports the complex ship maneuvering required for icebreaking (see p. 231).
(6) A driverless tractor system used for the transportation of supplies in Antarctica supports the activities of personnel who are wintering over in that region's extremely cold climate (see p. 229).
(7) A radiation measurement device with a color-coded display that measures amounts of radiation over a wide range is helping improve the efficiency of decontamination work in the affected areas (see p. 233).

WORK TOWARD A SAFER AND MORE SECURE SOCIETY

The need to prepare for the unexpected has grown in recent years, and society is seeking ways to achieve this and balance the costs. Hitachi draws on the technologies for safety and security it has built up over time to supply solutions that can deal in a scalable and flexible way with many different situations.

From underwater to outer space and cyberspace, Hitachi intends to utilize its accumulated technical capabilities to contribute to the building of safe and secure social infrastructure that can cope with the unexpected.

ABOUT THE AUTHORS

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Disaster Prevention Management Solution for National Security

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OVERVIEW: Based on lessons from the Great East Japan Earthquake, it is anticipated that even greater steps will be taken at a nationwide level to establish organizations and schemes and provide facilities and systems aimed at mitigating disasters in Japan. In particular, in the case of large disasters that affect a wide area and in which the situation changes rapidly with time, it is vital that an effective response be mounted that includes coordination with national and regional agencies, as well as the general public, in order to reduce the amount of damage and speed up the subsequent recovery and reconstruction. Hitachi already supplies disaster response support systems to central government ministries and agencies as well as local authorities. Currently, Hitachi believes that the best way to ensure national security is by raising awareness through education and training, and through wide-area coordination and decision making that takes account of operational concepts in times of emergency. Hitachi is working to expand disaster prevention management solutions intended to achieve this.

INTRODUCTION

TAKING note of the lessons from the severe damage that resulted from the Great Hanshin Awaji Earthquake in 1995 and the Niigata-ken-Chuetsu Earthquake in 2004, progress has been being made on establishing organizations and schemes and providing facilities and systems aimed at mitigating disasters in Japan. Following the Great East Japan Earthquake that struck in March 2011, it is anticipated that further nationwide measures for mitigating disasters will be undertaken in parallel with ongoing recovery and reconstruction in the affected regions. In particular, there is an urgent need to adopt measures for dealing with large, wide-area disasters that have a high probability of occurring in the next 30 years, such as the predicted Tokai Earthquake, Tonankai/Nankai Earthquake, a four-way simultaneous earthquake in which new Kyushu seismic region is added to these three seismic regions, or an earthquake occurring directly under Tokyo. In response, subjects under discussion include organizational structures and the formulation of a Basic Disaster Management Plan(1) aimed at strengthening the nation’s capacity for dealing with disasters, with the government’s Central Disaster Prevention Council taking a central role.

In addition to these preparatory measures, in order to reduce the amount of damage and speed up subsequent recovery and reconstruction, particularly in the event of a large and severe disaster covering a wide area that exceeds the capacity of local authorities to respond, it is vital that an effective response be mounted that includes coordination with national and regional agencies as well as the general public amid a constantly changing situation.

This article describes two aspects of Hitachi’s work in disaster prevention, a field that represents part of national security, including a disaster response support system currently being supplied and a disaster prevention management solution that is being expanded with the aim of supporting the response to multiple large disasters occurring over a wide area.

DISASTER RESPONSE SUPPORT SYSTEM

An essential requirement for ensuring a rapid reaction and an effective response when a disaster occurs is to make information about the situation available and to share it with relevant agencies. Hitachi has developed a disaster response support system to achieve this and has supplied it to central government ministries and agencies as well as local authorities.

The disaster response support system is based around geographic information system (GIS) technology that manages and utilizes data generated during a disaster in the form of geospatial information. It also includes remote sensing technology for data gathering, and search and distribution technologies

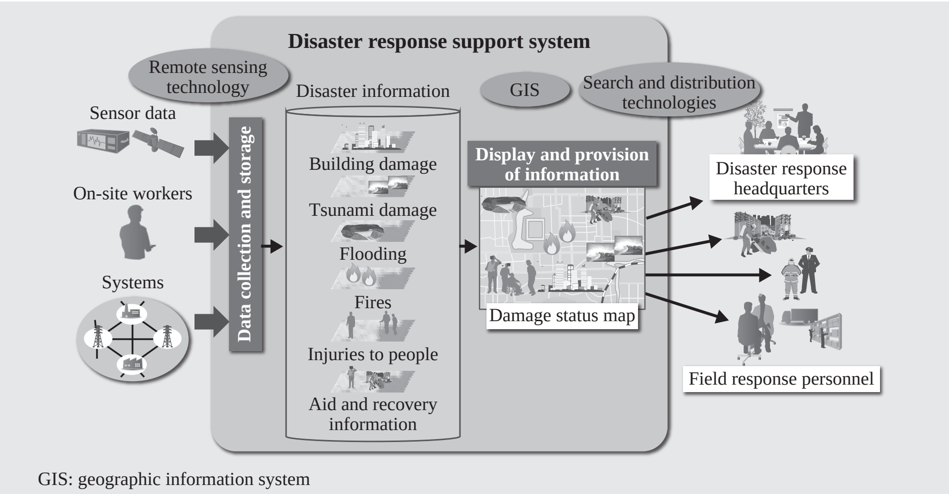


Fig. 1—Disaster Response Support System.
The system collects and collates sensor data and other information about damage acquired from disaster site, and presents it on a map. This provides a visual representation of the situation.

for communications. The system collects and collates information about the disaster and presents it on a map to provide a visual representation of the situation. This includes information acquired from the disaster site or from associated agencies, and also meteorological observations, satellite images, aerial images, and other sensor data (see Fig. 1). Providing the information shown on the map to associated agencies helps these agencies share a common operational picture (COP). Uses include identifying locations where major damage has occurred in order to provide prompt assistance, and enabling different agencies to mount a coordinated response in which each is aware of the others' activities.

Hitachi is investigating ways of enhancing this system to cope with multiple large disasters that occur over a wide area, and that exceed the scope of response able to be mounted by the affected areas.

The next section describes a disaster prevention management solution devised by Hitachi.

DISASTER PREVENTION MANAGEMENT SOLUTION

Philosophy

To cope with situations where large numbers of different incidents occur all at once, such as multiple large disasters occurring over a wide area, the affected local authorities and associated agencies need support to be able to make decisions quickly and accurately.

Also, multiple large disasters occurring over a wide area may exceed, by a considerable margin, the scope of response able to be mounted by the affected area. In this case, with central government, prefectural government, and local governments from neighboring districts each making decisions within their respective jurisdictions and levels of response, there is a need to share the information acquired, to work together to support cities, towns, and villages, and to maintain an environment in which cities, towns, villages, and the local disaster response can operate quickly and effectively.

Also, maintaining an environment in which cities, towns, villages, and the local disaster response can operate quickly and effectively during an emergency requires that training and education be conducted beforehand, including for the general public. In particular, in the case of activities that only occur during an emergency, such as the deployment of aid supplies, it is important that training be conducted during normal times so that adequate consideration can be given to the potential for dysfunction during an emergency due to factors such as that activities include some in which the participants have little experience, that advance plans include uncertainties such as human assistance and distribution resources operated by private-sector companies under specific agreements, and that demand may exceed expectations due to changes in the damage status. The Cabinet Office, local authorities, and other agencies also undertake ongoing steps to promulgate various knowledge about disaster prevention(2). It is believed that the benefits of performing this education and training in advance include reducing uncertainty and facilitating prompt and accurate actions during a disaster.

The Basic Disaster Management Plan of the Central Disaster Prevention Council states that reducing damage (disaster mitigation) requires that everyone, including central government, public agencies, local authorities, service providers, and the general public, work together to adopt the best possible measures. Hitachi believes that the best approach to national security is for decision making during emergencies,

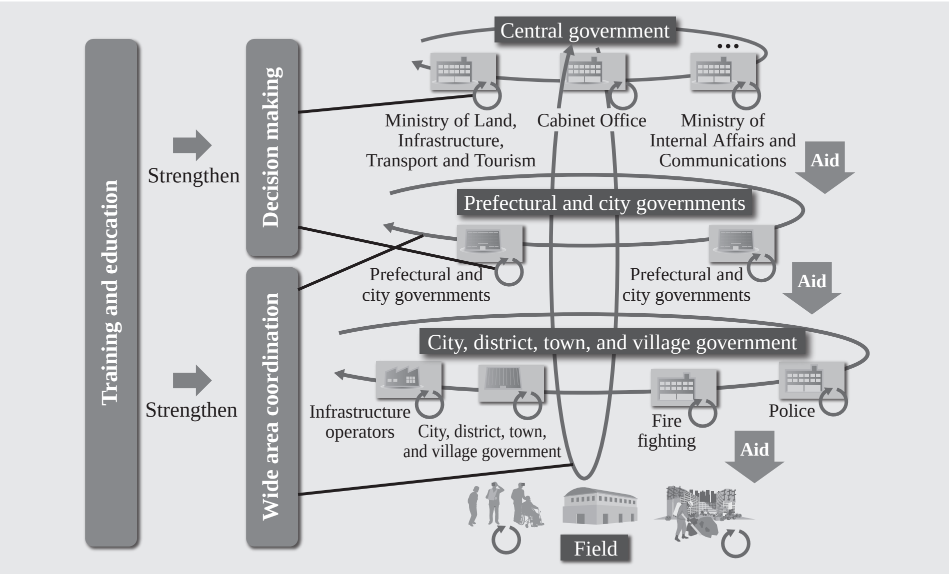


Fig. 2—Best Approach to National Security.
Each organization makes decisions quickly and accurately, with horizontal and vertical sharing and coordination of information. Also, training and education are conducted beforehand to ensure that these organizations function effectively during an emergency.

wide area coordination, and advance training drills to be conducted throughout Japan (see Fig. 2).

Solution Overview

Based on the above philosophy, the disaster prevention management solution supplies solutions that satisfy the following requirements for dealing with multiple large disasters occurring over a wide area.

(1) Decision support solution for faster and more accurate decision making

(2) Wide-area coordination support solution for coordinating activities and sharing information across different organizations

(3) Training and education support solution to improve disaster response capabilities

The disaster prevention management solution uses the observe, orient, decide, and act (OODA) loop decision methodology to facilitate fast and accurate decision making.

Based on insights from aerial combat, the OODA loop concept formalizes the situation response process, including decision making by the commanding officer. It achieves fast and accurate decision making by performing a repeated cycle of observation, orientation, decision, and action. The method is characterized by observation and situation assessment. The OODA loop method observes actual circumstances to obtain an overview of the situation before putting a plan into action. It also involves making predictions based on observations when obtaining an overview. While the method was developed for the battlefield where the aim is to maintain the upper hand without taking casualties amid circumstances that are changing rapidly, a situation that is constantly changing is a feature that both battlefields and large disasters have in common. The basis of OODA is about striving to maintain an understanding of the situation and to identify how far ahead it is possible to see, and these elements also form part of disaster response. How quickly the OODA loop can be worked through when responding to a disaster is the key to a successful disaster response (see Fig. 3).

Based on the OODA loop concept, the disaster prevention management solution overlays the rapid incoming flow of disaster information onto a map to manage it in temporal-spatial terms. This provides a service that produces intelligence for use in decision making and helps achieve a nationwide coordinated approach to Japan's national security that transcends the barriers between different organizations and people. Fig. 4 shows overview of the service.

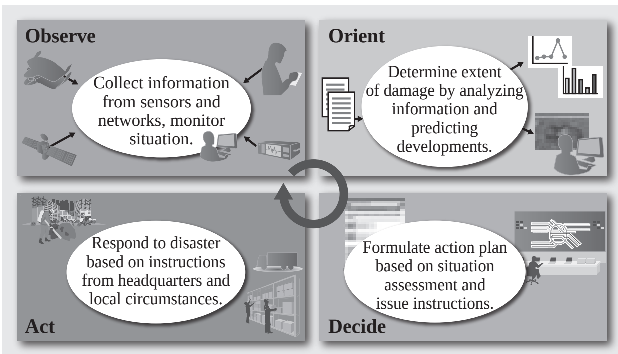


Fig. 3—Use of OODA Loop in Disaster Response.
Disaster response is conducted through an "observe, orient, decide, and act" cycle.

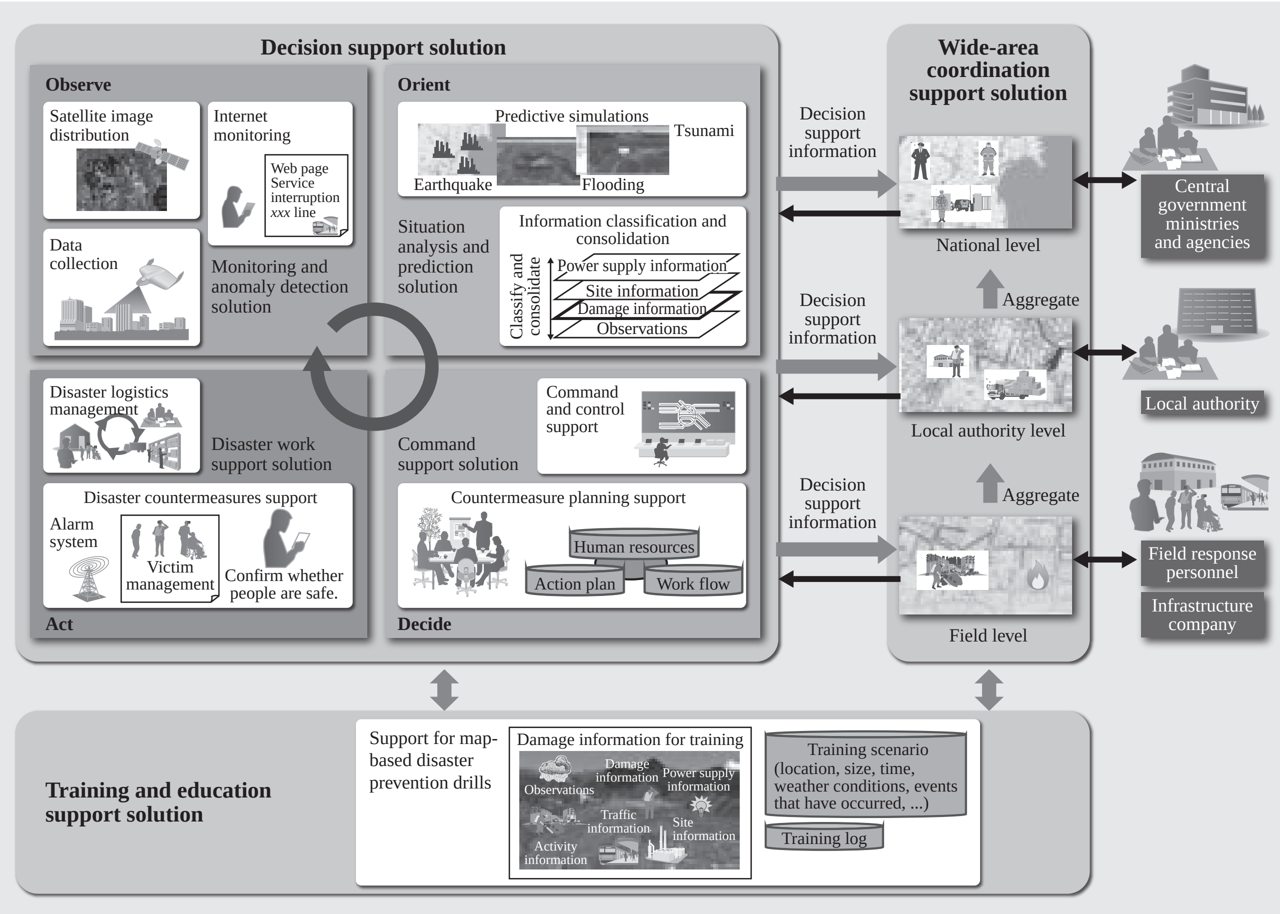


Fig. 4—Disaster Prevention Management Solution.
The disaster prevention management solution supports the best approach to disaster response through a decision support solution for faster and more accurate decision making based on the OODA concept, a wide-area coordination support solution that uses a GIS to share information that has been processed in accordance with OODA and present it with appropriate granularity, and a training and education support solution that supports risk awareness and response training.

Decision Support Solution

As noted above, the key to successful disaster response is to work through the OODA loop decision making cycle quickly and accurately. Hitachi supplies the following solutions that support this cycle.

Monitoring and anomaly detection solution

This solution collects information from sources such as sensors [seismometers, river level gauges, surveillance cameras, unmanned aerial vehicles (UAVs), satellites, and so on] and Internet social networking services (SNSs) to enable functions such as status monitoring in which this collected data is integrated with geospatial information, and anomaly detection is performed using techniques such as difference extraction (see Fig. 5).

Situation analysis and prediction solution

This solution provides functions for collating and classifying the information collected by the monitoring and anomaly detection solution and other systems to enhance its value as intelligence for use in situation analysis and prediction (see Fig. 6). It uses information classification techniques to classify

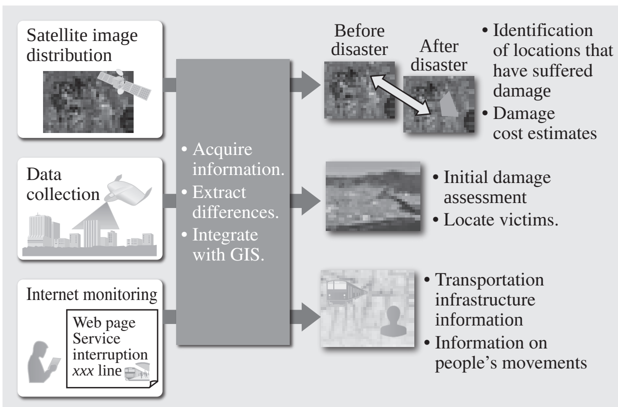
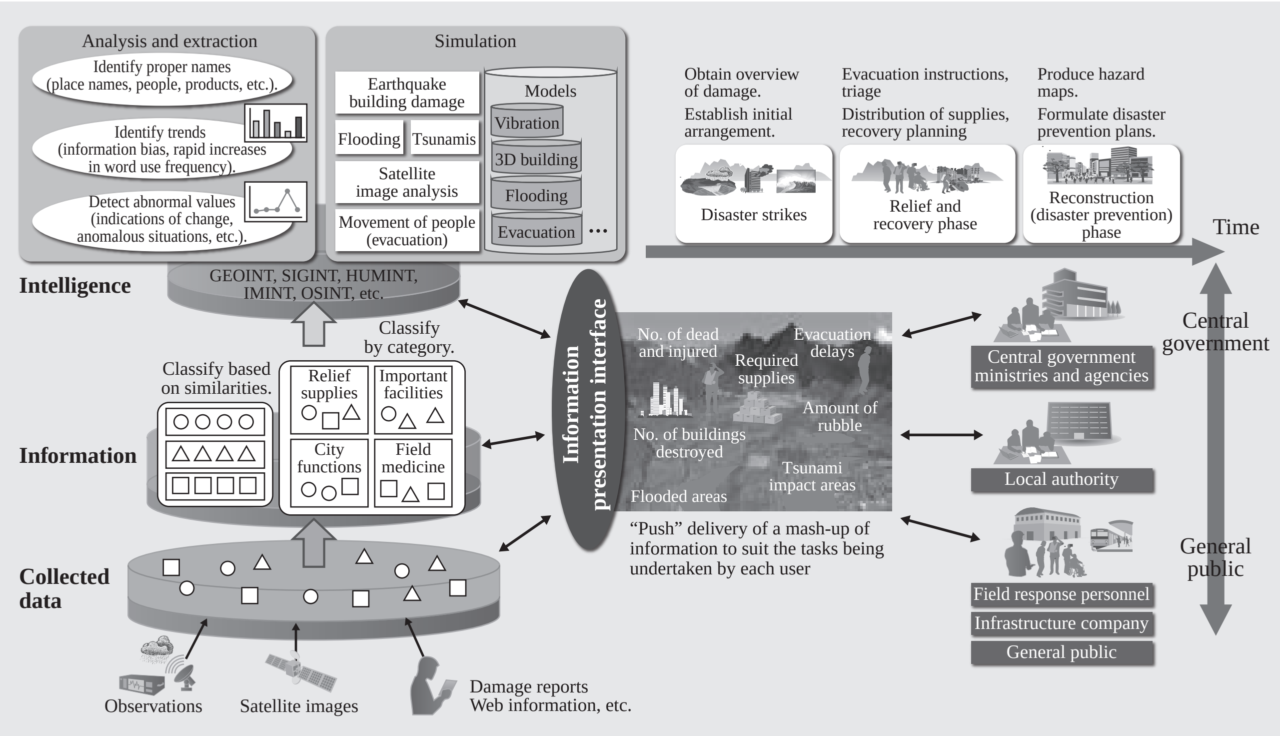


Fig. 5—Monitoring and Anomaly Detection Solution.
The solution collects information from sensors, the Internet, and other sources and detects any anomalies.



GEOINT: geographic intelligence SIGINT: signal intelligence HUMINT: human intelligence IMINT: imagery intelligence OSINT: open source intelligence
3D: three dimensions

Fig. 6—Situation Analysis and Prediction Solution.
The solution collects sensor data, damage reports, and other information, adds value by transforming it into intelligence, and presents each user with a mash-up of information suitable for the tasks they are undertaking.

and collate information based on similarities and categories, making it easier to obtain the desired information. This includes processing information in various ways such as collating damage statistics by region or sorting information by purpose (relief aid, healthcare, and so on), for example. It also generates intelligence that helps determine further action by, for example, using data mining technology to perform analyses and extract proper names, place names, and other identifiers to convert text data into geospatial information for display on a map, or detecting trends in word use on the Internet to identify what issues are concerning the general public. The solution also uses simulation techniques for earthquake building damage, flooding, tsunamis, or the movement of people to conduct risk simulations and provide information to help determine the current situation and assess changing circumstances and possible future developments.

The solution classifies and collates information from sensors, such as river level gauges, to calculate the rise in river levels, and incorporates information about upcoming weather conditions to perform flooding simulations. This can be used to generate intelligence such as warning that a particular district is at risk of a levee breach in an hour's time, for example. Intelligence like this facilitates fast and accurate decision making on evacuation alerts.

Utilizing this calculated intelligence in the actual disaster response requires screen information design that allows users to obtain knowledge in ways that take account of their responsibilities as well as where and in what circumstances they need this knowledge. This solution uses the concept of universal design and is based on screen designs that enhance situational awareness and prevent users from overlooking or misunderstanding information, regardless of their ability to utilize it. Meanwhile, the interface can be customized to display different information to suit each user, providing a mash-up that prioritizes information based on the nature of the user's activities, from the initial time of the disaster through to the reconstruction phase.

Command support solution

This solution supports effective and efficient command and control for relief and recovery. For example, it provides the disaster response headquarters with a map of the disaster situation that they can refer to as they assign people, organizations, and other resources in accordance with the evolving situation on the ground.

This solution builds a database from which the data required for the tasks associated with the event and their execution can be accessed quickly based on an event model of the time when the disaster strikes, a disaster response model (work flow), a data model that specifies the relationships between data, and a disaster management model that links these other models together. This allows the "push" delivery of information based on users' circumstances and responsibilities (see Fig. 7). For the people assigned the task of distributing relief supplies, for example, the solution supplies the information needed to compete this task, namely the information associated with the distribution of relief supplies (road damage status, where to distribute supplies, recommended routes, and so on).

Disaster work support solution

This solution provides functions for managing the activities of local authorities (confirming the safety of staff, evacuation site management, issuing victim certificates, and so on) as well as requests for relief supplies, stock control, dispatch instructions, and other aspects of logistics.

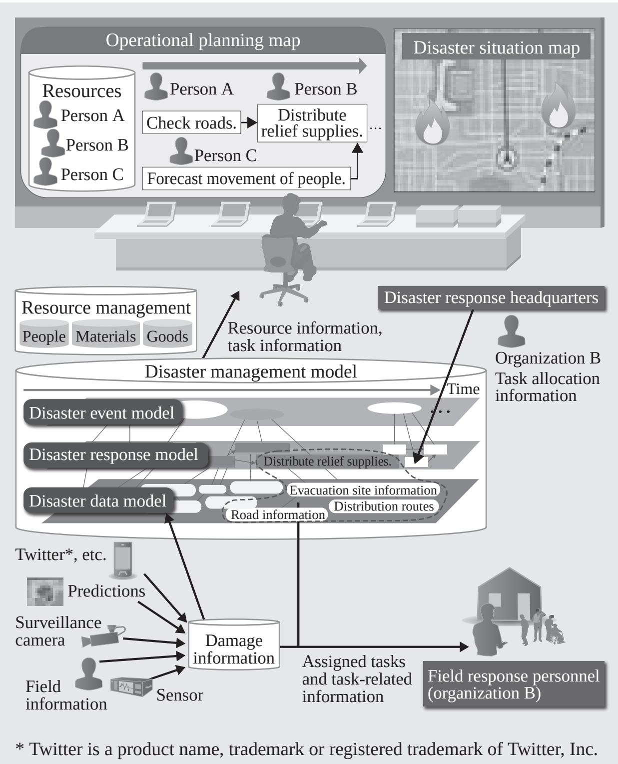


Fig. 7—Command Support Solution.
This solution is used to prepare an activity plan and support the assignment of personnel, organizations, and other resources. When a task is assigned to a person or organization, the information required to complete that task is extracted from the database and supplied to the person or organization using "push" style delivery.

Wide-area Coordination Support Solution

This solution uses a GIS to supply information that has been processed in accordance with OODA at an appropriate level of granularity. By sharing common information, the solution provides a consistent understanding of the situation while also presenting information in ways that suit the different response levels of each organization, thereby enabling coordination over a wide area. Information can also be provided in a range of forms to facilitate its distribution and reuse, including the international standard emergency data exchange language distribution element (EDXL-DE) format and public information commons(3) format (see Fig. 8).

Training and Education Support Solution

When it comes to saving people's lives, assisting people and having them help themselves to evacuate (survive) are both important. To assist people to evacuate, it is essential that disaster training be carried out beforehand so that the decision making and wide-area coordination described above can function immediately when a disaster strikes, particularly in the area of administration. For people to evacuate themselves, it is necessary to identify all the potential hazards and features of the place where they live, and to give them an idea of how a disaster will unfold.

This solution supports disaster response training for official personnel, residents and other participants by using a simulation to create a virtual disaster, displaying the situation on a map, and assigning missions from a training scenario (map-based disaster prevention drill). The solution also helps improve awareness of disaster prevention by providing individual residents with a hazard map based on their own residential circumstances and living arrangements (commuting, travel, and so on) (see Fig. 9).

Disaster Prevention Cloud Service

Taking note of what happened during the Great East Japan Earthquake, there is a growing need for remote support and the provision of information via networks by the central government, participating local authorities, volunteers, and others, and for the rapid restoration and maintenance of administrative services in situations in which government offices

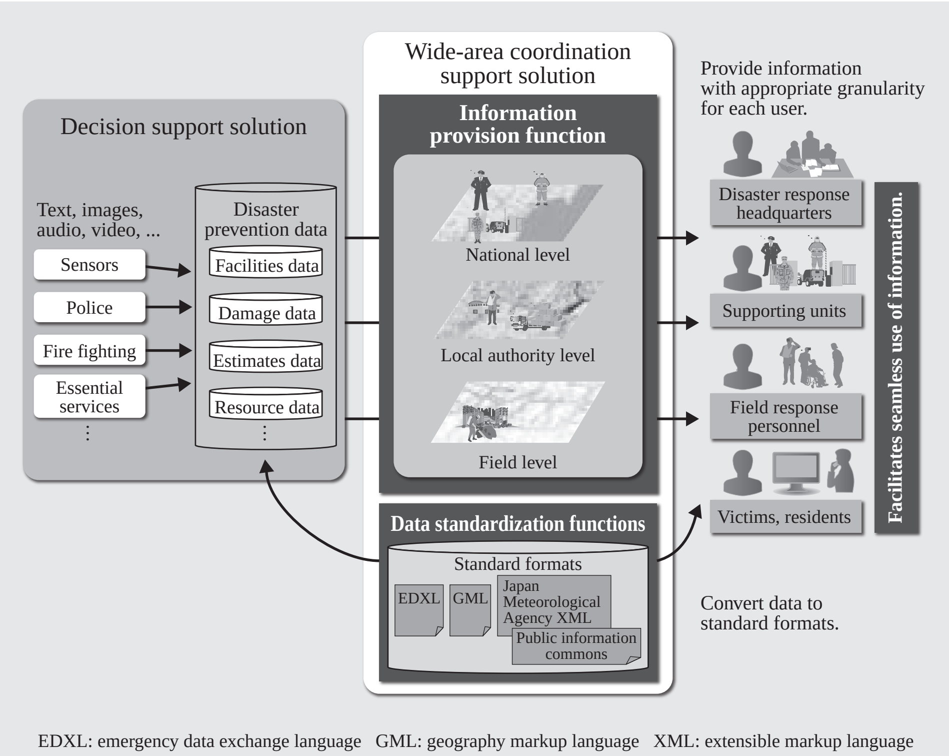


Fig. 8—Wide-area Coordination Support Solution.
This solution facilitates seamless use of information across different organizations.

have been damaged. By providing systems such as the disaster response support system and disaster prevention management solution via Hitachi's cloud (including Hitachi cloud computing solutions), which is referred to below as the disaster prevention modeling and simulation (M&S) cloud, Hitachi aims to satisfy these needs by supplying a wide range of disaster prevention services in accordance with users' actual circumstances (environment, cost, and robustness requirements). The forms in which these services can be provided include software-as-a-service (SaaS), in which a disaster prevention management solution is implemented at a robust Hitachi data center and supplied to the customer as a service; as a private solution, in which a customer-specific disaster prevention M&S cloud is implemented at a Hitachi data center; and as an on-premises solution, in which a disaster prevention M&S cloud is implemented on the customer's own systems. In addition to providing a disaster prevention management solution via a disaster prevention M&S cloud, the data standardization functions described above also support the sharing and utilization of information across different customers and support organizations. Hitachi also supplies autonomous and decentralized cloud services that perform data backups and similar functions for Hitachi data centers, customers who have installed a disaster prevention M&S cloud on their own systems, or across multiple customer sites, so that services can be restored quickly using an alternative healthy site if these are put out of action during an emergency (see Fig. 10).

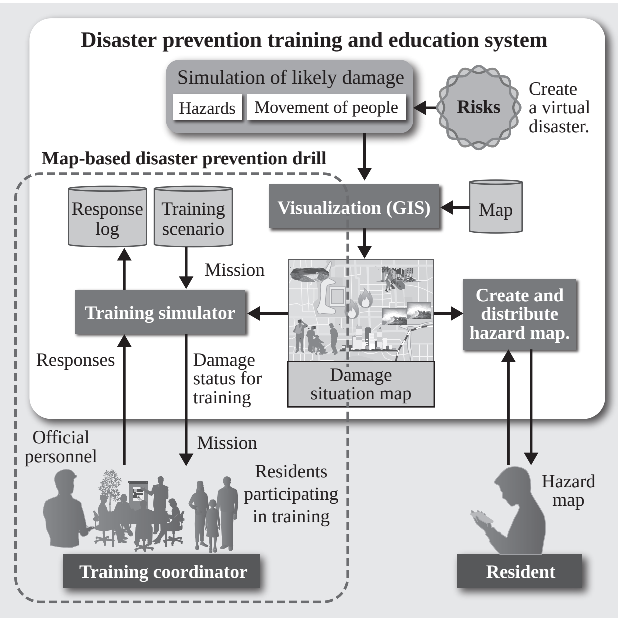


Fig. 9—Training and Education Support Solution.
This solution supports the conducting of map-based disaster prevention drills by residents and official personnel. It also provides individual residents with a hazard map based on their own residential circumstances, living arrangements, and other factors.

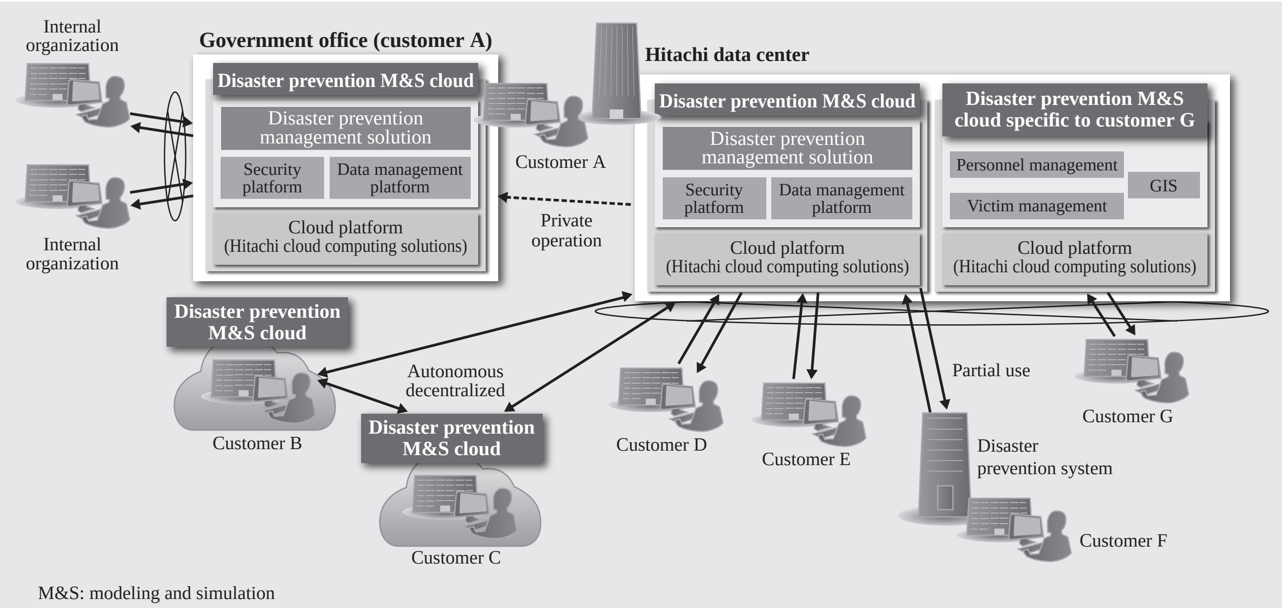


Fig. 10—Disaster Prevention M&S Cloud.
Hitachi provides a wide range of disaster prevention management solutions to suit users' actual circumstances (environment, cost, and robustness requirements).

CONCLUSIONS

This article has described two aspects of Hitachi's work in disaster prevention, a field that represents part of national security, including a disaster response support system currently being supplied and a disaster prevention management solution that is being expanded with the aim of supporting the response to multiple large disasters occurring over a wide area.

In the future, Hitachi aims to contribute to the achievement of national security, in which central government, local authorities, private-sector companies, and the general public work together, by helping to achieve safety and security from the perspective of disaster prevention in the planning, construction, and operation of smart cities and other types of next-generation cities (a field that Hitachi is pursuing globally), while also keeping in mind the prospects for initiatives such as international cooperation on disaster prevention to reduce the impact of disasters around the world, and international collaborations such as international relief aid when disasters strike.

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Nuclear Security and Incident Response

Kazuhiko Tanimura
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OVERVIEW: Since the Great East Japan Earthquake, there has been a requirement for even greater strengthening of nuclear incident response functions. It is also assumed that compliance with new recommendations issued by the IAEA in 2011 aimed at preventing terrorism will be required in the future. In addition to its know-how in ensuring the reliability of nuclear power plants built up through the past activities of its nuclear power business, Hitachi also has know-how in C2 and training exercise functions acquired through its defense business, and technologies and products in the field of crisis management. Hitachi intends to utilize these to make an even greater contribution to nuclear power plant safety and peace of mind in the future, including new nuclear incident response and security functions.

INTRODUCTION

LIVELY debate on the use of nuclear energy is currently ongoing in a variety of forums, and one of the issues raised in the context of new policy for nuclear power has been the strengthening of functions for incident response in the event of a severe nuclear accident.

Meanwhile, it is anticipated that use of nuclear energy will be pursued internationally in the future as an effective means for the development of emerging nations and for countering global warming.

Use of nuclear energy clearly requires meticulous design of systems that provide rigorous levels of safety, and there are calls to strengthen nuclear incident response functions to keep damage to a minimum in the event that a disaster does occur. There is also a need to strengthen security functions that protect against not only natural disaster and accidents, but also human threats such as terrorism(1).

In this context, the International Atomic Energy Agency (IAEA) issued a revised version of the "Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities" (INFCIRC/225/Revision 5) in 2011. The new revision included additional material relating to preventing nuclear terrorism that was motivated in part by the 9/11 terrorist attack in the USA.

This article describes how, with a view to compliance with Revision 5 of the IAEA Nuclear Security Recommendations, Hitachi aims to make further improvements in the future to the safety and security of nuclear power plants through new nuclear incident response functions that utilize know-how derived from its experience in the defense and security businesses, which include command and control (C2) and training exercise functions, and also technology for security systems.

ROLES OF NUCLEAR SECURITY AND INCIDENT RESPONSE

Table 1 lists the roles of nuclear security and incident response. The purpose of nuclear incident response is to protect the public, as stipulated in the 2004 Civil Protection Law (the Law Concerning

TABLE 1. Roles of Nuclear Security and Incident Response
The purpose of nuclear incident response is to protect the public, and the purpose of security is to protect nuclear material and information about nuclear material.

Items	Nuclear incident response	Security
Potential threat	• Natural disasters • Plant accidents (• Armed or terrorist attack)	• Armed or terrorist attack • Cyber-attack
Objective	• Protect general public.	• Protect nuclear material and information about nuclear material.
Users	• Central government • Local authorities (local government) • Nuclear power companies	• Nuclear power companies • Security forces (police, Japan Coast Guard)
Existing functions	• Radiation management • Radiation monitoring (local government, power companies)	• Nuclear PPS (compliance with Revision 4 of the IAEA Nuclear Security Recommendations)
Common requirements for next-generation systems	• C2 (COP, M&S technology) • Training (exercise scenarios, TTX/CPX/FTX) • Cyber-security	

PPS: physical protection system IAEA: International Atomic Energy Agency
C2: command and control COP: common operational picture
M&S: modeling and simulation TTX: table top exercise
CPX: command post exercise FTX: field training exercise

the Measures for Protection of the People in Armed Attack Situations, etc.), and the purpose of security is defined in the IAEA recommendations as "the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.(2)"

In the past, the systems used for these purposes have been implemented independently. Although planned and implemented separately, parts of the designs and utility systems and equipment can be shared, with examples including differentiating between unnecessary and useful redundancy, mutual backup, and complementarity. Based on experience from incidents such as the Great East Japan Earthquake and the 9/11 terrorist attacks, there is also a need to strengthen cyber-security to prevent malicious attacks and thefts of information, and also to provide comprehensive C2 and training exercise functions so that the organizations that operate incident response and security systems can function more quickly and effectively (see Fig. 1).

NUCLEAR INCIDENT RESPONSE

Training in the defense sector includes the regular conduct of a variety of exercises aimed at raising the preparedness of personnel and organizations, including table top exercises (TTXs), command post exercises (CPXs), and field training exercises (FTXs). This allows these organizations to maintain their ability to react appropriately to all sorts of different situations, as was demonstrated by many news reports relating to their disaster relief activities in the aftermath of the Great East Japan Earthquake.

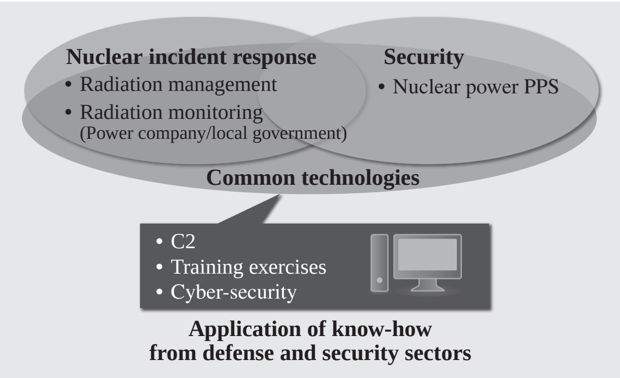


Fig. 1—Application of Know-how from Defense and Security Sector.
Know-how from the defense and security sector is applied to nuclear incident response and security to make further improvements in safety and peace of mind.

In the case of the emergency response to a severe accident at a nuclear power facility, it is worthwhile drawing on know-how in C2, training exercises, cyber-security, and other fields derived from the defense and security sectors to enhance functions for responding to a severe accident.

(1) C2

Establishing a common operational picture (COP) is one of the key concepts of C2. Having participants share a progressively changing situation in realtime allows the commander to issue appropriate instructions on what to do next, and personnel in the field can anticipate what preparations to make for the next tasks to be accomplished. When sharing information, providing people with information in accordance with their particular roles and responsibilities prevents them from being overwhelmed by large amounts of information.

In addition to the current plant status and level of radiation, other information that could be presented in a COP includes drawings and computer-aided design (CAD) data, tasking lists (realtime display of tasks, events, and task progress to groups formed during an emergency), aerial or satellite images, and the security information described later in this article (see Fig. 2).

(2) Training exercises

Training exercises are very important for ensuring that an accurate response is mounted when an incident occurs. The different types of training exercises include TTXs, in which a problem is debated around a table and a solution devised; CPXs, which are used for decision making training, and in which role playing based on simulation plays a central part; and FTXs, which involve practicing actual response activities in the field. In addition to making the various objectives of an exercise clear, establishing the framework for conducting exercises is also important. Once the

Fig. 2—C2 Image.
The COP function for sharing a changing situation in realtime at the command center and in the field is one of the key concepts.

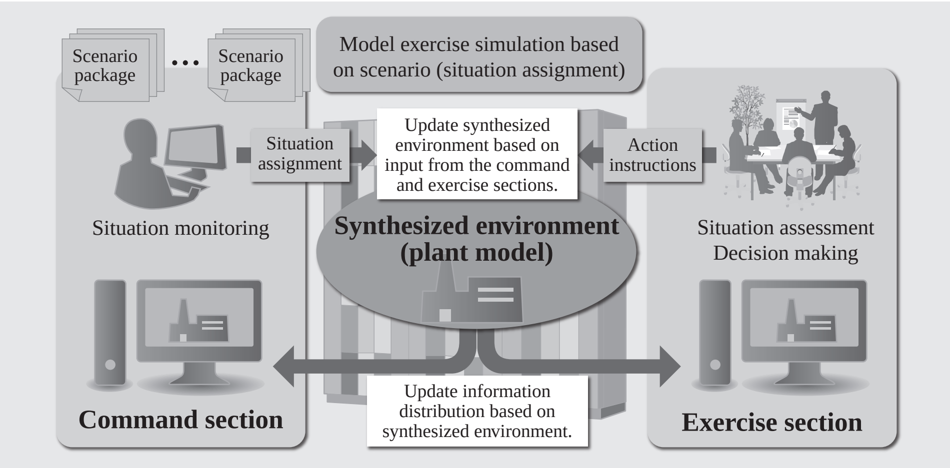


Fig. 3—Training Exercise Image.
To improve the effectiveness of training exercises, they are conducted based on scenarios created for each exercise objective.

objectives and exercise framework have been put in place, the exercise can be organized into scenario packages for each objective. These scenario packages are used in the process of conducting the exercise and for purposes such as assigning situations.

The C2 COP display includes exercise mode functions that enhance the effectiveness of an exercise by allowing people to view the assigned situations on screens that are formatted the same as the actual displays (see Fig. 3).

SECURITY

Security Trends

The focus on security that dates back to the Convention on the Physical Protection of Nuclear Material (CPPNM) in 1980 was initially concerned with ensuring the security of cross-border transportation. Subsequently, taking note of new concerns such as the diversion of nuclear materials resulting from the breakup of the Union of Soviet Socialist Republics and the September 11, 2001 terrorist attacks, the CPPNM was revised in 2005, extending its scope to also include the security of nuclear plants and the nuclear materials held by each country[3]. In December 2005, Japan amended the Nuclear Reactor Regulation Law (Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors) to strengthen the scope of nuclear material security. A Nuclear Security Summit was held in Washington, D.C. in the USA in April 2010, and the IAEA issued Revision 5 of its Nuclear Security Recommendations in November 2010.

Revision 5 of the IAEA Nuclear Security Recommendations designates the utilities that possess and manage nuclear material at nuclear facilities or other sites as having primary responsibility for conducting risk analyses of physical protection, and for implementing systems based on these analyses, expanding crisis management plans to include the period after actions that cause damage or other disruption, and putting organizational arrangements in place.

Main Points of Revision 5 of IAEA Nuclear Security Recommendations[1], [3]

Revision 5 of the IAEA Nuclear Security Recommendations adds the following requirements for the security of nuclear facilities.

(1) Need for design of delaying measures

Consideration of nuclear security from the site selection and design stage

(2) Response that takes account of potential for coordination between external and insider threats

(3) Measures for dealing with remote attacks and cyber-attacks, etc.

(4) Introduction of a nuclear security culture

(5) Force-on-force exercises

Recommendation of regular performance testing and TTX

(6) Sharing of measurement management information

(7) Installation of backup alarm stations

(8) Redundancy for central alarm stations

Security System Solution

The following solutions are available for implementing the security enhancements specified in Revision 5 of the IAEA Nuclear Security Recommendations described above. These solutions are supplied through Hitachi's defense and social infrastructure security businesses.

(1) Flexibility to establish delaying measures

It is assumed that measures such as the installation and reassignment of sensors through the application

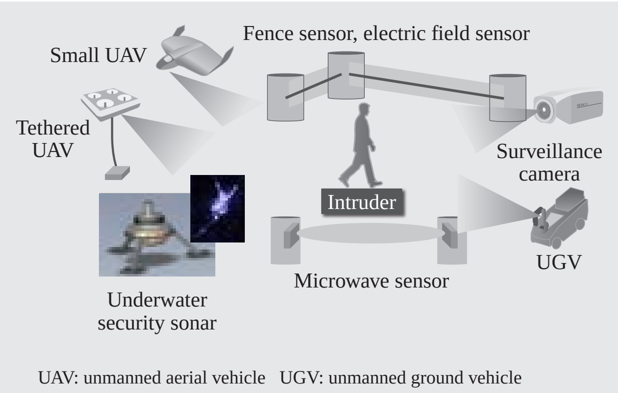


Fig. 4—Overview of Monitoring Sensors.
Appropriate monitoring sensors are selected to suit the location and purpose from among the wide range of sensors available.

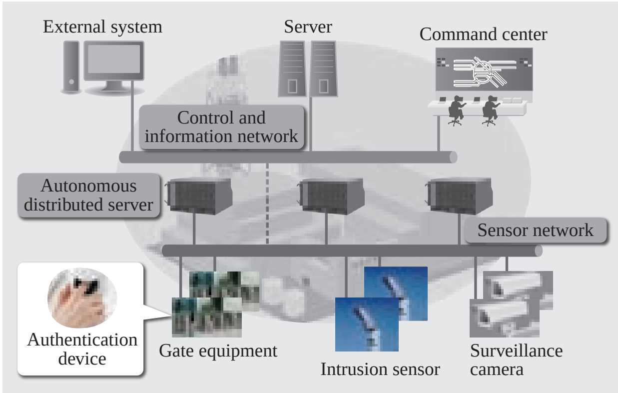


Fig. 5—Highly Reliable Design Using Autonomous Distributed Architecture.
An autonomous distributed architecture is used to achieve a fault-tolerant system design.

of graded methods will be used to establish or change protected areas. When installing gates and other provisions for access control, appropriate sensors, gates, and other devices can be selected from the range of such equipment available for this purpose (see Fig. 4).

These devices are connected to autonomous distributed servers that are installed at different locations, as required. Use of an autonomous distributed architecture with a fault-tolerant system design that complies with the IEC 61508 standards (International Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems) allows the system to operate continuously in such a way that the overall system can maintain the required level of functional performance even when equipment is upgraded or retrofitted (see Fig. 5).

Command centers are designed to coordinate information from sensors and video surveillance, while also reducing the amount of surveillance work required from security staff by using automatic tracking, whereby suspicious activity and other features of people and vehicles within the monitored area are identified from a large number of surveillance cameras (see Fig. 6).

(2) Cyber-security

As frequent cyber-attacks targeting particular groups or organizations have occurred in recent years, there is a need to provide stronger protection against such attacks on important infrastructure. Measures that can be used against threats from insiders include solutions that encrypt all data on hard disk drives (HDDs) and other devices so as to prevent access from all but authorized personnel (see Fig. 7 and Fig. 8).

(3) Force-on-force exercises

The use of personal equipment such as wearable communications devices, sensors, and ad hoc communications is considered to be an effective way to conduct worthwhile FTXs at a level commensurate with the force-on-force exercises conducted in the USA and other countries. Having guards and other security staff wear such devices facilitates the realtime sharing of information and the rapid and accurate issuing of instructions (see Fig. 9).

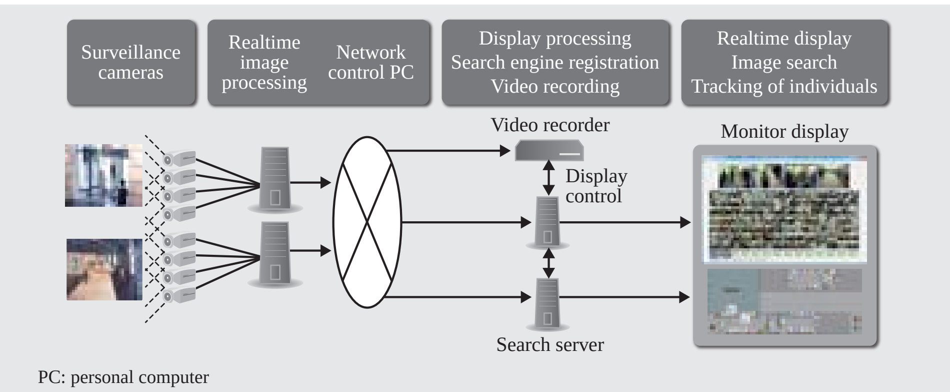
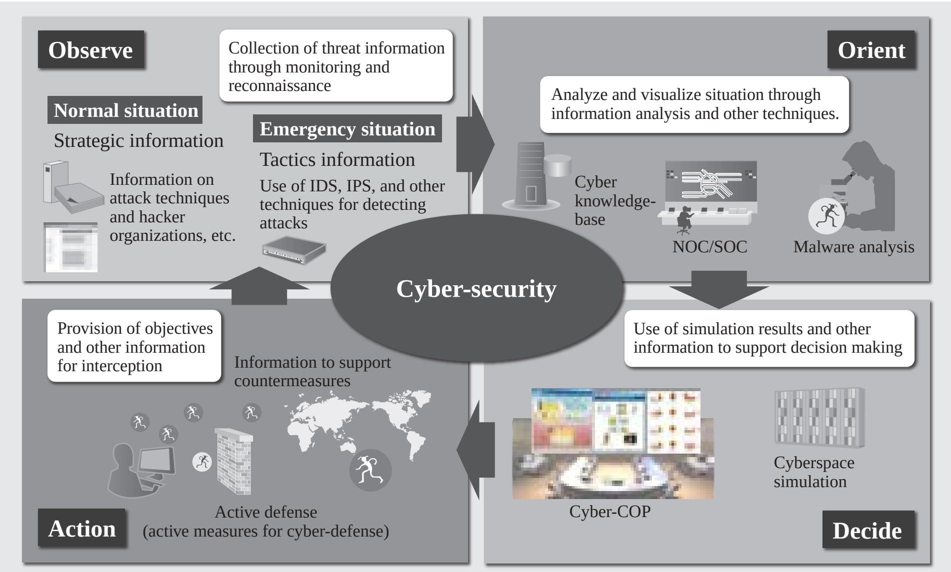
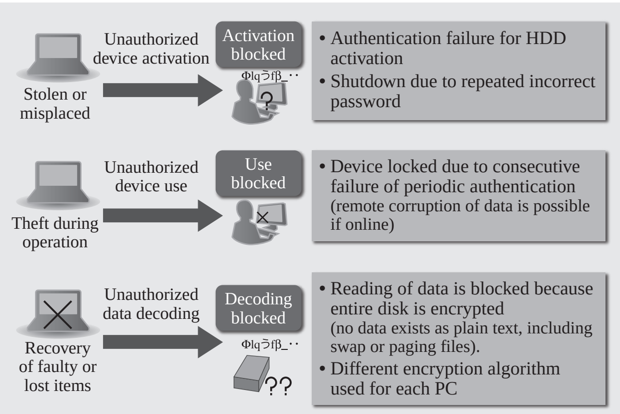


Fig. 6—Extensive Video Surveillance.
Automatic tracking is performed by identifying features or suspicious activity by people or objects from a large number of surveillance cameras.



IDS: intrusion detection system IPS: intrusion prevention system NOC: network operation center
SOC: security operation center

Fig. 7—Cyber-security.
Cyber-security guards against cyber-threats by establishing the cyber-security cycle of observe, orient, decide, and action.



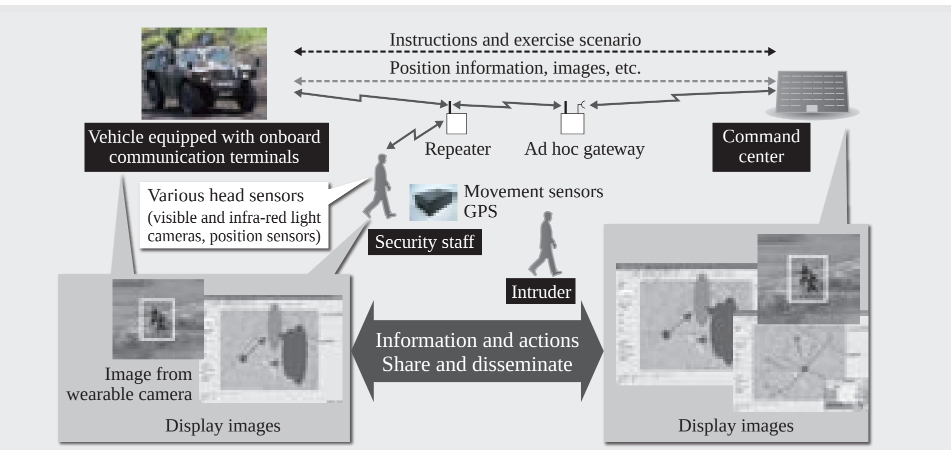
HDD: hard disk drive

Fig. 8—Use of Hard Disk Encryption.
Hard disk encryption is used to protect against theft and other threats.

CONCLUSIONS

This article has described how, with a view to compliance with Revision 5 of the IAEA Nuclear Security Recommendations, Hitachi aims to make further improvements in the future to the safety and security of nuclear power plants through new nuclear incident response functions that utilize know-how derived from its experience in the defense and security businesses, which has been applied to C2 and training exercise functions, and also technology for security systems.

Use of the C2 concept from defense systems is considered to be an effective way of conducting operations efficiently in the event of a severe accident. Conducting regular training exercises is also important, and their uses include demonstrating safety



GPS: global positioning system

Fig. 9—Information Sharing in FTX.
The use of personal equipment, such as wearable communications devices, sensors, and ad hoc communications, is an effective practice for the conduct of training exercises.

and security to the general public as well as preparing for an actual incident.

It is also likely that there will be situations during major disasters, such as the Great East Japan Earthquake, that require joint operations and the coordination of information in incident response and security systems. Possible examples of this include conducting investigations from the perspective of mutual back up of nuclear incident response and security systems in relation to requirements such as the need for redundancy in central alarm stations stipulated in Revision 5 of the IAEA Nuclear Security Recommendations.

In addition to the solutions described here, Hitachi also has a range of other technologies suitable for use in crisis management at nuclear power plants, including enterprise asset management that incorporates preventive maintenance and anomaly prediction and detection techniques that use data from plant sensors, wearable communication devices, and containerized data centers. Hitachi also supplies a wide range of other systems associated with nuclear power generation, including power reactors, reactor core control, electric power generation and transmission control, radiation management, and environmental monitoring systems, and believes itself capable of helping achieve further improvements to the safety and security of nuclear power plants.

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Flexible Communication Infrastructure Using Existing Systems and Terminals

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Kazunori Muraki

OVERVIEW: In the aftermath of the Great East Japan Earthquake that inflicted tremendous damage over a wide range of areas, disruptions in communications caused functional failures in a variety of different systems, which in turn complicated and caused confusion in the exchange of information. This led to a renewed awareness of the importance of communication infrastructures in securing the ability to share identical information between civil services. In response, Hitachi is providing a wide-area communication system that is being realized as a part of the Great East Japan Earthquake recovery projects. This system is designed to "integrate information via an IP network" as the desired communication infrastructure, and has been adopted as versatile joint communication equipment at Matsushima Air Base of Japan Air Self-Defense Force.

INTRODUCTION

THE communication infrastructures used by civil services are comprised of regular work wireless, disaster control wireless, internal telephone networks, security systems, and other systems, and are independently constructed and utilized by each civil service. Since these communication systems have been independently developed, operated, and maintained over many years, the mutual exchange and sharing of information between communication systems have been lacking. This has made it difficult to implement the seamless exchange of information between various

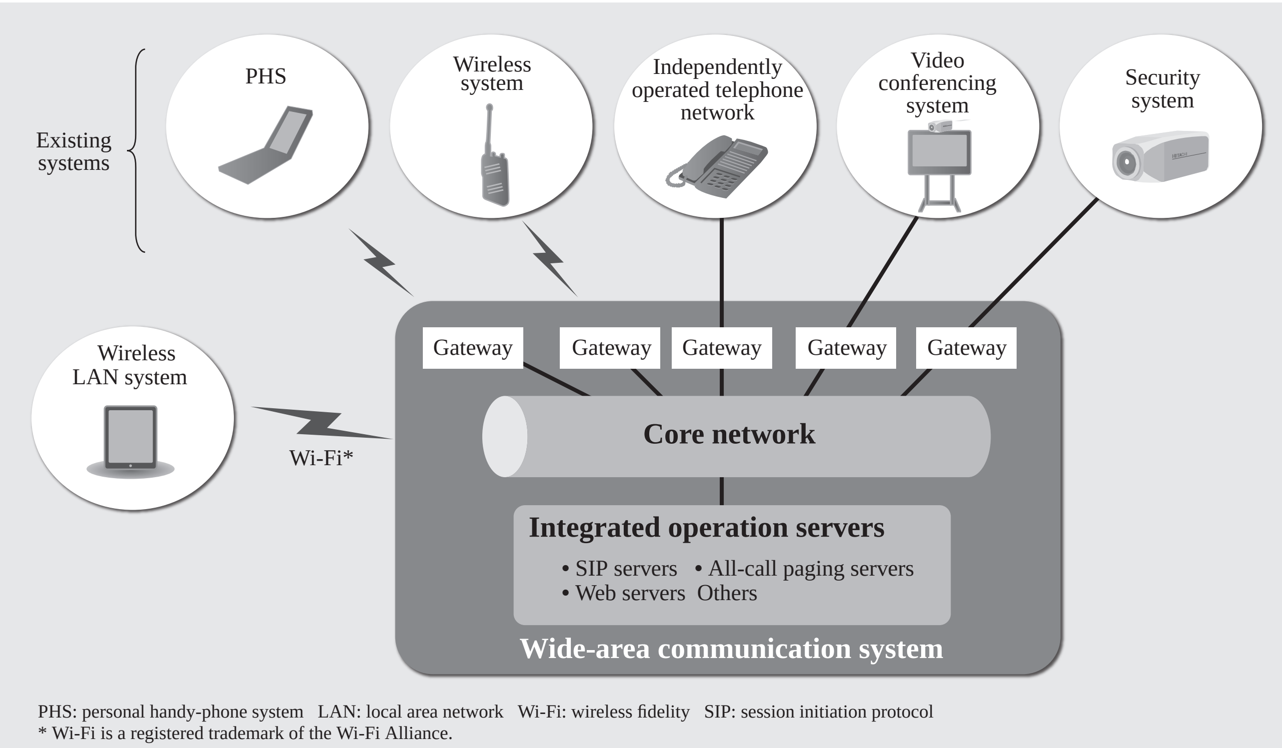

Fig. 1—Connection between Wide-area Communication Systems and Existing Systems.
The construction of systems centered on a core network makes it possible to seamlessly share information.

systems used by civil services and departments, or to implement automation processes that work over multiple systems, and in many cases information has been shared manually through the use of memos, messages, and other methods that require human intervention. It is essential, however, that during a major disaster, each civil service can collaborate in their response to situations by rapidly securing shared access to information that is both unified and identical. This is why “information integration” must be achieved in order to enable the sharing of information across the barriers between communication systems independently developed by each civil service.

The most important issue in the realization of information integration is a lack of compatibility between communication protocols. When information is exchanged between an existing communication system using an old communication protocol and a new system using a new communication protocol, functions must be made to match the existing system. For instance, when an existing system running under an old protocol is connected to a system running under a new protocol, the additional functions that one might expect the new system to provide may be restricted due to differences between the protocols of the new and old systems.

In order to resolve this problem, an information and communication infrastructure must be built that can seamlessly exchange information with existing communication systems, and which allows for the easy addition and expansion of new functions and operations.

This article describes the system technologies that can be used to achieve this interconnectivity through the application of new efforts at supporting communication infrastructures, by promoting a concept of seamlessness in the adoption of a variety of different communication terminals and media in order to respond to changes in the technological environment.

ACHIEVING INFORMATION INTEGRATION WITH A WIDE-AREA COMMUNICATION SYSTEM

Objectives of Development

A wide-area communication system is to be achieved that will enable information sharing and collaboration over the barriers between regions and organizations by linking the various communication systems developed separately in the past. Development is aimed at the following three objectives:

(1) Improved interconnectivity utilizing existing communication infrastructures

In the past, mutual communication was only possible between terminals inside each separate communication system. This development work is aimed at enabling communication and the sharing of information between terminals belonging to different communication systems, and will make it possible to implement new functions without the need to replace existing systems. No troublesome procedures are required, and the users can use systems without being aware of differences between them. In addition, it is also possible to link with new terminals that offer new functions added to the wide-area communication system.

(2) Addition of new functions

New functions are to be easily added in order to support new operations. New functions must be executable using terminals connected to existing communication systems, not just new terminals. Furthermore, not only is communication possible between terminals connected to different communication systems, new functions can be added to create new value based on the connection of both types of terminals.

(3) Strengthened responses to contingency situations

Ordinary communication infrastructures are often unavailable for use during emergency situations such as when a disaster has occurred. Even when this happens, the configuration of available terminals and communication infrastructures is to be changed dynamically in order to provide a bare minimum of functionality.

Basic Architecture

In order to achieve the objectives described above, a core network that can connect multiple existing communication systems is provided along with integrated operation servers providing new functions to support new operations (see Fig. 1).

(1) Core network

The core network is an Internet Protocol (IP) network that connects existing communication systems such as personal handy-phone systems (PHS), wireless systems, independently operated telephone networks, video conferencing systems, and security systems. The use of an IP network means that advances in network technology can be easily followed, and benefits are also afforded in terms of cost and functionality.

The unique communication protocols used by existing communication systems are converted to a protocol that allows IP connection by gateways. This enables communication and the sharing of information between the terminals of different types of communication systems, which used to be impossible.

(2) Integrated operation servers

A group of integrated operation servers is able to implement new operations and services by linking different types of communication systems. By sifting through the data flowing from terminals through the core network, converting the data and sending it to the target terminals, the servers enable communication and the sharing of information between different types of subsystems, all of which was not possible before. By putting a different server in charge of each function to be implemented, independence is heightened between functions, and this makes it possible to flexibly support the modification or addition of functions.

Function Implementation

The specific functions implemented in a wide-area communication system are as follows:

(1) Function for communicating between different types of terminals

This function enables terminals connected to different terminals to connect to each other on an equal footing and seamlessly communicate. This function expands the functionality of a session initiation protocol (SIP)* server by implementing communication with terminals that have been designed without considering the concept of a session.

(2) Function for conferencing between different types of terminal

In the past, specialized equipment was necessary for using conferencing, and a conferencing system involved connecting dedicated terminals to a dedicated network. With a wide-area communication system, any terminal connected to the core network can participate in a conference.

Any terminal can participate in a conference, with the state of every terminal in the system displayed in such a way as to allow for the selection of the terminals to participate, as well as the specification of audio mixing method, calling method, and other settings. The system also offers features such as the ability to remove restrictions on the terminals that can participate, for instance by allowing an audio-only terminal to participate in a video conferencing system.

* A protocol that controls the sessions necessary for exchanging audio, video, and text messages between two or more parties in the application layer.

(3) Sensor linkage function

This function notifies each terminal regarding abnormal information detected by any of the different types of sensors connected to the system. By updating and modifying the correspondence table listing abnormal information and terminals that must be notified, it is easy to maintain an up-to-date state along with any new terminals.

(4) Forced connection and simultaneous broadcast functions

These functions are used by the commander to force a connection and initiate a call with specified terminals, or to simultaneously broadcast to all specified terminals, especially during a disaster situation (see Fig. 2).

(5) Core network extension function

This function extends the core network, which is the backbone of the system. When a contingency situation occurs, this function is designed to support activities in a location that has been cut off from the network. By extending the core network using portable wireless transmission equipment, the use of public address systems, PHS, video conferencing systems, and other types of equipment is enabled at remote locations. This makes it possible to use the same wide-area communication system at remote locations as in the center of the network (see Fig. 3).

Operational Examples

In addition to operations during ordinary times, the wide-area communication system was also developed with the objective of automatically providing rapid support during disasters and emergency situations. Specific examples of how this works are described below.

(1) Remote public addresses

Public addresses, which are ordinarily broadcast from a dedicated microphone, can now be broadcast from an easily portable terminal via a separate system, such as a wireless system, PHS, or smart phone. This makes it possible to take refuge and broadcast from a safe location during a disaster. In this example, the following conversion process is executed in order to broadcast audio: audio via two-way radio, telephone line, IP packets, SIP server, IP packets, IP speaker, and finally an audio broadcast.

(2) Alarm notifications

When alarm information is detected by the sensor system, abnormal situation information and alarm announcements are automatically broadcast to telephone terminals and public address terminals.

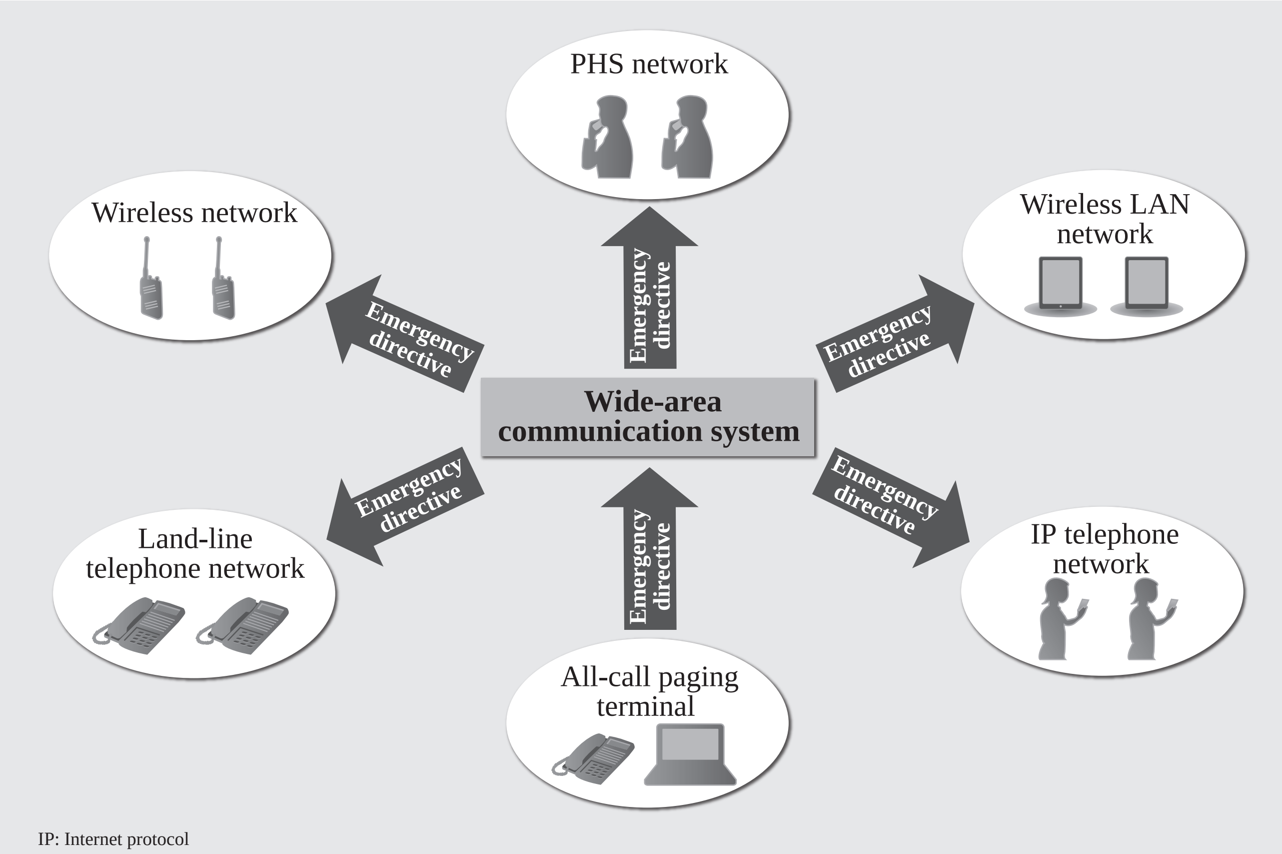

Fig. 2—All-call Paging.
An all-call paging terminal can be used to call specified terminals during an urgent or emergency situation.

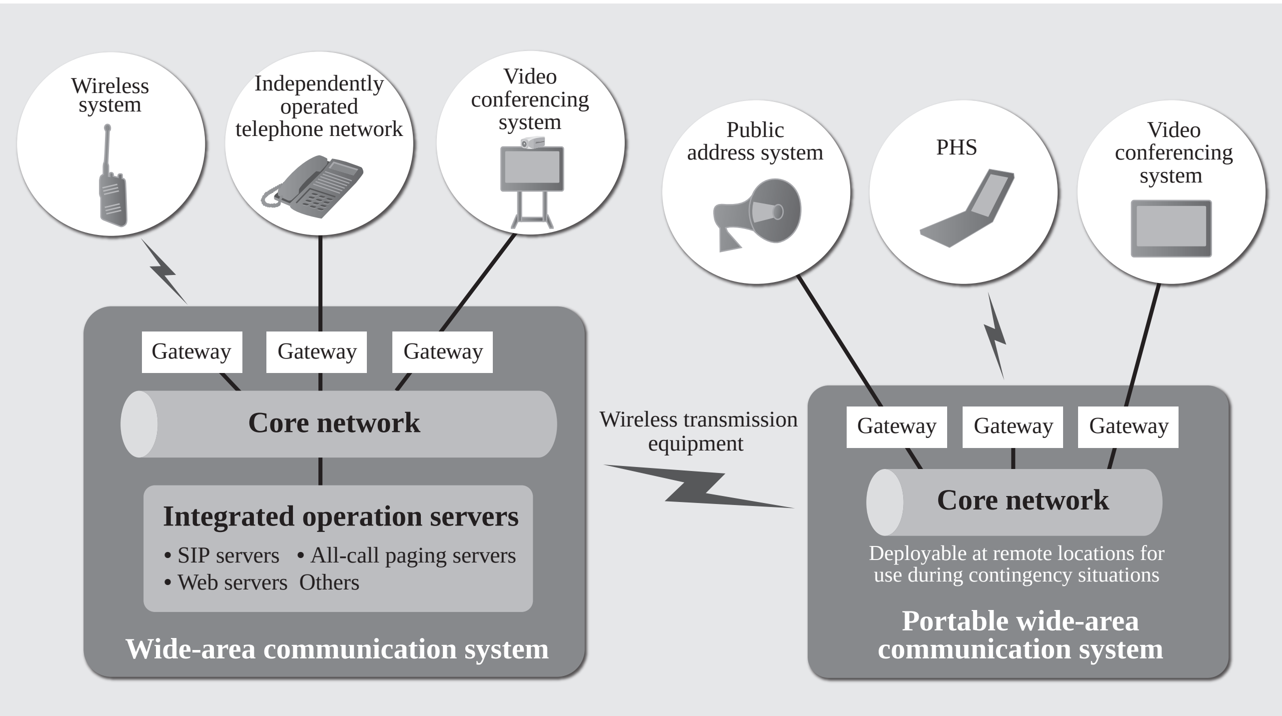

Fig. 3—Configuration of System for Contingency Situations.
A portable wide-area communication system is deployed to remote locations for use in contingency situations, and information can be shared via wireless transmission equipment.

Alarm information is also sent to PHS telephones and other devices via text-based e-mail.

APPLICATION AT MATSUSHIMA AIR BASE

Matsushima Air Base of Japan Air Self-Defense Force, which is located on the Pacific coast side of Miyagi Prefecture, was completely flooded with tsunami water approximately two meters deep after the Great East Japan Earthquake, causing the base to lose some of its functions. A large number of airplanes and facilities were submerged and damaged to the extent that they became unusable. In order to deal with this crisis, Japan Air Self-Defense Force quickly switched to business-use mobile phones with waterproofing features and used them during recovery operations.

In response to this situation, the Communications Section of the C4 Systems Division in the Japan Ministry of Defense's Air Staff Office took the initiative in deciding to introduce versatile joint communication equipment [Japan Air Self-Defense Force Joint IP Communication System (AJICS)] as part of the recovery of Matsushima Air Base, adopting Hitachi's wide-area communication system.

The most important function of the communication system at Matsushima Air Base was the sharing of voice-based information, and so the versatile joint communication equipment was used to implement joint communication and broadcast functions. This system can use the previously adopted business-use mobile telephones as internal extension telephones, utilizing PHS cards for on-site use. In addition, seamless communication with existing communication equipment including private branch exchanges, various types of wireless systems, and public address systems was established by connecting to the core network via gateways. Also, the all-call paging server that is one of the features of the wide-area communication system can be used to connect to equipment without the need for the user to be aware, which makes it possible to communicate with all types of media in the same way one would place a telephone call.

Representative examples of operation are described below.

(1) Operational example #1

When the commander at the command post wants to verify on-site information for carriers of wireless mobile devices, he/she can use the all-call paging terminal to connect commander, wireless mobile devices and broadcast equipment in order to grasp the situation while monitoring details of conference calls with all personnel inside the indoor broadcast facilities.

(2) Operational example #2

By connecting the commander's IP telephone and public address equipment, on-base broadcast facilities can be used to convey weather, disaster, and other information.

(3) Operational example #3

During a contingency situation, a portable wide-area communication system can be deployed to the municipality through the nearby mountain region for the sharing of information. Microwave wireless transmission equipment is used for nearby communication extensions in order to enable communication with regions that lack communication infrastructure facilities.

The exterior of the main versatile joint communication equipment is shown in Fig. 4.

By using versatile joint communication equipment as described above, it was possible to use a wide range of equipment that had escaped damage from the tsunami by linking it with equipment adopted during recovery operations, thereby achieving unified operations.

CONCLUSIONS

This article described a new approach towards supporting communication infrastructures by responding to changes in the technological environment while promoting a concept of seamlessness that can be

Photograph courtesy of Japan Air Self-Defense Force

Fig. 4—Versatile Joint Communication Equipment.
Exterior of main equipment for versatile joint communication installed at Matsushima Air Base of Japan Air Self-Defense Force.

applied to a wide range of different communication terminals and communication media, as well as system technology that can be used to implement this concept.

In the future, Hitachi will continue working to improve the sophistication of system technology through application to every type of communication infrastructure, both domestic and international, while contributing to the achievement of social systems that offer both flexibility and sustainability.

Finally, the authors would like to acknowledge their heartfelt gratitude to the members of the Communications Section of the C4 Systems Division in the Japan Ministry of Defense's Air Staff Office for providing their generous time and invaluable advice regarding the contents of this article.

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Enhancement of Counter Cyber-attack Capabilities from Viewpoint of National Defense

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OVERVIEW: Use of cyber-attacks for military purposes has grown in recent times, with an increasing number of these attacks being made on defense industries or other important infrastructure, and this has made the strengthening of capabilities for preventing these attacks an urgent requirement for national defense. Hitachi is utilizing the defense sector know-how of its Defense Systems Company in fields such as the implementation of command and control systems to investigate, from a defense perspective, the best ways of providing the capabilities needed to counter these cyber-attacks. Based on the results of this investigation, Hitachi intends to contribute to creating a safe and secure society that includes cyberspace by further enhancing its solutions that facilitate improvements in the capabilities for countering cyber-attacks.

INTRODUCTION

IN July 2011, the U.S. Department of Defense published the Department of Defense Strategy for Operating in Cyberspace[(1)] that specifies its initial cyberwar strategy. The background to this publication includes a series of cyber-attacks on government and other important infrastructure, and an increasing number of cases in which cyber-attacks have been used for political or military purposes.

The publication represents a strong stance by the USA on cyberwar, identifying five strategies that include the concept of cyberspace as the fifth operational domain (after land, sea, air, and space), and also the strengthening of organizations and equipment as well as relationships with relevant government agencies, corporations, and others.

One example of the actual use of a cyber-attack for military purposes occurred in a 2007 aerial campaign conducted by the State of Israel against the Syrian Arab Republic[(2)]. Israel launched a cyber-attack against Syria that disabled the detection capabilities of Syrian air defense systems while it carried out bombing attacks, making this an example both of the use of a cyber-attack for military purposes and a high level of coordination with physical operations.

Cyber-attacks targeting corporations have also been increasing in recent times, with such attacks taking place against defense industry and other targets in Japan, Israel, India, and the USA during 2011[(3)].

These examples clearly differ in character from conventional security risks involving information leaks achieved through infection with computer viruses and their indiscriminate spreading. Cyber-attacks are being perpetrated that use advanced strategies and accumulated technologies to achieve specific objectives.

Meanwhile, modern society has become highly dependent on information technology (IT). For example, IT underpins important infrastructure such as electric power, gas, water, transportation, and communications. The same applies to the defense equipment and other infrastructure of government agencies, where greater modernization brings an increasing reliance on IT. This means that the impacts

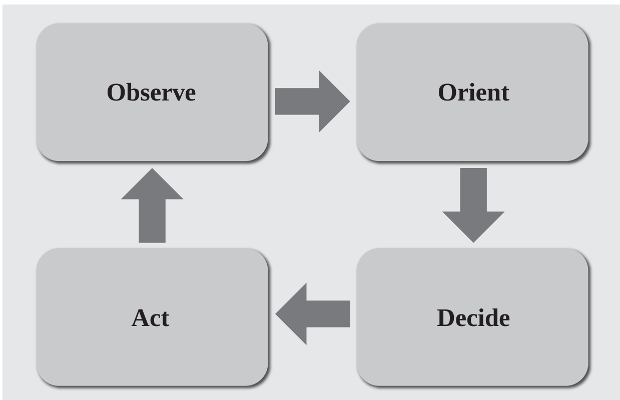

Fig. 1—OODA Loop.
A decision making methodology proposed by U.S. Air Force Colonel John Boyd involving the use of a repeated "observe, orient, decide, and act" cycle to achieve fast and accurate decisions.

of a cyber-attack are not limited to cyberspace and extend into the real world.

Given this potential for cyberwar, meaning the use of cyber-attacks to pose a risk to national security, there is a need to strengthen capabilities for countering cyber-attacks from the perspective of national defense.

This article describes how to go about strengthening capabilities for countering cyber-attacks, US policies and the response of corporations, and what Hitachi is doing in this field.

INVESTIGATION INTO STRENGTHENING CAPABILITIES FOR COUNTERING CYBER-ATTACKS

The OODA loop is a methodology, originally proposed by U.S. Air Force Colonel John Boyd, that has a long history of use in the military world. Based on insights gleaned from the experience of successful air campaigns in the Korean War, the OODA loop formalizes the process of decision making by the commanding officer. Over time, it has also come to be used in the business world and other civilian applications.

OODA stands for “observe, orient, decide, and act,” and the concept behind the OODA loop is to achieve fast and accurate decision making by repeatedly working through this cycle (see Fig. 1).

The following section uses the OODA loop as a basis for considering, from a defense perspective, what needs to be done to strengthen capabilities for countering cyber-attacks (see Fig. 2).

Observation

The main objective of observation is to acquire information, such as identifying and tracking enemies. Tactics can be pursued more effectively by using analysis of collected information to infer information about the enemy, such as their capabilities and objectives, and also by protecting one’s own side’s information from the enemy.

Examples of observation in cyberspace might include functions for detecting the presence of attacks or other external threats to one’s organization by using tools such as anti-virus software, intruder detection devices, and log collection utilities. Unfortunately, using these functions alone, it is very difficult to determine the objectives or intentions that have motivated a detected cyber-attack.

Additional functions for identifying objectives and intentions can be provided in the form of cyber-intelligence functions that include the collection and sharing of a wide variety of information. Specific examples of the type of information to collect include system, software, and other vulnerabilities (security weaknesses), infections by new viruses or other threats,

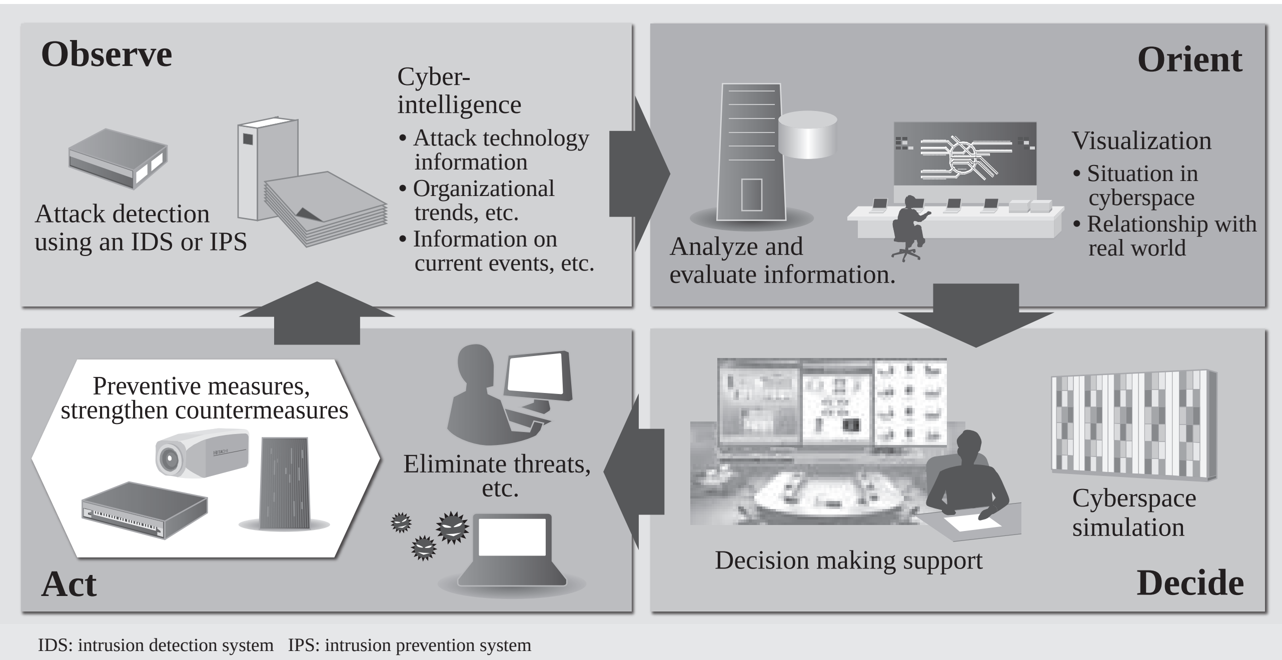

Fig. 2—Use of OODA in Cyberspace.
The OODA loop is used as a basis for investigating, from a defense perspective, what needs to be done to strengthen capabilities for countering cyber-attacks.

and activities by malicious hacker groups. When current trends in cyber-attacks are considered, information sharing between relevant organizations is also very important. In particular, to prepare for attacks on government agencies or other important infrastructure, it is necessary to consider the relationships between different incidents, such as the increasing number of attacks on private companies that form part of the supply chain. To achieve this, in-house monitoring needs to perform the collection and sharing of information in a way that considers how incidents are interconnected.

However, careful attention needs to be paid to the requirements and scope of cyber-intelligence when designing the operation. It is also most important to protect information about the organization's own objectives, intentions, and capabilities (such as what information to collect and what it is possible to detect) to prevent this falling into the hands of potential attackers.

Orientation

Situation development (orientation) is performed to identify the objectives and intentions of an attack, and to use this as a basis for determining the impact on one's own organization.

This involves analyzing the observations to determine whether an incident is an inadvertent or other indiscriminate attack, or whether it is a cyber-attack with a deliberate military intent. It also includes analyzing the scope and severity of the impact that the attack will have on the organization's systems and tactics. In this way, the risk level can be determined in a way that includes the real world impact.

Performing a situation development in cyberspace requires the use of tools for analyzing the collected information, including log analysis, network monitoring, and incident management utilities.

One of the tools used for orientation in the military world is called "common operational picture" (COP). This supports situation development by displaying information, such as friends' and enemies' capabilities, status, objectives, and conditions (ground, weather, and sea conditions), based on the role, rank, and other attributes of the commanding officer or other personnel so that everyone has a consistent understanding of the situation.

Performing a situation development in cyberspace requires similar tools. Furthermore, by coordinating these tools with the real world COP, it is possible to perform situation developments in a way that includes correlations between the real world and cyberspace.

Decision Making

In the military world, decision making is one of the most important capabilities demanded of a commanding officer, and decision making is essentially something best done by people. However, it is also possible to help commanding officers make decisions by providing functions that improve decision making speed and accuracy.

Simulation functions are one example. In the case of cyberspace, this means setting up a test version of the organization's own system and network environment that can be used for activities such as assessing the impact of cyber-attacks and other threats, or for running training exercises to test responses.

Certain very special concepts are relevant to decision making in the context of national security. If a threat such as a device being infected by malware (malicious software) is detected within the organization, for example, common security practices include reinitializing the device or disconnecting it from the network to prevent secondary infection of other devices.

However, if this is something that could have an impact on military operations, there are cases, based on an appropriate risk assessment, in which priority is given to mission completion and the implementation of security measures is delayed. There may also be cases when, rather than responding immediately, a wait-and-see approach is taken to observe how the situation develops. For example, observing how the attacker goes about mounting a cyber-attack can help with situation development by providing information about their methods and other details.

Action

The action phase includes solving problems and eliminating risk factors. A key feature of the OODA loop approach is that the next observation phase makes active use of the results up to and including the action phase. That is, the cycle does not end with the action phase, and instead it places an emphasis on feedback to the observation phase.

Based on this approach, rather than treating countermeasures such as the removal of malware or the disconnection of unauthorized communications as being the end of the process, the OODA loop methodology uses the analysis and prediction of attack trends as the basis of feedback, such as setting up preemptive countermeasures or expanding the scope of data collection.

US POLICY MEASURES AND CORPORATE RESPONSE

U.S. Department of Defense is pursuing policies that recognize the importance of sharing information and the increasing number of cyber-attacks on companies in the supply chain. In addition to helping the U.S. Department of Defense strengthen its observational capabilities based on the OODA loop, this can also be seen as indicative of their desire for the defense industry to establish their own capabilities based on the OODA loop.

One specific policy being pursued in collaboration with the U.S. Department of Homeland Security involves taking steps to protect confidential defense information located on the networks or other systems of defense companies. This includes the Defense Industrial Base Cyber Security/Information Assurance (DIB CS/IA) Program(4).

In a pilot program that started in June 2011 and ran for approximately one year, the U.S. Department of Defense and a number of corporations (20 at the time the program started) shared information about cyber-threats, including confidential information. In May 2012, the program was upgraded from a pilot program to being open to all companies in the defense industry.

Under the DIB CS/IA Program, Department of Defense provides participating DIB Companies with unclassified indicators and related, classified contextual information. DIB Companies can choose whether to incorporate the indicators into their own traffic screening or other security tools, and they can review or act on the contextual information as they wish to better address the cyber security threats they face. Similarly, participating corporations are free to pass on any information they acquire about cyber-attacks to the U.S. Department of Defense or other program participants.

In this way, as a countermeasure against cyber-attacks that are becoming more sophisticated and serious, the USA is extending the sharing of information to include the supply chain and strengthening its ability to respond.

ACTIVITIES BY HITACHI

Hitachi, Ltd. adopted its company-based organizational structure in 2009. One of these companies is the Defense Systems Company that runs Hitachi's security business for social infrastructure, which includes the defense sector. The Defense Systems Company supplies a cyber-security solution that supports national security.

Based on the OODA loop, this solution provides functions for enhancing capabilities for countering cyber-attacks. Drawing on the investigation into strengthening capabilities for countering cyber-attacks described earlier in this article, Hitachi intends to enhance the following two aspects of the solution in particular.

Cyber-intelligence Solution

The types of information that should be collected to counter cyber-attacks cover a wide range. This extends beyond technical information, such as logs from in-house networked devices, asset management information, and e-mails. Instead, it is possible that a diverse range of information gathered from a variety of sources will be needed, such as background information on real world trends or examples of attacks that have taken place elsewhere.

In addition to systematizing this information so that it can be collected and used efficiently, its ease-of-use, meaning, and value as a basis for decision making can be established by classifying, assessing, and correlating the collected information, and subjecting it to forecasting and other analyses.

Solution for Cyberspace Situation Awareness

An awareness of the actual situation is important for achieving a fast and accurate response to a cyber-attack.

In addition to assessing risks associated with a cyber-attack and the scope of its impact on the organization, the solution makes the required information available in a visual format based on factors that include the user's role and rank, such as whether they are a commanding officer or part of the system management staff. In other words, it provides a COP for cyberspace. During a cyber-attack, this provides a consistent understanding of the situation across the organization, and allows a comprehensive response to be mounted.

CONCLUSIONS

This article has described how to go about strengthening capabilities for countering cyber-attacks, US policies and the response of corporations, and what Hitachi is doing in this field.

As noted in this article, the objectives and methods used in cyber-attacks have been changing recently, and the potential for cyberwar has arisen.

Hitachi is utilizing the defense sector know-how it has built up in fields such as the implementation of command and control systems to investigate, from a defense perspective, how to strengthen the capabilities needed to counter these cyber-attacks. In the future, Hitachi aims to make an even greater contribution to achieving a safe and secure society, including cyberspace, through initiatives that include enhancing its solutions based on the results of this investigation.

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Anti-tamper and Cryptographic Solutions for Information Protection

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OVERVIEW: As leaks of information from public infrastructure systems can cause damage at a national scale, it needs to be recognized as a top priority for national security. Based around anti-tamper and cryptographic technologies, Hitachi supplies solutions for preventing leaks that include tools for blocking reverse engineering and functions for full disk encryption and communication encryption. These products are designed and implemented based on know-how that Hitachi has built up through its experience with system development, and on its own risk analyses that assume large-scale attacks.

INTRODUCTION

AT most companies and other organizations, a data leak usually means the loss of personal information or commercial secrets. Such a leakage of information is a major problem that can have serious consequences, including reputational damage to the company or organization and the payment of compensation.

In the case of public infrastructure systems, on the other hand, the damage from information leaks can potentially extend much further than just compensation and reputational damage. In particular, leaks of authentication data or information about the system's configuration or installed software (such as its vulnerabilities) can result in the use of this information to mount cyber-attacks, with consequences such as widespread system shutdowns or the hijacking of system control authorities. In other words, attacks launched against large systems such as those used for homeland security or public infrastructure have the potential to cause damage at a national scale.

Hitachi sees the problem of information leaks as being the top priority for national security. Through the development of systems for national security, Hitachi has also conducted risk analyses that assume large-scale attacks, and has established stringent security against such an eventuality. Hitachi utilizes know-how derived from this experience to supply technology for preventing information leaks that takes account of countermeasures at the level of national security.

This article reviews Hitachi's perspective on the threat of information leaks, and describes two core protection methods, namely anti-tamper and cryptographic technologies, together with Hitachi's solutions for preventing information leaks that utilize these technologies.

INFORMATION LEAK THREATS AND COUNTERMEASURES

Treating data and software as assets that need to be protected, this section describes both the threats to which these assets are exposed and the techniques used to protect them against these threats.

Threats to Information Assets

Fig. 1 shows the threats to data faced by a typical corporation. The figure shows three different environments: the company headquarters, a branch office, and outside the company. This scenario includes the use of fixed personal computers (PCs) for work at headquarters and branch offices, and the use of mobile

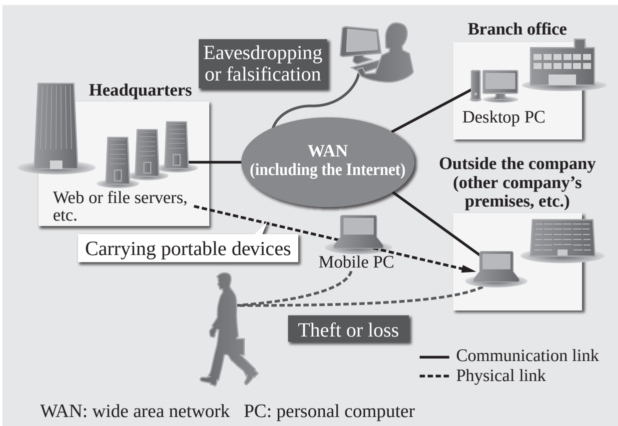

Fig. 1—Threats to Data.
The figure shows the main threats to corporate PCs. These include eavesdropping or falsification via a WAN, and the theft or loss of devices when out of the office.

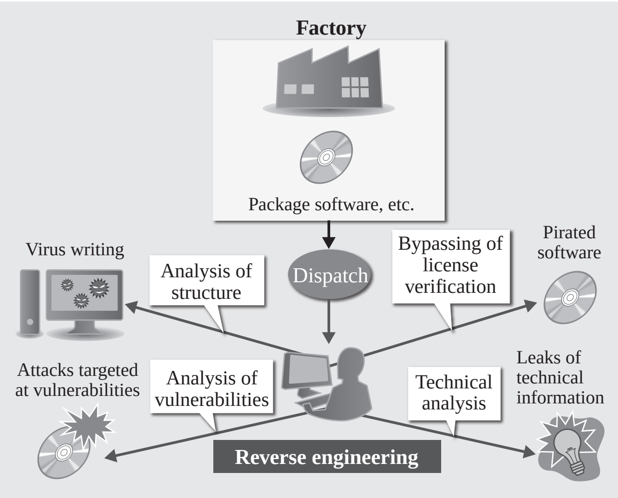

Fig. 2—Threats against Software.
The unauthorized reverse engineering of software can identify how the software works and be used in damaging ways such as the production of pirated versions.

PCs for sales calls and other out-of-the-office work. They also use a wide-area network (WAN) such as the Internet for communications between headquarters, branch offices, and staff on the road. In a situation like this, the main information leak threats are the eavesdropping or falsification of communications data on the WAN, and the theft or loss of PCs or other devices when out of the office. Of particular note in the case of PCs is that, because it is still possible to read the contents of a hard disk simply by removing it and connecting it to another PC, the threat posed by theft or loss cannot be mitigated even if their basic input/output system (BIOS) and operating system (OS) require authentication to access.

Similarly, Fig. 2 shows the threats faced by software. Rather than the vulnerabilities of specific programs that can be resolved by applying a software patch, the critical threat is seen as coming from the sort of malicious reverse engineering shown in this figure. In this context, reverse engineering means the analysis of a program's structure and operation. Reverse engineering can be used to steal technical information or produce pirated versions of software, and attackers can use vulnerability analysis and other techniques on these as the basis for writing viruses. This makes it a starting point for mounting a cyber-attack. Of these, virus writing and vulnerability analysis in particular can be precursors to cyber-attacks, and mounting an attack on special-purpose software typically requires that the software first be reverse engineered. As described above, cyber-attacks on large infrastructural systems can result in damage on a national scale.

TABLE 1. Threats Faced by Different Types of Information Assets
Of the various information assets that need to be protected, different types of information face different threats.

Type of information	Threat
Software	Reverse engineering
Data on hard disk	Theft or loss
WAN communications data	Eavesdropping or falsification

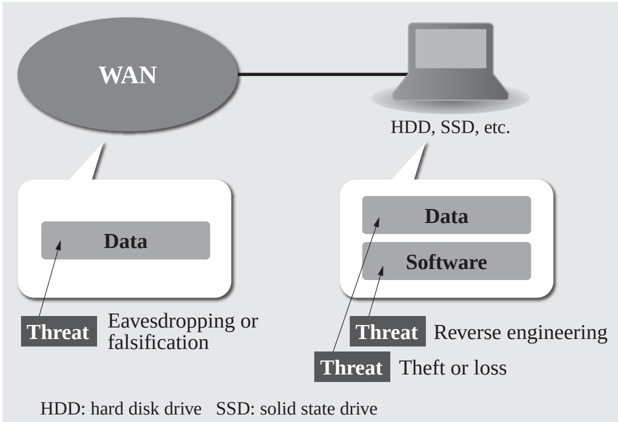

Fig. 3—Types of Information and Threats they Face.
The nature of the threats faced and the countermeasures they require are different depending on the type of information (data or software) and where it is located (WAN or HDD).

Table 1 lists the threats faced by different types of information assets, and Fig. 3 shows the types of information and the threats they face.

The following section describes the countermeasures against these threats.

Use of Anti-tamper and Cryptographic Technologies to Protect Information Assets

Hitachi sees anti-tamper and cryptographic technologies as playing a core role in countering threats to information assets.

Cryptography is an effective way to prevent the loss of information in the form of data. While cryptography can be used for any type of data, it offers limited protection for software. This is because, even if the programs on a computer are encrypted, they must ultimately be decrypted in order to execute. Anti-tamper technology, on the other hand, protects software that cannot be secured by cryptography by making reverse engineering more difficult. Using these two technologies together prevents leaks of both data and software.

Hitachi's Strengths

Hitachi draws on its experience with establishing security for information systems, such as those

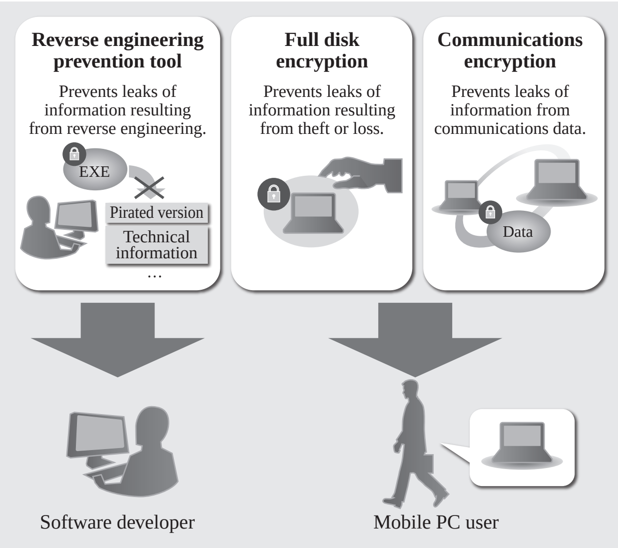

Fig. 4—Solutions for Preventing Information Leaks.
These three key functions protect software, hard disk data, and communications data from leaks.

associated with national security, to supply cryptographic functions that provide a high level of protection. These include techniques for evaluating cryptographic strength (how difficult it is to break the cypher), and Hitachi is able to provide customized cryptographic algorithms for applications that required protection at the level of national security. Because it possesses skills in software implementation and know-how in fields that are essential to anti-tamper techniques, such as central processing units (CPUs) and OSs, Hitachi is also able to supply functions that effectively block reverse engineering.

The following section gives details of a solution that takes advantage of these strengths to prevent information leaks from Windows*1 PCs.

SOLUTIONS FOR PREVENTING INFORMATION LEAKS

This section first gives an overview of solutions for preventing information leaks, then describes the security functions supplied by Hitachi.

Overview

In addition to anti-tamper and cryptographic technologies, countermeasures against the threats described above also need to be implemented in ways that take account of the nature of the threats. Furthermore, PC users do not need to be aware of the countermeasures being used, and comprehensive protection against information leaks is an important feature for guarding against inattention and other forms of human error.

To overcome these challenges, Hitachi supplies following three key security functions for Windows PCs (see Fig. 4).

(1) Reverse engineering prevention tool
(2) Full disk encryption
(3) Communications encryption

These functions provide measures against the three types of threat described in the earlier example (in Table 1). In particular, full disk encryption and communications encryption used together can provide comprehensive protection against leaks of data from PCs. They are effective measures for mobile PCs that are especially at risk from security threats. Comprehensive and enforced use of encryption to secure all information in PCs and elsewhere, with full disk encryption for data on hard disks and communications encryption for communications data, ensures that information leaks do not occur.

Reverse Engineering Prevention Tool

The reverse engineering prevention tool is a software utility for incorporating anti-tamper functions into completed programs in order to make them difficult to reverse engineer.

The following sections describe the methods used for reverse engineering and the anti-tamper functions that counter them, and provide details about how the tool works.

Methods used for reverse engineering

Static code analysis and dynamic code analysis are two ways of reverse engineering software.

Static code analysis analyzes software without executing it. Typically, a disassembler or decompiler is used to convert the executable file (machine language) into a programming language that can be analyzed. Because the person doing the analysis needs to visualize how the program will run, a high level of skill is required.

Dynamic code analysis analyzes software while it is running. This is done using tools such as a debugger (a utility that allows the user to view and manipulate the status of the CPU and memory during program execution) or virtual machine. A virtual machine is a program that emulates the PC hardware and provides the environment for executing the debugger and the software being analyzed. Because it can view the actual operation of the software, dynamic code analysis has the advantage of being comparatively easier to

*1 Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

perform than static code analysis. On the other hand, because the software actually has to execute, there is a potential for unforeseen consequences. For example, some software is designed to detect unauthorized analysis and terminate with an error to prevent the analysis proceeding, or even to corrupt the analysis system. Accordingly, it is subject to a different set of analysis restrictions to static code analysis.

Because the two approaches have their respective strengths and weaknesses, reverse engineering makes use of both, depending on the circumstances.

Overview of anti-tamper functions

The anti-tamper functions in the reverse engineering prevention tool include mechanisms for obstructing both static and dynamic code analysis.

(1) Obstruction of static code analysis

This is done using the executable file encryption function [see Fig. 5 (a)]. Essentially, protection is achieved by encrypting the executable file, and by obfuscating its decryption function and the cryptographic key. This prevents the program from being converted back to assembly language or some other programming language through the use of static code analysis tools such as disassemblers or decompilers.

(2) Obstruction of dynamic code analysis

This incorporates code into the executable file that monitors the CPU, memory, and OS to detect when the program is being analyzed using a debugger and virtual machine [see Fig. 5 (b)][(1), (2)]. If such analysis is detected, the code takes some action to prevent it from proceeding, such as halting execution [see Fig. 5 (c)].

To prevent the analysis detection function itself from being reverse engineered, its operation is obfuscated (its operation made more complex so as to be difficult to analyze) to prevent easy analysis. Through these multi-layered measures, resistance to reverse engineering is enhanced.

Implementation of anti-tamper functions

Trying to incorporate these anti-tamper functions during coding makes software development more difficult. They require each programmer to be familiar with the functions, and incorporating the functions in a program adds complexity to the process of writing it. To overcome these problems, what is required is a simple way of protecting software that can incorporate the anti-tamper functions into programs without having to modify their source code. Of particular concern are how to implement decoding of encrypted executable files and analysis detection.

To solve this problem, Hitachi developed a technique for incorporating additional processing without affecting the operation of the executable file, taking account of factors such as the structure of the executable file and the way OS runs software. This allows functions for detecting the decoding and analysis of encrypted software to be added to any executable file. Because decoding is performed

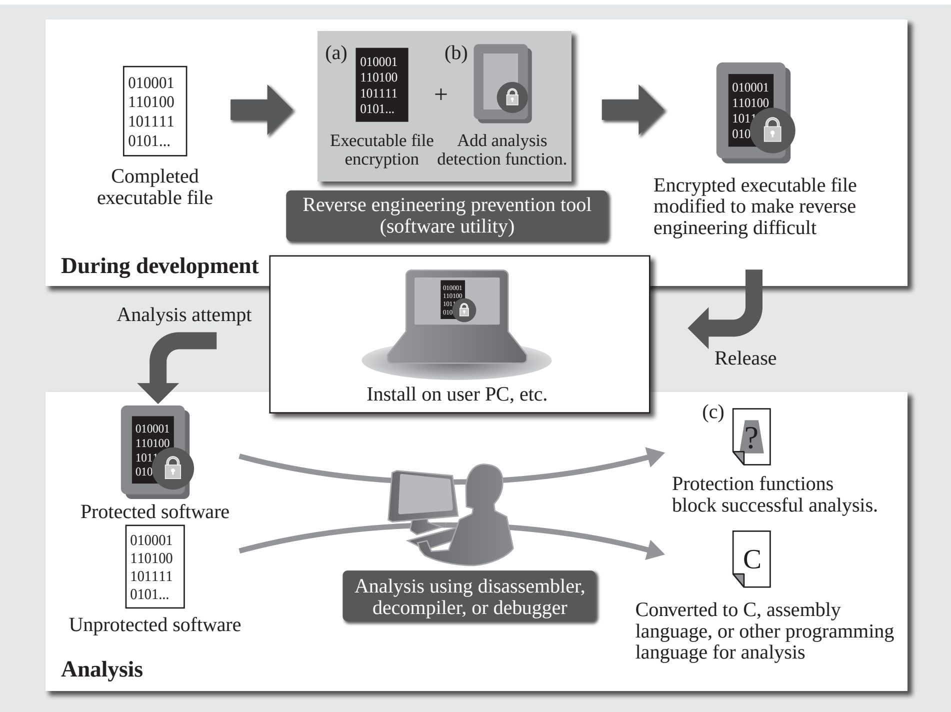

Fig. 5—Reverse Engineering Prevention Tool.
The completed software (executable file) is input to a tool that automatically incorporates anti-tamper functions to make reverse engineering difficult.

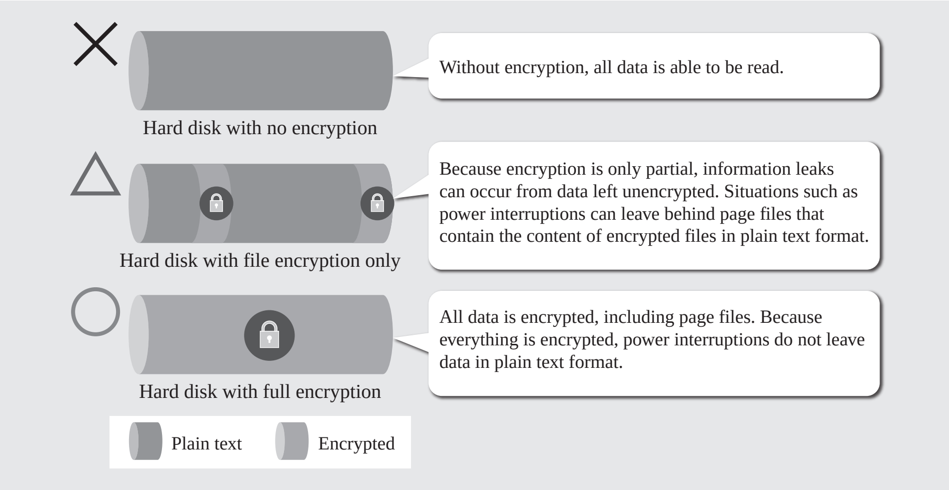

Fig. 6—Full Disk Encryption. Encrypting the entire hard disk prevents data from being left unencrypted. File encryption cannot prevent information leaks from occurring in unanticipated situations.

automatically when the software is run, encrypted programs can be invoked in the same way as the originals, and their operation once running remains unchanged. For example, a program that is invoked by clicking an icon is still invoked this way after the tool has been used to add the anti-tamper functions, and its operation remains the same as before. Also, as the decrypted program is only output to volatile memory (hardware), its code cannot be read off the hard disk.

Using this method, all that is required is to feed the software to be protected as input to the tool and have the tool output the software with the anti-tamper functions added (see top of Fig. 5). The output software is then released and anti-tamper functions protect it from any subsequent unauthorized reverse engineering (see bottom of Fig. 5). This prevents any information from being extracted from the software.

Full Disk Encryption

Use of full disk encryption to enforce encryption prevents information leaks resulting from theft or loss.

Three challenges face this function. The first is automatic encryption of the entire hard disk, including the OS, the second is how to boot an encrypted OS, and the third is preventing a removed hard disk from being decrypted.

To overcome the first challenge, the encryption function is built into the device driver layer (as a filter driver). This means that the encryption function operates as part of the OS, and all write access to the hard disk by application programs or the OS is encrypted automatically (full encryption). Also, because it runs in the same layer as the OS, the encryption function does not affect the behavior of application programs or other user operations. The second challenge is overcome by preboot authentication that performs authentication before the OS boots. Finally, the third challenge is dealt with by using a proprietary boot loader to decrypt the OS as it boots. The following sections describe full encryption and preboot authentication in detail, both of which have important security roles in full disk encryption.

Full encryption

Full encryption enforces the encryption of all data on the hard disk, including files output by the OS (see Fig. 6). One advantage of this function is that it prevents information leaks from occurring through inattention, such as a user forgetting to encrypt data. Another advantage is that even files output by the OS are encrypted.

Although users are not generally aware of files output by the OS, there have been cases when information has been extracted from these files. Paging files are one way this can happen. Paging files are used by the OS to cache data temporarily when memory hardware capacity is insufficient. Such files can be a source of leaks because they can contain data from the volatile memory unencrypted without the user knowing. While a simple file encryption function cannot perform encryptions for these special files, the full disk encryption can, thereby preventing theft of the information they contain.

Preboot authentication

Preboot authentication is a function added along with the full disk encryption function to perform user authentication prior to the OS booting. As decrypting of the hard disk data cannot start until after this authentication is successful, an unauthorized user cannot read its contents even if they remove the hard disk and attach it to another PC. This function provides PCs with a very robust authentication mechanism because it uses its own authentication method, making it separate to any other authentication such as that performed by the BIOS or OS.

Communications Encryption

Communications encryption prevents leaks of information from communications data by encrypting all communications.

A challenge for this function is to ensure that the communications data from all application programs running on a Windows system is encrypted automatically.

To achieve this, communications encryption is implemented in the device driver layer, the same as the full disk encryption function. This ensures that communications data from all application programs is encrypted automatically, and there is no effect on the behavior of the application programs or user operation.

This function can be provided for the following two types of communications, depending on the application.

Communications via encrypted virtual hub

This method encrypts Ethernet frames and uses Transmission Control Protocol/Internet Protocol (TCP/IP) encapsulation (see Fig. 7). As indicated in Fig. 7, the method can be used for multipoint-to-multipoint communications. Also, authenticating each communications packet prevents the tampering with or spoofing of communications data, and communications can use proprietary cryptographic algorithms to achieve high levels of security, as required. Another feature of this method is that each PC communicates via a server called an "encrypted virtual hub."

Encrypted virtual hubs are servers that emulate a physical hub. They are used to run a single virtual network on top of a WAN (called an "overlay network") so that PCs located both inside and outside the company that connect to the encrypted virtual hubs can communicate as if they are all on the same local area network (LAN). Multipoint-to-multipoint communications works on the same principle. A feature of this communications mechanism is that, since these communication traffic streams are encapsulated as TCP/IP packets (such as port No. 80: Hypertext Transfer Protocol packets), each peer in the network can communicate even over firewalls or Network Address Translation (NATs). For this reason, this way of communication has advantage when a user cannot choose an ideal network environment.

IPsec transport mode communications

Security Architecture for Internet Protocol (IPsec) transport mode communications means IPsec communications in which only the Transmission Control Protocol/User Datagram Protocol (TCP/UDP) payload is encrypted (see Fig. 8). As indicated in Fig. 8, it can be used for point-to-multipoint communications. Like encrypted virtual hub communications, it can use proprietary cryptographic algorithms and perform authentication for each communications packet. Being simpler than encrypted virtual hub communications, high throughput is an advantage. This makes it suitable for use on communication links that can be configured as required, such as between headquarters and branch offices, for example.

CONCLUSIONS

This article has reviewed Hitachi's perspective on the threat of information leaks, and described two core protection methods, namely anti-tamper and cryptographic technologies, together with Hitachi's solutions for preventing information leaks that utilize these technologies.

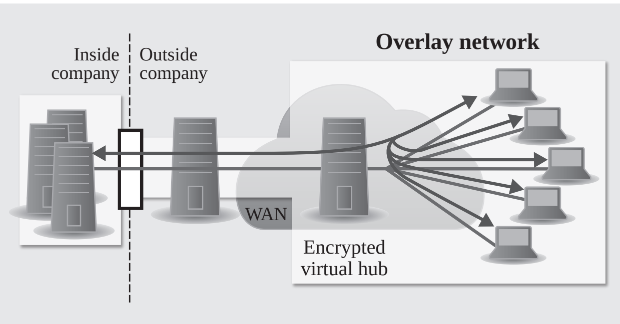

Fig. 7—Encrypted Virtual Hub Communications.
A feature of this method, which encrypts Ethernet frames, is that it makes it difficult to intercept communications in firewalls or other network devices.

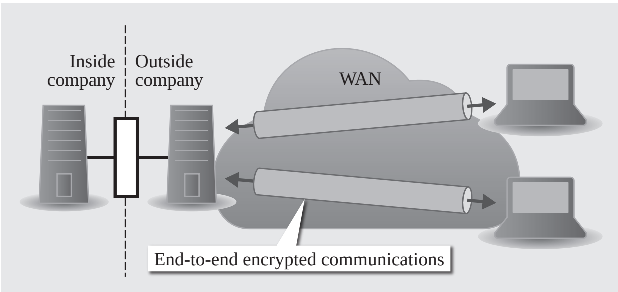

Fig. 8—IPsec Transport Mode Communications.
Security Architecture for Internet Protocol (IPsec) transport mode communications is a comparatively simple communications method that only encrypts the Transmission Control Protocol/User Datagram Protocol (TCP/UDP) payload.

The reverse engineering prevention tool is a high-security technology for preventing information leaks that has been designed and implemented based on detailed risk analyses and experience that Hitachi has built up for itself in system development, as have the full disk encryption and communications encryption functions.

While this article has focused on technology for Windows PCs, the same technology can also be applied to a range of other platforms. In particular, in addition to systems made up of PCs and other general-purpose devices, concern has been growing in recent years about cyber-attacks on systems that include embedded special equipment, including calls highlighting the importance of security measures in fields such as public infrastructure. Hitachi believes that defending systems against attacks like these requires that anti-tamper and other similar functions be provided as standard features in various different types of software. However, before these technologies can be applied to the proliferating number of different platforms, risk analysis and technical investigations are needed to consider their specific requirements.

In the future, Hitachi intends to utilize these technologies for preventing information leaks to make a contribution to greater safety and security in society by supplying advanced custom security solutions in a wide range of fields, including national security and public infrastructure.

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Carbon-hydride Energy Storage System

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OVERVIEW: The carbon-hydride energy storage system stores hydrogen, which is difficult to handle, in the form of the stable liquid methylcyclohexane, thereby making it easy to transport and keep hydrogen in long-term storage as an energy medium. Since this makes it easy to convert energy into hydrogen for storage and reuse, it can contribute to the stable supply of renewable energy such as wind power, which fluctuates greatly. Expectations are high for this system as a means of improving Japan's energy self-sufficiency ratio by helping expand the use of renewable energy and accelerating the achievement of a low-carbon hydrogen society. Based on a 2011 contract with the National Institute of Polar Research, Hitachi, Ltd. has been working in the city of Nikaho in Akita Prefecture on the development of a practical version of this system while acquiring basic data that will, among other things, help improve the energy self-sufficiency ratio of Antarctica in the future.

INTRODUCTION

THE carbon-hydride energy storage system (CHES) makes it easy to store and transport large quantities of renewable energy such as wind and photovoltaic power, which fluctuates greatly. The electric power generated using renewable energy is converted into hydrogen, which is itself converted into methylcyclohexane (MCH), thereby transforming the energy medium of hydrogen into a form that is easy to handle. As a result, the excess amounts of wind power, photovoltaic power, and other forms of renewable energy where it is difficult to provide supply that matches demand can be stored for long periods of time, making it possible to achieve a stable energy supply.

This system, which makes it possible to store energy for a long period of time, can contribute to energy self-sufficiency in regions where the supply of renewable energy is a burden. For instance, the fuel currently used at Antarctica's Showa Station is transported by the Antarctica icebreaker Shirase, and it takes up approximately half of the vessel's cargo capacity. Since as energy demand increases in the future, fuel transportation will limit the amount of energy available, and so by obtaining renewable energy that is available in Antarctica itself such as wind and photovoltaic power, the station will need to achieve energy self-sufficiency. Antarctica faces the polar night without sun during winter, however, and the sun never goes down during the midnight sun period of summer. This is why Antarctica is an ideal candidate region for testing this system by acquiring large amounts of photovoltaic energy during summer for storage and reuse (re-generation) during winter.

As the case with Antarctica, expectations are high in a wide range of different scenarios for systems that can continuously supply stable renewable energy that enables self-sufficiency, including remote islands or international peace-keeping operations by Japan Ministry of Defense where energy supplies are unreliable, or disaster regions where externally supplied energy is not available due to isolation caused by the disaster.

This article provides an overview of the efforts of Hitachi with regards to CHES, and in particular describes the demonstration that was conducted in the city of Nikaho in Akita Prefecture based on a 2011 contract with the National Institute of Polar Research (an Inter-University Research Institute Corporation Research Organization of Information and Systems).

OVERVIEW OF CHES

The use of storage batteries is being considered as an efficient means of energy storage. However, when storage batteries are used to store energy, there are problems such as natural discharge over long periods of time, the volume necessary for large-scale storage, transport (weight) issues, cost, and other issues, all of which make storage batteries suitable for short-term electric power storage, but not suitable for long-term, large-scale energy storage and transport. In response to these issues, CHES uses a type of organic hydride called MCH as the energy storage medium.

Characteristics of MCH

"Organic hydride" is a general term for a hydrogenated aromatic compound that is obtained by adding hydrogen to an aromatic compound. Organic hydrides can use the reversible reactions hydrogenation and dehydrogenation with a catalyst to exchange hydrogen with an aromatic compound. The hydrogenation reaction is exothermic and the dehydrogenation reaction is endothermic, and these reactions can be used to create a cycle of storing and supplying hydrogen.

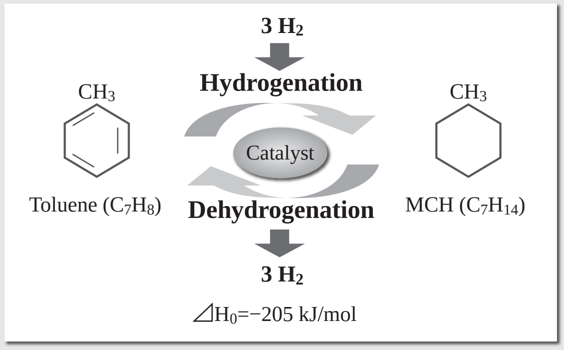
MCH is an organic hydride obtained from a toluene hydrogenation reaction, and both toluene and MCH are stable liquids at ordinary temperatures and pressures (see Fig. 1).

Both toluene and MCH are classified as Class IV petroleum in Category 1 hazardous materials under the Fire Service Act, and therefore offer a benefit whereby existing gasoline storage and transportation equipment and facilities can be used as they are.

The energy storage density offered by MCH is limited by the amount of energy in hydrogen that can be used in the dehydrogenation reaction, or approximately 1.58 kWh/L, which is roughly equivalent to eight times the energy density of a lithium-ion battery (see Fig. 2). Also, when it comes to storage, MCH is a liquid at normal temperatures and can be handled like gasoline, which means that it can be stored in large tanks just like petroleum products, and can be divided into smaller quantities for transport.

The transfer of hydrogen during MCH's hydrogenation and dehydrogenation reactions can be thought of as a means of storing hydrogen. Current mainstream methods of hydrogen storage include high-pressure hydrogen, liquid hydrogen, hydrogen storing alloys, and others, but hydrogen storage using organic hydrides is an extremely strong candidate as a storage method due to the aforementioned ease of handling and storage density benefits (see Fig. 3).

Organic hydrides include combinations such as benzene/cyclohexane, naphthalene/decalin, and others. Since the benzene in the benzene/cyclohexane combination is carcinogenic and requires careful handling, and the naphthalene in the naphthalene/decalin combination has a melting point of 80°C and is solid at normal temperatures, both of these combinations have problems in terms of practicality. The parts of the toluene/MCH combination are easy to handle and obtain, and are superior in terms of toxicity levels as well, making them an extremely practical type of organic hydride.



	MCH	Toluene	Class III light oil	Gasoline
Distillation temperature (°C)	100.4	110.6	175 or higher	17 to 220
Solidification point (°C)	−126	−95	−37.5	−40

MCH: methylcyclohexane

Fig. 1—MCH Hydrogenation and Dehydrogenation Reactions and Temperature Characteristics.
Toluene (C_7H_8) becomes MCH (C_7H_{14}) after a hydrogenation reaction (exothermic reaction) with three hydrogen molecules. MCH emits toluene and three hydrogen molecules after a dehydrogenation reaction (endothermic reaction). Both MCH and toluene are liquids at ordinary temperatures.

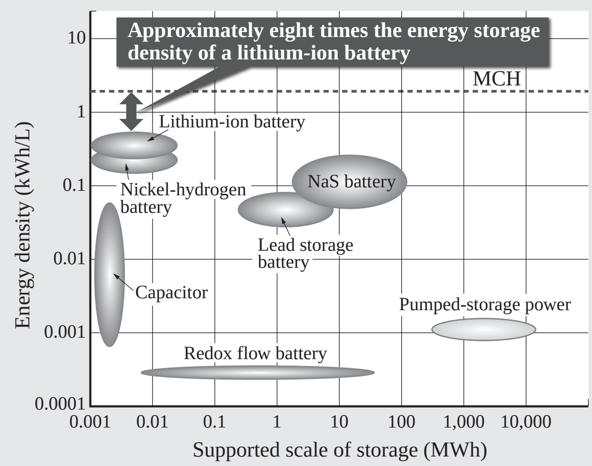


Fig. 2—Comparison of Energy Densities and Possible Scales of Storage Using Different Energy Storage Methods.
The energy density of MCH is approximately eight times that of a lithium-ion battery. The amount of MCH that can be stored depends on the volume of the storage tank, as with other petroleum products.

Principles and Issues of CHES

CHES is comprised of the following three subsystems (see Fig. 4).

(1) Hydrogen generation subsystem

This subsystem generates hydrogen by using the electric power derived from renewable energies such

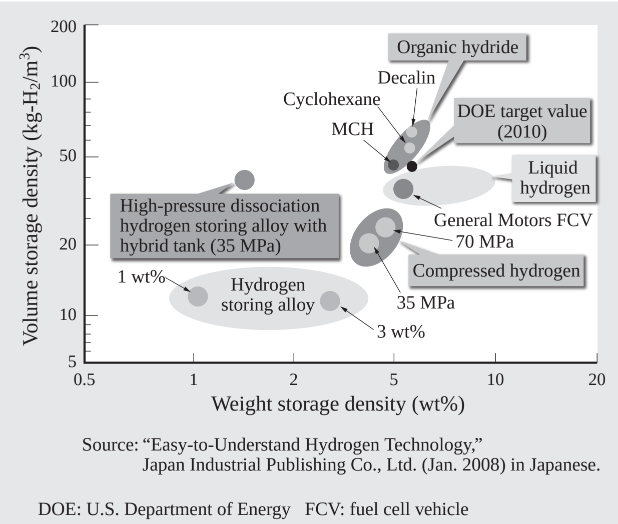


Fig. 3—Comparison of Storage Efficiencies Using Different Hydrogen Storage Methods.
This figure compares the storage efficiency of various hydrogen storage methods. Organic hydride is also an effective method from the perspective of hydrogen storage density.

as wind or photovoltaic power, excess power, or other sources of energy to electrolyze water using a water electrolyzer.

General water electrolyzers are designed for rated operation, and do not respond well to large fluctuations in input. For this reason, it is difficult to efficiently generate hydrogen from renewable energy due to the way it fluctuates.

A water electrolyzer must be developed that can respond to fluctuations in electric power input, so that generated renewable energy can be efficiently recovered, stored, and reused.

(2) Storage subsystem

The hydrogen generated by the hydrogen generation subsystem and the toluene stored in a tank are sent to the hydrogenation device in order to generate MCH through the hydrogenation reaction. The generated MCH is then stored in another tank.

The reactor used for the hydrogenation reaction was large, and there were issues related to reducing the size of the reactor for use in decentralized power supply systems and other situations. In addition, it is necessary to control the amount of toluene supplied based on the amount of hydrogen supplied by the hydrogen generation subsystem.

(3) Re-generation subsystem

The MCH stored in the MCH tank is sent to the dehydrogenator, and a dehydrogenation reaction is used to separate it into hydrogen and toluene. The reaction heat required for this dehydrogenation reaction is supplied using the exhaust heat of a hydrogen combined engine generator.

The separated hydrogen is used in the hydrogen combined diesel engine generator or hydrogen combined gas engine generator to generate electric power and heat, which is then supplied to the consumer. The separated toluene is stored in a tank, and then reused to produce MCH.

Engine control technology is indispensable here in order to optimize the combustion of the hydrogen mixing engine.

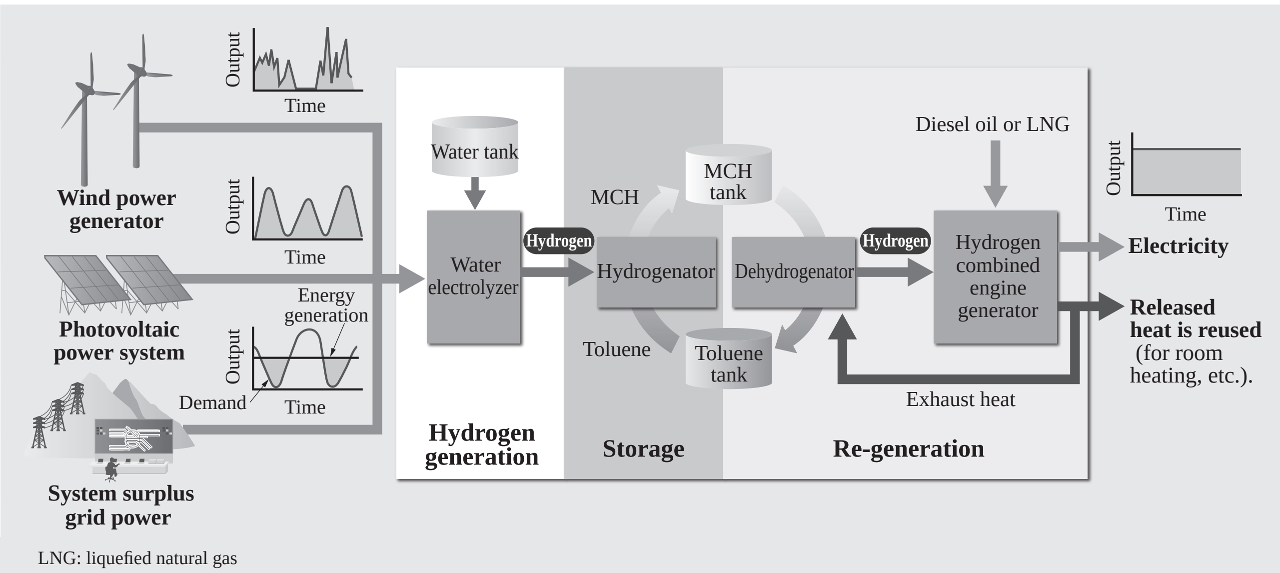


Fig. 4—Configuration of Carbon-hydride Energy Storage System (CHES).
The CHES is comprised of three subsystems: hydrogen generation, storage, and re-generation.

The efficiency of diesel engine generators used in power generation is generally around 40%, with most of the loss due to exhaust heat, and this is the number one cause of reduced energy efficiency in this system. Therefore, the effective utilization of exhaust heat is an issue that must be addressed in order to improve energy efficiency.

Development of CHES

Hitachi has been researching systems using organic hydrides for a long time. The issues described above have already been resolved, and a 40-kW-class demonstration plant has already been built in the city of Hitachi in Ibaraki Prefecture in order to work towards practical application of the system. This plant has implemented high-efficiency water electrolyzers, small and highly efficient hydrogenators, dehydrogenators, and other equipment (see Fig. 5).

This demonstration plant has hydrogen combined diesel engine generators that mix hydrogen in the diesel generator during combustion, which has been verified to reduce diesel oil consumption by approximately 30%. The plant where these facilities are installed is implementing on-site microgrid demonstrations such as wind power generation facilities, photovoltaic power facilities, power cogeneration facilities, large-scale lead storage batteries, and other experiments. There are plans to collaborate with these facilities as well.

(1) High-efficiency water electrolyzer

In order to resolve the hydrogen generation subsystem issue of responding to fluctuations in electric power input due to the use of renewable energy, a specially developed electrode material was adopted for use in the water electrolyzer that offers excellent corrosion resistance and responsiveness. Furthermore, by partitioning the electrolyzer into a large number of cells and controlling the number of operating cells in realtime based on the amount of electric power input , each electrolyzer cell can be run under the most efficient conditions possible, thereby achieving a high level of electrolysis efficiency that corresponds to fluctuations in input (see Fig. 6).

(2) Compact high-efficiency hydrogenator/dehydrogenator

The hydrogenator/dehydrogenator used in the storage subsystem and re-generation subsystem has optimized physical properties in the catalytic surface, and catalytic material was developed that is suited to both hydrogenation and dehydrogenation reactions based on temperature and pressure conditions (see Fig. 7).

Fig. 5—40-kW Class Cycling Renewable Energy Demonstration Plant.
A 40-kW-class demonstration plant was built in the city of Hitachi in Ibaraki Prefecture, and is being used to develop practical applications of CHES.

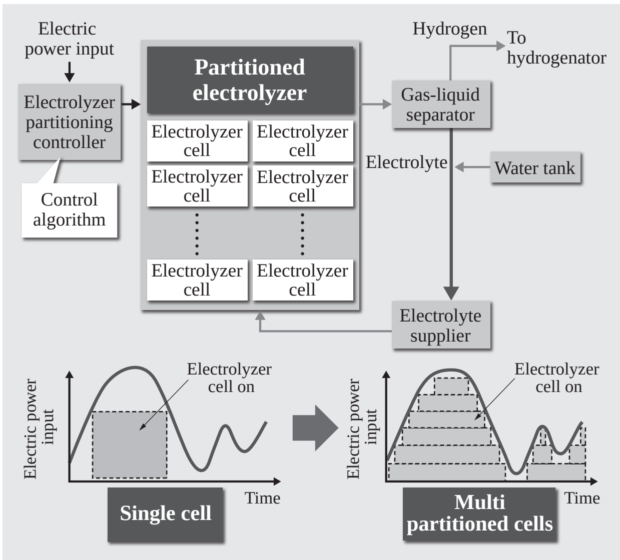


Fig. 6—Water Electrolyzer Features.
The electrolyzer cell is split into many segments in order to follow the fluctuations in electric power input and constantly operate at the ideal voltage, thereby achieving high-efficiency electrolysis.

The reactor's heat transfer path was optimized, and a compact, high-efficiency heat exchange reactor was developed that can be attached to the engine's exhaust pipe for use with the engine's high-temperature exhaust gas. This reactor's hydrogenation reaction occurs at approximately 200°C, and its dehydrogenation reaction occurs at approximately 350°C, both of which are within the range stipulated by the regulations of the High Pressure Gas Safety Act (less than 0.2 MPa). The implementation of this compact high-efficiency reactor means that the system does not suffer from

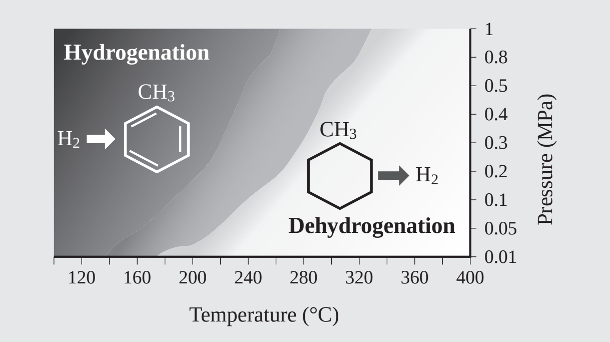


Fig. 7—Characteristics of Catalyst for Hydrogenator/ Dehydrogenator.
Hydrogenation and dehydrogenation are switched between based on temperature and pressure conditions. This can be used within the range stipulated by the regulations of the High Pressure Gas Safety Act (under 0.2 MPa).

restrictions in installation locations, and is practical in that it can be adopted for use as a dispersed power source and in other such situations.

Furthermore, by recovering and reusing the heat of the high-temperature exhaust gas, the efficiency of the engine generator was improved by an equivalent of 5%.

CHES Issues and Solutions

The issue facing this system is energy efficiency. With the current system, the ratio of electric power output to input is approximately 30%. Multiple processes must be performed between input and output, and loss accumulates with each one.

Of these processes, the heat lost as exhaust heat at the diesel engine generator is the biggest factor, and the re-generation and reuse of this heat is the key to improving efficiency. Even in the current system, some of the exhaust heat is recovered for the dehydrogenator's endothermic reaction, and the efficiency of the diesel engine generator is improved by approximately 5%, but the remaining exhaust heat must be utilized in order to improve energy efficiency further.

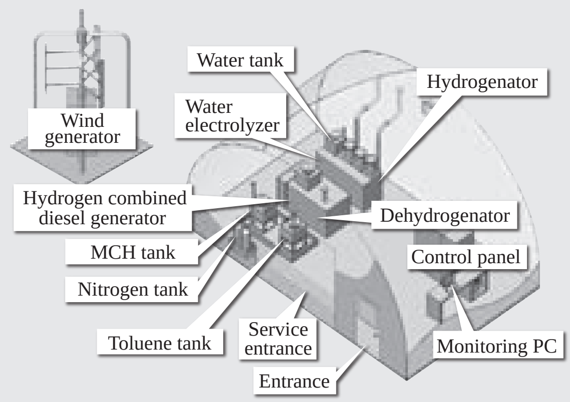
The goal is to recover more than 60% of input energy in the future, including the engine's exhaust heat supply, heat and power supply due to cogeneration, and so on.

DEMONSTRATION IN NIKAHO

Objectives, Test Equipment Configuration, and Test Details

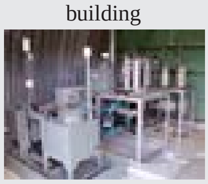
In the future, it is expected that large amounts of renewable energy will be generated in Antarctica at Showa Station, for the station's own use. Based on a contract with the National Institute of Polar Research, Hitachi conducted a demonstration at Nikaho Heights in the city of Nikaho in Akita Prefecture between November 2011 and March 2012 in order to gather basic data that can be used to improve the energy self-sufficiency ratio of Showa Station in the future (see Fig. 8).

The test equipment's engine generator capacity is envisioned with wind generator capacity utilization at between approximately 10% and 15%, and a 3-kW generator was adopted based on the wind generator's rating of 20 kW. Based on a balance between electric power input and the scale of equipment, the water electrolyzer cell tank was split into 16 segments.



Configuration of demonstration testing equipment at Nikaho Heights

Exterior view of building



Exterior view of system

Equipment	Specifications
Wind power generator	20 kW
Water electrolyzer	16-segment electrolyzer cell (volume: 3 L)
Toluene tank	90 L
MCH tank	90 L
Diesel engine generator	3 kW
Hydrogenator	1.28 L
Dehydrogenator	1.28 L

Fig. 8—Demonstration in Nikaho, Akita Prefecture.
The system was connected to a previously installed wind generator owned by the National Institute of Polar Research (an Inter-University Research Institute Corporation Research Organization of Information and Systems) to collect test data.

TABLE 1. Results of Demonstration Testing at Nikaho Heights
Other than the toluene recovery rate, each value is slightly lower at Nikaho Heights.

Performance item	Performance indicator	Test results at factory	Test results at Nikaho Heights
Electrolysis efficiency	Hydrogen production efficiency (%)	65%	61.4%
MCH production rate	MCH production rate (%)	99%	94%
Diesel oil saving	Diesel oil saving rate (%)	23%	22%
H_2 re-generation efficiency (dehydrogenation efficiency)	Dehydrogenation efficiency (%)	85%	82%
Toluene recycle rate	Toluene recycle rate (%)	95%	99.6%
—	Outside air temperature (°C)	Between 14 and 23°C	Between −3 and 2°C

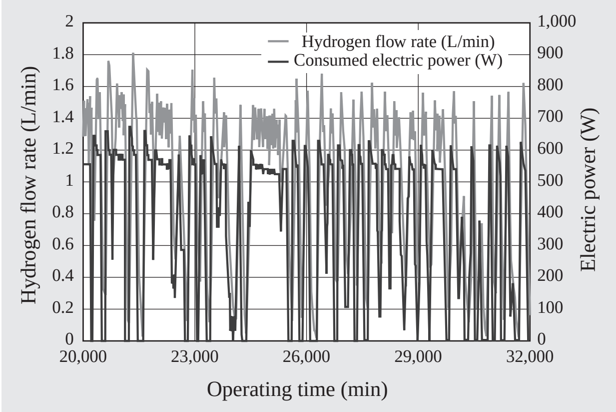


Fig. 9—Water Electrolyzer Responsiveness.
There is a time lag of approximately 10 seconds after fluctuations in electric power, and it was verified that based on a consideration of the buffer caused by pipes and other factors, that this is a good level of responsiveness.

The wind conditions of Nikaho Heights are similar to those of Showa Station because it also has a cold climate, and therefore the results of analyzing CHES characteristics and problems distilled here will be vital information for application to the development of a practical system for use in Antarctica in the future.

Specifically, before the system was sent to Nikaho Heights, factory testing was performed to collect data on 16 items, including the electric power input to the electrolyzer, temperature, density, amount of hydrogen generated, and so on, and the results were compared with the same data acquired on Nikaho Heights in order to analyze characteristics particular to use in a cold climate while distilling issues.

Solutions to these issues will be implemented as the system is prepared for future practical application in Antarctica.

Test Results and Considerations

As a result of testing, diesel oil was reduced by approximately 22%. In addition, the rate of toluene recovery was shown to be more beneficial for vapor-liquid separation as the temperature dropped, with the result that efficiency in this area was higher at Nikaho Heights. On the other hand, electrolysis efficiency, MCH generation rate, and regeneration efficiency were all slightly lower at Nikaho Heights (see Table 1).

When the water electrolyzer's electric power input is compared with the flow rate of generated hydrogen, it was found that there is a time lag of around 10 seconds after the wind generator's input fluctuations, showing that when compared to rated operation during testing within the plant, electrolysis efficiency did not drop drastically with respect to fluctuations in electric power at Nikaho Heights. This delay is thought to be caused by the buffer effect in pipes and other equipment, and the effects of splitting the electrolyzer cell into many segments were verified (see Fig. 9).

It is conjectured that the reductions in electrolysis efficiency, MCH generation rate, and regeneration efficiency were caused by the reductions in catalyst efficiency in the electrolyzer cells and reactor due to the low-temperature environment. Therefore, countermeasures are being considered so that when the system is put to practical use in the future, heat can be retained while heat radiation is inhibited so that the temperature environment of each reaction process is improved based on the ambient temperature, and efficiency can be otherwise improved for each process.

CONCLUSIONS

This article provided an overview of the CHES efforts of Hitachi, and described the demonstration Hitachi conducted in Nikaho, Akita based on a 2011 contract with the National Institute of Polar Research.

Since CHES makes it possible to store the renewable energy generated in Antarctica for long periods of time, and since reuse makes it possible to reduce fuel consumption, it is seen as a way to contribute to resolving Antarctica's energy problems. Also, since it reduces consumption of fossil fuel, it also contributes to a reduction in carbon dioxide (CO_2) without modification.

According to the "Energy White Paper 2011," Japan's energy self-sufficiency ratio is 7%, or 19% if nuclear energy is added. Even when the results of resource development led by Japan is added, the autonomous energy ratio is still as low as 38%, and this shows incontrovertibly that Japan's energy foundation is fragile.

It is imperative that Japan improve its energy self-sufficiency ratio from an energy security perspective, and to this end, expectations are high regarding the prospects of improving the usage ratio of renewable energy. This system offers an easy way to store, transport, and otherwise handle the power generated through renewable energy, which fluctuates greatly. As such, it is a technology that can also contribute to improving Japan's energy self-sufficiency ratio.

For this technology to contribute to improving the energy self-sufficiency ratio, however, the use of the hydrogen energy provided through CHES must expand, diversify, and spread correspondingly. For this to happen, hydrogen must be adopted as fuel for the hydrogen mixed combustion used in thermal power generation, fuel cells, burners, boilers, absorption refrigerators, and other purposes, while a wide range of technologies using hydrogen must be developed, spread, and expanded, including hydrogen engines.

Although the "hydrogen society" has been proposed for a long time, it is unfortunately true that realization of this goal still eludes Japan. Reasons for this include the fact that hydrogen is difficult to handle, and that hydrogen usage technology has not progressed. Hitachi will continue researching and developing this system in the hope that the spread of this technology will help make hydrogen easy to handle, that the growth of hydrogen energy usage technology will gain momentum, and that this will help open the door to a low-carbon hydrogen society.

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Water Resource Cycle Simulation System

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OVERVIEW: Hitachi is collaborating with Geosphere Environmental Technology Corporation in the construction of a water resource cycle simulation system that can contribute to both water resource management as well as water disaster countermeasures. This simulation system makes it possible to analyze both surface water and groundwater in a unified manner, and includes visualization functions that enable the rapid and easy-to-understand display of a wide range of representations. These functions provide an accurate picture of the current conditions as well as future predictions of water resources and water disasters. Hitachi plans to use this simulation system to contribute to finding solutions to issues affecting the entire planet, including the securement of water resources and the resolution of various problems stemming from water disasters.

INTRODUCTION

THE world has been faced with a large number of increasingly serious problems in recent years due to issues such as global warming, rapid population growth, and societal developments, including a lack of industrial and drinking water, the growth of drought regions and corresponding crop failures, and flooding or inundation caused by torrential rain. A diverse range of complicated measures will be required in order to resolve these problems.

Japan faces threats such as a disorganized supply of water resources and frequent sudden torrential rains, all of which require solutions in the areas of water resource usage and water disaster countermeasures. In order to solve these problems, the “Emergency Measure Bill Regarding Regulating the Use of Groundwater” was submitted to the National Diet of Japan in January 2012 as lawmaker-initiated legislation intended to protect water resources. In addition, implementation of water measures is gaining momentum, including the installation of X-band multi-parameter radars that can observe regional rainfall amounts almost in realtime.

It is against this background that a need has arisen for functions that can correctly predict changes in water resource distribution both inside and outside the country, as well as the occurrence of water disasters, while supporting rapid and smooth decision-making regarding policies. To this end, Hitachi is collaborating with Geosphere Environmental Technology Corporation in order to help popularize the use of a water resource cycle simulation system.

This article discusses a water resource cycle simulation system that can contribute to water resource management and water disaster countermeasures, as well as the specific technologies that comprise this system.

NEEDS AND TECHNOLOGICAL ISSUES

Needs

Functions that support the decision-making that goes into solving various problems related to water resources and water disasters must meet the following two needs:

(1) Accurate understanding of the current conditions and future predictions

The ability to grasp the current amount and quality of groundwater resources that cannot actually be seen, and the ability to make predictions about the future based on the changing climate and human activities, are extremely important elements involved in the formulation of water resource plans. Accurate predictions about the future are also important when it comes to developing countermeasures for water disasters. Simulation technology must meet these needs.

(2) Ability to attach meaning to huge amounts of data and visualization functions

It is important that functions exist with the ability to systematically organize and easily attach meaning to the relationships between data and events based on huge amounts of data, including observational data and simulation results. In other words, a drawing function that utilizes the geospatial information system (GIS) is a key part of helping water policy decision-makers and local residents easily understand the data.

Technological Issues

Simulation issues

(1) Modeling interactions between surface water and groundwater

In the past, simulations of the water cycle were limited to specific areas based on objective, such as groundwater or flow analysis. For this reason, interactions between surface water and groundwater (river influent seepage, springs, and so on) were often not considered, making highly accurate analysis difficult.

(2) Analysis including material transfer

In order to enable quick and safe decision-making during the determination of a water policy or disaster response, it is necessary to analyze the transfer processes of materials such as nutrient salts and radioactive nuclides.

(3) High-speed calculation

Huge amounts of calculations must be performed in order to implement the consideration of surface water and groundwater and the analysis of the material transfer process as described in (1) and (2). Algorithms that can quickly execute these huge amounts of calculations are necessary to contribute to rapid decision-making.

Water resource cycle visualization issues

(1) Groundwater flow time series display

Easy-to-understand representations of water resource cycle simulation results that deal with surface water, groundwater, and how this water changes over time must display the conditions of surface and underground water flows in a time series format. In the past, GIS often lacked the ability to display underground conditions or time series data.

(2) Statistical processing of information distributed in three-dimensional space

Information distributed in three-dimensional space must be statistically processed so that the simulation results can be understood by the decision-makers.

(3) High-speed responsiveness

Information processing technology that can support rapid decision-making is necessary, including the ability to process and draw large amounts of data at high speed.

SIMULATION AND VISUALIZATION TECHNOLOGIES

Simulation Technology from a New Perspective

Calculations of water flow are generally executed by defining models of flow channels, such as river channels, drainage paths, pipeline networks, and others. The general purpose terrestrial fluid-flow simulator[1] (GETFLOWS*) system developed by Graduate School of Engineering, The University of Tokyo's Professor Hiroyuki Tosaka (Chairman of Geosphere Environmental Technology Corporation), on the other hand, can take terrain, the shape of strata, hydrological properties, precipitation conditions, and other information to automatically create models of natural river networks, lakes, and groundwater flow systems[2].

(1) Unified analysis of surface water and groundwater

By comprehensively analyzing the equations of motion that are derived from rivers, lakes, and other surface water, groundwater in the ground, and compressible fluids such as air, water cycle analysis can be used to unify surface water and groundwater in a manner that was not possible with previous simulations. This makes it possible to consider interactions between surface water and groundwater.

Fig. 1 shows an example of groundwater flow analysis. By analyzing surface water and groundwater in a unified manner, it is possible to derive the routes taken by rainwater that has seeped into mountainous terrain as it discharges in rivers or the ocean. This sample analysis shows how the system can contribute to decision-making with regards to water policies, such as excessive groundwater intake requires countermeasures to deal with ground subsidence, or the securement and regulation of water resources for use as agro-industrial water.

* GETFLOWS is a trademark of Geosphere Environmental Technology Corporation.

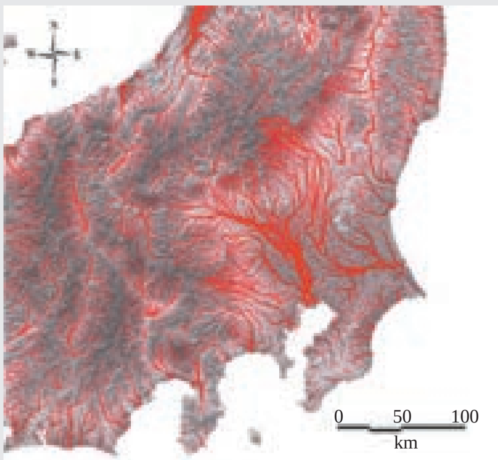

Fig. 1—Groundwater Flow Analysis.
Groundwater flow analysis can be used to track the routes taken by rainwater that has seeped into a mountain as it discharges in a river or ocean.

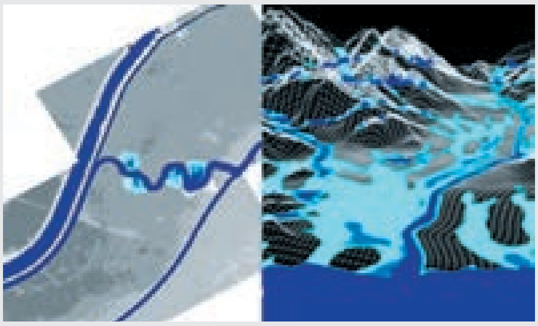

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Fig. 2—Flood Prediction.
Inundation calculations can give consideration given to the levee break point (left) and the moistness of the soil (right).

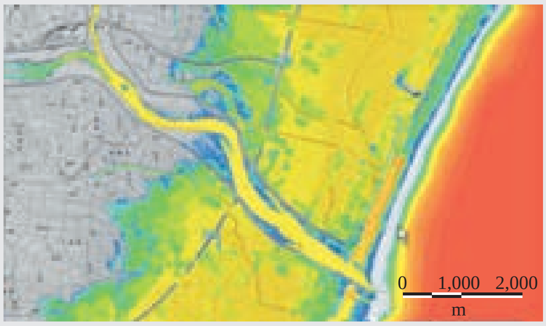

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Fig. 3—Simulation of Tsunami Flooding.
This figure shows the distribution of water depth three hours after a tsunami occurs.

A sample flood prediction analysis is shown in Fig. 2. The left side of this figure shows the flooding calculation with consideration given to the levee break point, and the right side shows an example of a flooding calculation that gives consideration to the moistness of the soil. This unified analysis of surface water and groundwater makes it possible to represent the rapid increase in the groundwater level during torrential rains together with inundation inside a levee, in order to predict the location where flooding will start, the flooded region, and the amount of flooding at a high level of accuracy.

(2) Analysis of material transfer processes

The system also offers the ability to consider kinetic changes in material that are caused by degradation and chemical reactions. The incorporation of material transfer processes such as river transportation, leakage of substances into the ground, sorption/desorption, and advection-dispersion make it possible, for instance, to analyze the behavior of radioactive nuclides.

Fig. 3 shows an example of a flooding simulation for three hours after a tsunami occurs. By inputting the tsunami waveform as it varies over time, it is possible to analyze the tsunami's dynamic behavior in coastal regions, including intrusion into rivers and inundation flows. The analysis can also simulate how salinity decreases due to factors such as rainfall in regions flooded by a tsunami, based on the soil characteristics of each land-use classification. This capability can be utilized during the consideration of a wide range of environment restoration effects, including salt removal planning during reconstruction projects.

Fig. 4 shows a simulation of nitrogen contamination in surface water and groundwater due to economic activities. The left side of the figure shows the results

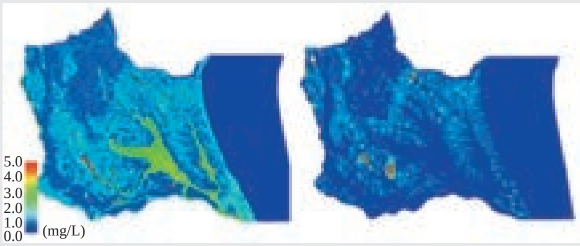

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Fig. 4—Simulation of Nitrogen Contamination of Surface Water and Groundwater Due to Economic Activities.
The left side of this figure shows the total nitrogen concentration in surface water, and the right side shows the same in groundwater.

of an analysis of the total nitrogen concentration in surface water, and the right side shows the same for groundwater[(3)]. By analyzing the transportation and distribution of materials in this way, it is possible to follow the details of the material movement processes while tracing contaminant materials as they spread through surface water and groundwater, so that decontamination policies can be considered in case the contaminant material flows.

(3) High-speed calculation using clusters of personal computers

Although the amount of data in high-speed calculation simulation results created using a cluster of personal computers (PCs) will depend on the size of the model, the results of simulating a grid of approximately 20 million points will require an output of around 1 Tbyte. For this reason, parallel calculation with a PC cluster is used to achieve high-capacity and high-speed computation in order to support rapid decision-making.

Characteristics of Visualization Technology

Hitachi is working to develop visualization technology that uses GIS as a means of visualizing groundwater, which usually cannot be seen directly. This technology offers the following three characteristics:

(1) Highly accurate display of surface, underground, and time series data

A map of the entire world is managed in a uniform manner using a geographical coordinate system, and a global model has been adopted that enables three-dimensional display so that both surface and underground can be included in a highly accurate, textured display. Furthermore, functions have been added to show underground structures that are ordinarily not visible. Also, by adding a time axis to the three-dimensional geospatial information, it is possible to display simulation results that vary over time, such as the conditions of a disaster.

Fig. 5 shows analysis results including the cross-section view of an underground grid covering areas including the watershed of the Sagami River in Kanagawa Prefecture, as well as a translucent satellite image[4]. The cross-section view of the underground grid makes it possible to represent both surface and underground. By overlaying the simulation results on the translucent satellite image, it is possible to intuitively understand the flow of surface water and groundwater.

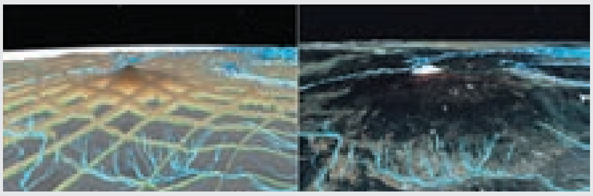

Fig. 5—Cross-section of Underground Grid and Translucent Satellite Image.
A cross-section of the underground grid is displayed over the flow of groundwater in a translucent satellite image to create an easy-to-understand representation.

Fig. 6 shows an example of animation. The flow routes of surface water and groundwater can be represented through animation, and by displaying this on top of three-dimensional geospatial information, it is possible to visualize dynamic changes in behavior over both space and time.

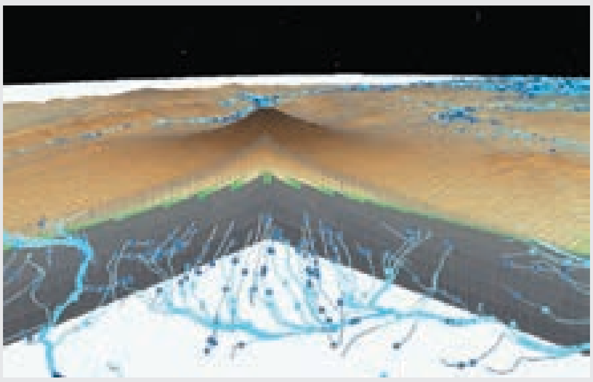

Fig. 6—Animation.
The flows of surface water and groundwater are animated for easy visualization.

(2) Spatial analysis functions

Spatial analysis functions make it possible to spatially summarize the results of governmental or watershed boundary simulations, in order to represent simulation results such as the amount of available groundwater resources in an easy-to-understand manner.

Fig. 7 shows a color-coded display of a summary of the distribution of water resources available underground based on spatial analysis[5]. The ability to understand the distribution of usable groundwater resources can contribute to the formulation of water resource usage plans.

(3) High-speed responsiveness

Although previous GIS systems would experience delays during rendering processes such as zooming in, this system improves rendering speed through means such as data culling based on scale reduction.

EXPECTATIONS FOR THE WATER RESOURCE CYCLE SIMULATION SYSTEM

Hitachi and Geosphere Environmental Technology Corporation are working to develop this water resource cycle simulation system as a product that combines data organization, simulation, spatial analysis,

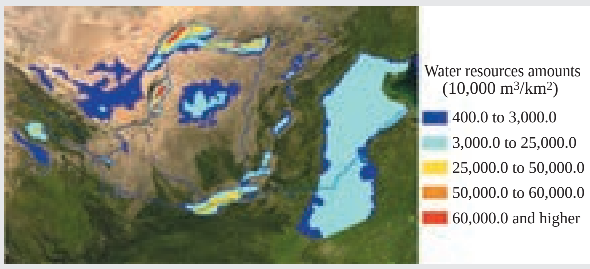

Fig. 7—Color-coded Distribution of Amount of Available Groundwater Resources Based on Spatial Analysis.
Amount of available groundwater resources are summarized and displayed with color codes corresponding to amounts.

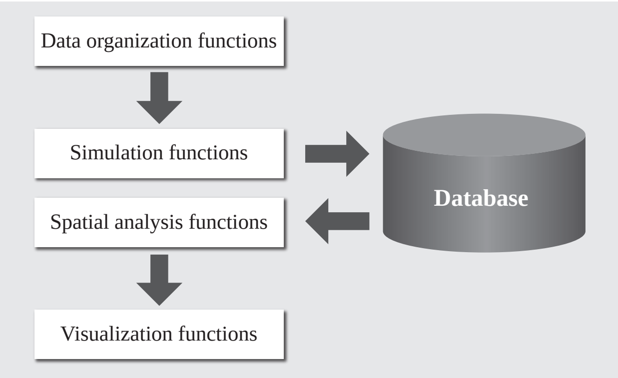

Fig. 8—System Functions and Flow.
This figure shows each function and a system flow chart. The data organization and simulation functions make use of water resource cycle simulation technologies, and the spatial analysis and visualization functions make use of visualization technologies based on the geospatial information system (GIS).

and visualization functions in a cloud service that can be used by a wide range of users (see Fig. 8). Further improvements in simulation accuracy and the provision of even faster and easier-to-understand visualized information to decision-makers will enable this system to support the correct management and prediction of water (the "oil of the 21st century") while contributing to the achievement of a sustainable public infrastructure and a society that is safe and secure.

CONCLUSIONS

This article mainly focused on a water resource cycle simulation system that can contribute to water resource management and water disaster countermeasures, as well as the specific technologies that comprise this system. In summary, the water resource cycle simulation is a fusion of water resource cycle simulation technologies that unifies analyses of surface water and groundwater with visualization technology based on GIS. It is a tool that can rapidly provide easy-to-understand representations of the current conditions and future predictions of surface water and groundwater.

In a world faced by water resource shortages and water disasters, this water resource cycle simulation system is an exceedingly important tool. Hitachi will continue contributing to solutions to the various global problems related to water resources and water disasters.

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Satellite Imagery Solutions for Monitoring of Forest and Ecosystems

Kojiro Saito
Hideyuki Sakaguchi

OVERVIEW: Forest conservation activities aimed at curbing global climate change and ecosystem conservation activities aimed at preventing loss of biodiversity have been carried out on a global level in recent years. Monitoring based on the analysis of satellite imagery for which time-series data exists from the past is an effective way of quantitatively evaluating these conservation activities. Hitachi provides satellite imagery analysis solutions and monitoring systems that coherently offer everything from image collection through processing and analysis for use in forest and ecosystem conservation.

INTRODUCTION

DEBATES are being held and countermeasures are being taken to combat global climate change and the biodiversity crisis, centered on the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity. Hitachi is working on satellite imagery solutions to monitor forest and ecosystem conservation[(1)], and is promoting the provision of satellite imagery analysis solutions (the sales of satellite imagery data and data analysis services) and monitoring systems.

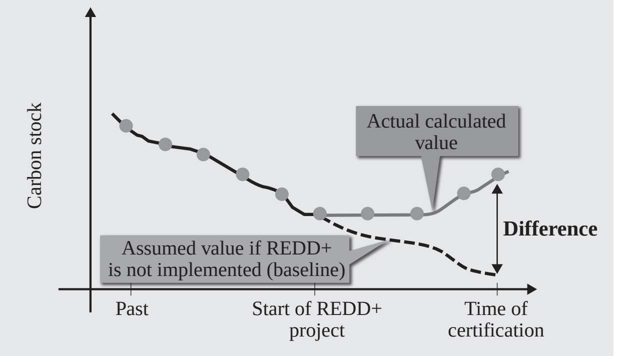
This article discusses the satellite imagery solutions Hitachi is working on for evaluating forest and ecosystem conservation activities.

SATELLITE IMAGERY SOLUTION FOR EVALUATING FOREST CONSERVATION

REDD+ Procedures

As a forest conservation activity that developing economies are participating in to combat climate change, the Reducing Emissions from Deforestation and Forest Degradation in Developing Countries Plus program (REDD+: a program that seeks to reduce the emissions caused by deforestation and forest degradation in developing countries while conserving forest carbon stock and managing forests in a sustainable manner so as to improve forest carbon stock) is starting to incorporate a concept whereby increases in carbon stock stemming from forest conservation are rewarded with credits. REDD+ includes both the efforts of the UNFCCC as well as voluntary efforts running in parallel. At present, voluntary REDD+ efforts are leading the way, including the independent Verified Carbon Standard (VCS), which is influencing discussions of REDD+ methods at the United Nations. The procedures of REDD+ based on VCS are described briefly below.

First, the carbon stock is estimated based on the state of the forest, starting in the past. This information is extrapolated to draw up a baseline (the assumed amount of carbon stock if the REDD+ project were not implemented). When a REDD+ project is started, the amount of carbon dioxide (CO_2) emitted from the forest is reduced by measures such as curbing deforestation and forest degradation, thereby causing the carbon stock of the entire forest to increase (see Fig. 1). The difference between the actual calculated value of the carbon stock and the assumed baseline value is certified by the VCS certificate authority, and carbon credits are issued.



REDD+: Reducing Emissions from Deforestation and Forest Degradation in Developing Countries Plus

Fig. 1—Increasing Carbon Stock.
By implementing REDD+, carbon stock increases over the baseline predicted value. Credits are issued once the difference is calculated and certified.

The business operator involved in the REDD+ project can then earn revenue by trading credits on the market, and then use this money as funding to manage the forest for the project, or to contribute to the costs involved in certification or monitoring.

Use of Satellite Imagery for REDD+

At the COP15 conference held in 2009, it was made clear that an effective means of REDD+ monitoring is to combine remote sensing with field surveys[(2)]. Remote sensing and field surveys are being combined just as in the case of VCS REDD+ monitoring. Examples of these monitoring procedures are shown in Fig. 2. VCS REDD+ monitoring uses satellite imagery for the two purposes of formulating a baseline and evaluating the amount of carbon stock increase due to a REDD+ project, based on the methodology.

Baseline formulation

With the VCS REDD+ methodology, the use of remote sensing data is stipulated for formulating baselines, and there are exacting regulations for items such as satellite imagery, spatial resolution, and observational frequency[(3)]. Fig. 2 (a) shows one example of a baseline formulation procedure.

Evaluating amounts of increase in carbon stock

After the REDD+ project starts, increases in carbon stock due to the implementation of forest conservation are evaluated on a regular basis [see Fig. 2 (b)]. As with the baseline formulation procedure, the total amount of biomass in the project region is calculated using a combination of satellite imagery and field surveys, and the change in carbon stock is derived.

Fig. 3 shows the satellite imagery analysis solutions for forest conservation monitoring conceived of by Hitachi based on the VCS REDD+ monitoring methods, guidelines by the Intergovernmental Panel on Climate Change (IPCC)[(4)], and other considerations.

(1) Satellite imagery acquisition plan

Investigate whether or not satellite imagery (especially medium-resolution satellite imagery) archives exist for the REDD+ project target region

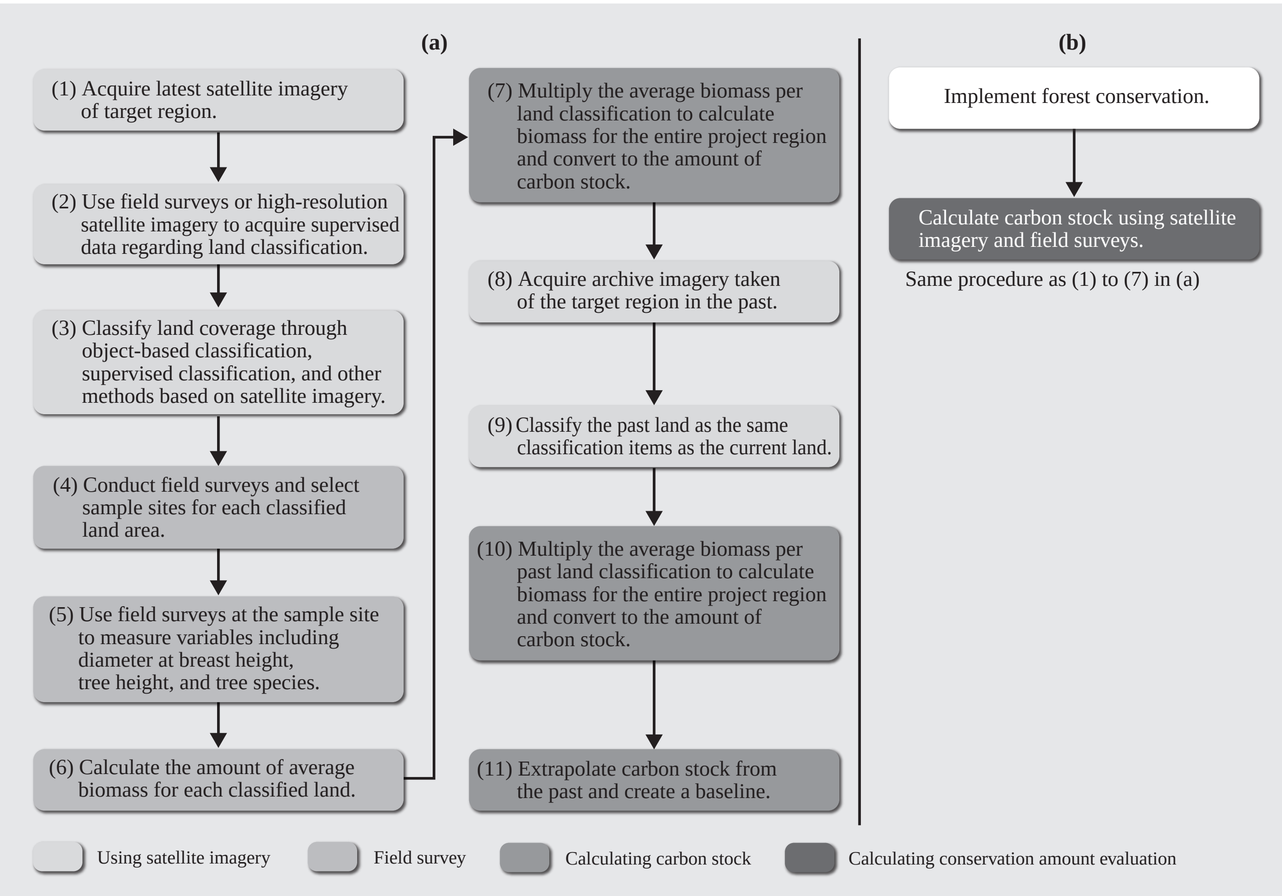


Fig. 2—Example of REDD+ Monitoring Procedures.
The monitoring procedure for formulating a baseline is shown in (a), and the monitoring procedure for evaluating increases in amounts of carbon stock is shown in (b).

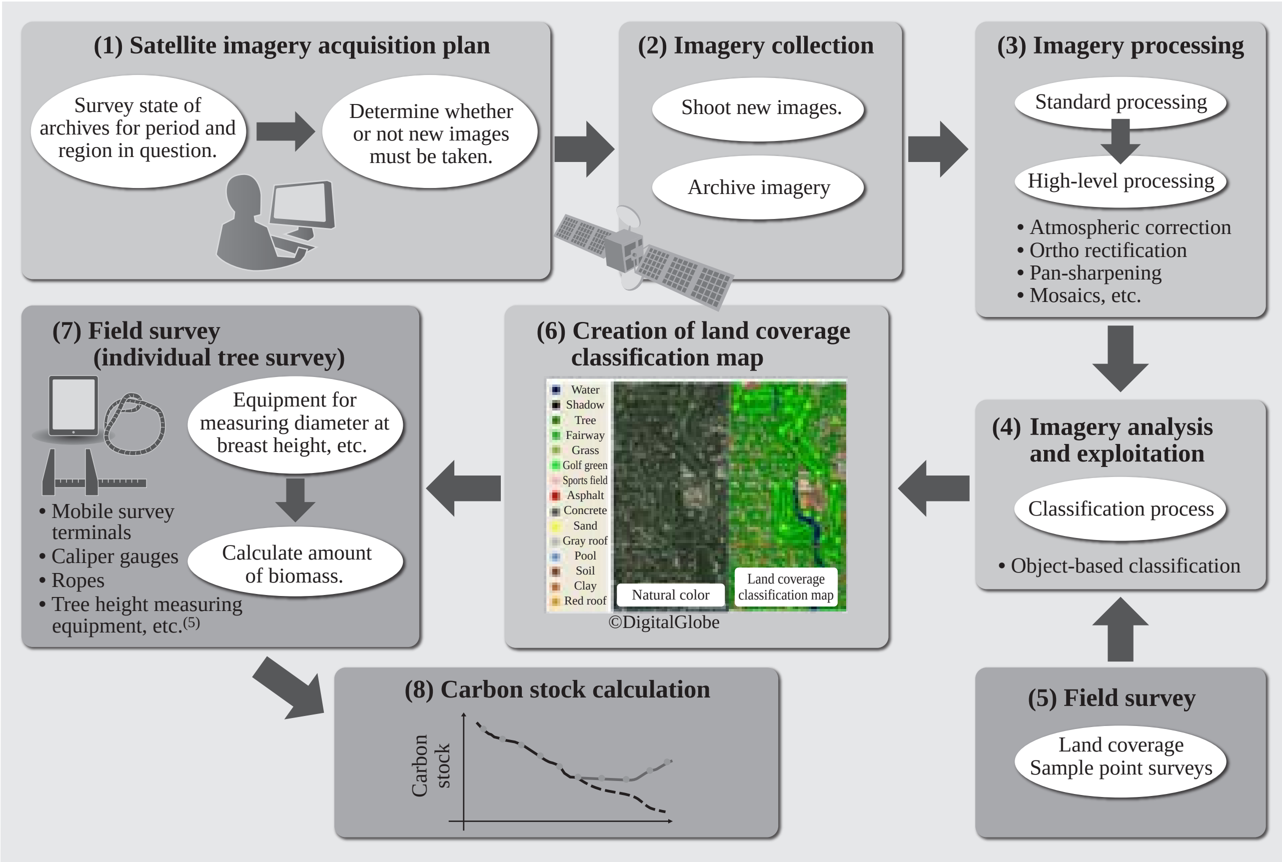


Fig. 3—Satellite Imagery Analysis Solution for Monitoring Forest Conservation.
Changes in carbon stock are calculated by combining satellite imagery [(1)—(4), (6)] and field surveys [(5), (7), (8)]. Hitachi takes advantage of a wealth of knowledge in satellite imagery systems in order to contribute to the monitoring of forest conservation.

during the timeframe used as the baseline, and determine whether or not new images must be taken based on whether or not there is recent satellite imagery.

(2) Imagery collection

Acquire archives or newly taken imagery.

(3) Imagery processing

The imagery acquired in (2) is processed in order to adjust for deformations specific to the sensors, and to apply atmospheric correction, orthogonal (ortho) rectification, and other corrections. Positions are aligned with past images in order to investigate changes in the forest over time.

(4) Imagery analysis and exploitation

Object-based and supervised classification are applied to the imagery along with other forms in order to classify land coverage.

(5) Field survey

Accuracy verification and correction are applied on-location to check land coverage classification as necessary.

(6) Creation of land coverage classification map

The results of (4) and (5) are combined in order to create a land coverage classification map for the target region.

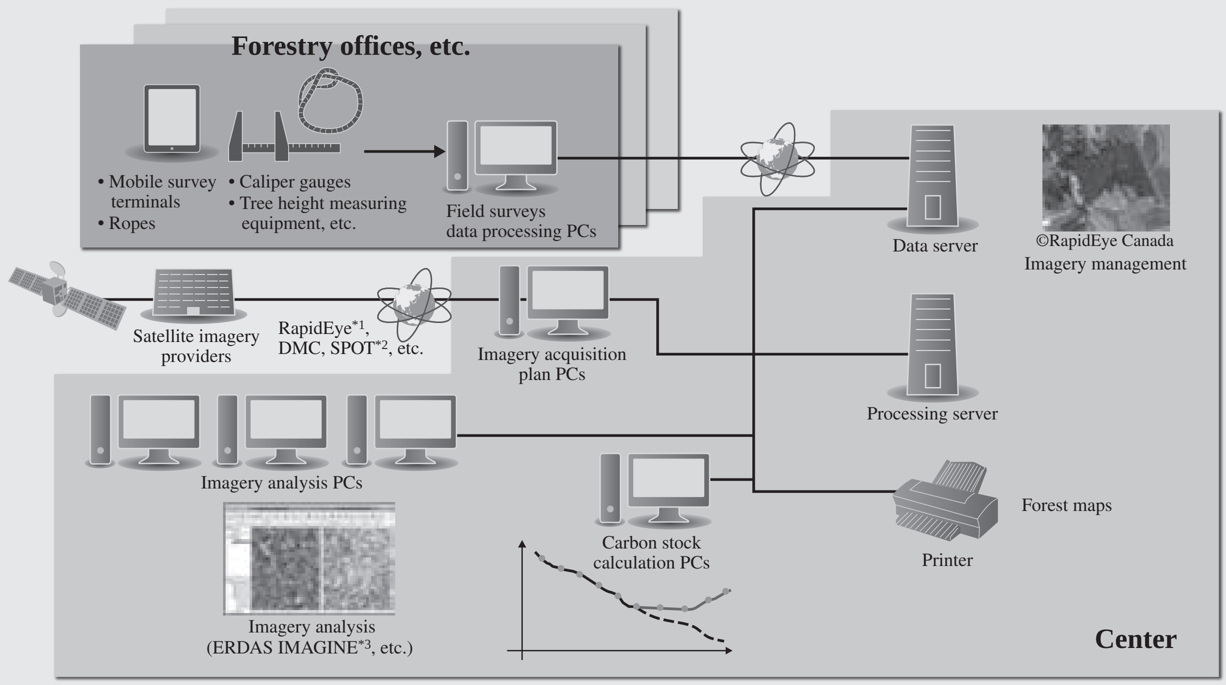
(7) Field survey (individual tree survey)

Sample points are surveyed on location to acquire data such as tree height and diameter at breast height.

(8) Carbon stock calculation

The results of (6) and (7) are combined to find the amount of biomass stored in the trees and calculate the carbon stock.

Fig. 4 shows an overview of the system of satellite imagery solutions described above. Field survey information owned by national forestry offices and other organizations is stored in a central data server, is combined with satellite imagery obtained from satellite imagery providers (mainly medium resolution satellite imagery including RapidEye, DMC, SPOT, and others), and is used for tasks such as the creation of forest maps and the calculation of carbon stock. By applying its track record and the knowledge it has cultivated in satellite imagery utilization systems, Hitachi supports the evaluation of forest conservation projects in developing countries through the construction of the types of forest monitoring systems shown in this figure.



PC: personal computer
*1 RapidEye is a registered trademark of RapidEye Canada Ltd.
*2 SPOT is a trademark or registered trademark of Spot Image in France and other countries.
*3 ERDAS IMAGINE is a trademark or registered trademark of ERDAS, Inc.

Fig. 4—Overview of Forest Monitoring System Using Satellite Imagery.
This system is used to analyze and manage the satellite imagery obtained from satellite imagery providers, as well as to calculate carbon stock.

SATELLITE IMAGERY SOLUTION FOR EVALUATING ECOSYSTEM CONSERVATION

Debates and discussions have been held at the Convention on Biological Diversity's COP conferences, and ecosystem conservation efforts are being carried out around the world to protect biodiversity. In addition to forests, which are ecosystems that are important for biodiversity, coral reefs, seaweed beds, and other marine ecosystems are also important ecosystems in which large numbers of organisms live. The use of remote sensing data including satellite imagery is also effective for monitoring these types of ecosystems as well(6), and is contributing to the evaluation of biodiversity.

The use of satellite imagery solutions to monitor ecosystem conservation is envisioned to work the same way as in the monitoring of forest conservation, and satellite imagery can be effectively utilized for ecosystem conservation as well. WorldView-2, which is owned by the American company DigitalGlobe* and for which Hitachi has data distribution rights in the Asian region, has a high resolution of 2 m in multispectral ranges, and includes a highly water-permeable coastal band (observation wavelength band between 400 and 450 nm). By combining the

Fig. 5—Coral Reef Imagery from WorldView-2.
The imagery of WorldView-2 with its highly water-permeable coastal band can be utilized in the monitoring of coral reefs and other coastal region ecosystems.

* DigitalGlobe is a registered trademark of DigitalGlobe.

WorldView-2 coastal, blue, and green bands and measuring relative absorption amounts, it is potentially possible to measure down to a water depth of between 20 and 30 m[7], which makes this an effective means of monitoring coral reefs and other ecosystems in coastal regions (see Fig. 5).

CONCLUSIONS

This article discussed the satellite imagery solutions Hitachi is working on for use in evaluating forest and ecosystem conservation activities.

It is expected that forest and ecosystem conservation efforts will increase around the world in the coming years, and Hitachi will continue working to ensure that the satellite imagery solutions it offers for use in evaluating these conservation activities will contribute even further.

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Small Unmanned Aerial Vehicle System for Advanced Information-gathering

Shota Ikenoza
Fumitaka Otsu
Toru Furukawa
Norimichi Sato

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

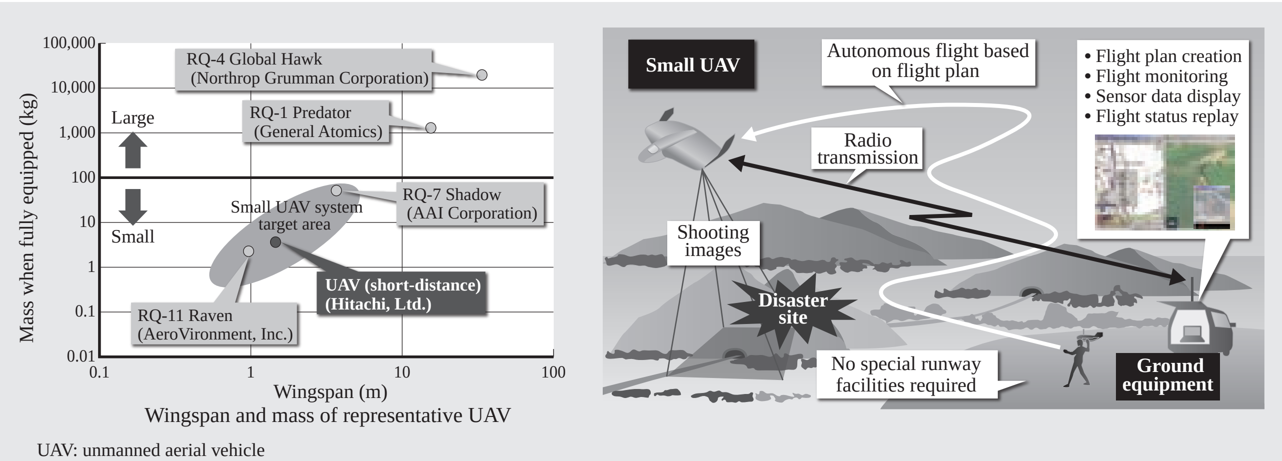

Fig. 1—Target Areas of World Trends in Small UAV Systems and Operation.
As a wide variety of UAVs are being developed around the world, Hitachi has developed a small UAV system with an airframe mass of less than 100 kg that can be used by a small number of operators, in order to gather information on-site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

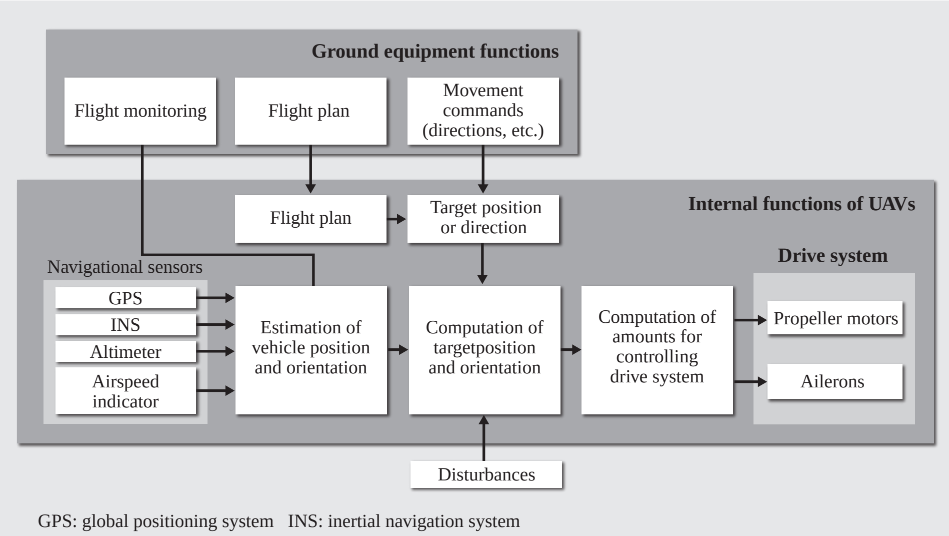

Fig. 2—Basic Autonomous Flight Control Method.
This figure shows the autonomous flight control system used with small UAVs. A vehicle uses its on-board navigational sensors to determine its own position and orientation, and controls its drive system in order to arrive at the next flight pass point.

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.

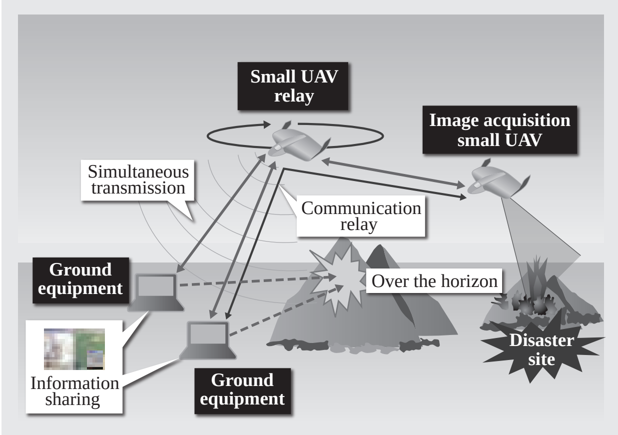

Fig. 3—Aerial Mesh Network Overview.
Multiple devices create a flexible network. By flying small UAVs as relays, it becomes possible to communicate in realtime with other small UAVs that are over the horizon.

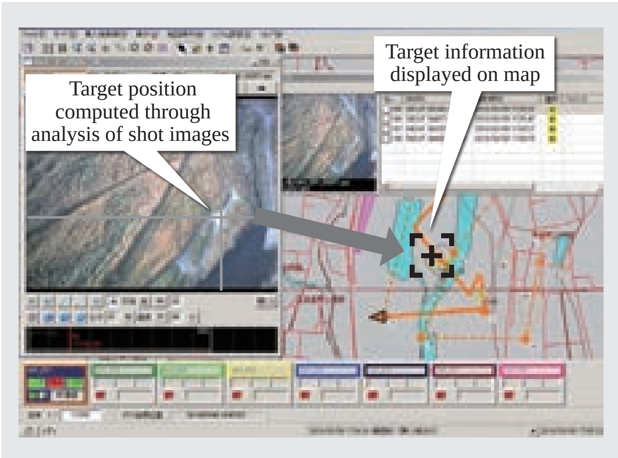

Fig. 4—Example of Target Position Computation.
Shot images are used to compute the position coordinates of the specified target, and the target information is displayed on the map.

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.

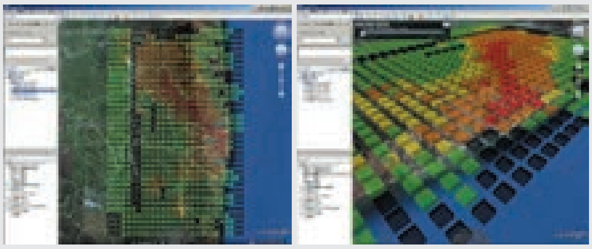

Fig. 5—Example of Visualizing Environmental Information.
This is an example of measured radiation data visualized using Google Maps. Visualization makes it possible to grasp information visually.*

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.

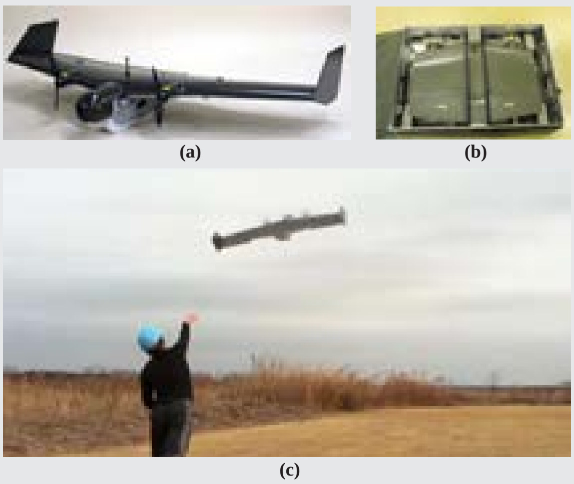

Fig. 6—Exterior of UAV (Short-distance) JUXS-S1 and Thrown Takeoff.
Due to the small and light airframe, this UAV can be easily carried and operated by a small number of people. (a) shows the UAV after assembly, and (b) shows it packed. A thrown takeoff (c) has also become possible, and no special devices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

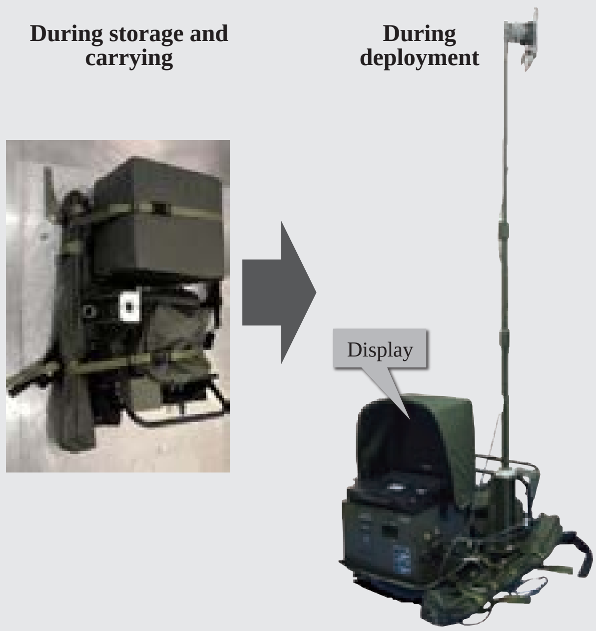

Fig. 7—Exterior of Ground Equipment during Storage, Carrying, and Deployment.
Ground equipment is small and lightweight, just like the fuselage. Information from the small UAV can be verified in the display.

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.

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Maritime Infrastructure Security Using Underwater Sonar Systems

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OVERVIEW: Hitachi has been developing and manufacturing sonar systems for use in the ships of the Japan Maritime Self-Defense Force since the 1950s. This technology, which at first was mainly developed as a means of finding submarines and underwater mines, is currently being used for the protection of public infrastructures located along the coast, and to contribute to the improvement of both efficiency and safety in underwater civil engineering work. Hitachi will continue aggressively working to achieve safety and security in each type of public marine infrastructure, with a focus on underwater acoustic system technology.

INTRODUCTION

JAPAN, which is comprised of islands, is a marine nation, and not only does it enjoy countless benefits from the ocean, it also relies on the ocean for more than 90% of its cargo shipments. Various types of marine security have been important topics in recent years due to problems such as a range of terroristic actions, piracy, and other issues.

In the 1950s, Hitachi began to work on the research and development of sonar systems that can search for various types of undersea objects using ultrasonic waves, and has delivered these systems for use on ships in the civil service.

This article provides an overview of sonar systems and discusses Hitachi's track record in participating in research related to marine infrastructure security.

OVERVIEW OF SONAR SYSTEM

Visible light, radio waves, and other electromagnetic waves attenuate quickly underwater, making it extremely difficult to locate objects using radar. A sonar system works in the same way as the method used by the dolphin, a type of marine mammal, to locate the positions of underwater objects with sound waves.

History of Development

In 1912, the luxury liner Titanic hit a gigantic iceberg during its maiden journey from the UK to New York, sinking and taking with it the lives of approximately 1,500 passengers. Spurred on by this tragedy, the USA developed a device that could detect icebergs by bouncing sound waves off their underwater parts and picking up the reflected sound, called "sound navigation and ranging," or "sonar." Sonar technology has been improved in various ways since then, and was used by the navies of Europe and the USA to detect submarines during the ship battles of the First World War.

Basic Principle

A sonar system uses a sensor that converts between electrical and acoustic signals to send ultrasonic waves underwater. The sound reflected off underwater objects and the seafloor is received and converted back into electrical signals, which are then turned into images through various types of signal processing. Sonar uses this basic principle to detect underwater objects, and similar ultrasonic wave technology is also used by fishing industry's fish detectors, and by the medical sector's ultrasonic imagers. Fig. 1 shows this basic principle in a system block.

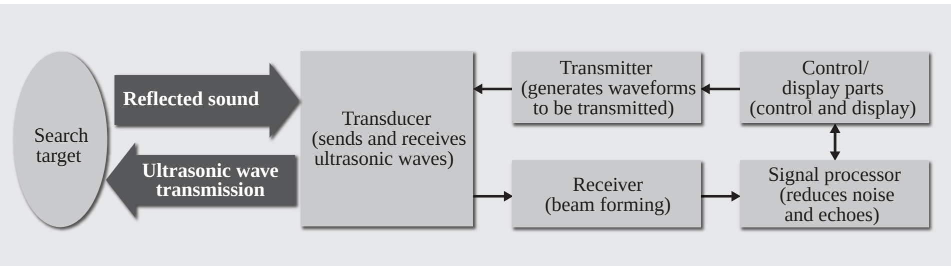

Fig. 1—Basic Principle of Sonar.
This system block shows the basic principle used by sonar to detect underwater objects.

OVERVIEW OF MINE HUNTING SONAR SYSTEM

Hitachi was the first company in Japan to develop sonar for detecting submarines and mines in the postwar era (based on the research conducted by Hitachi, Ltd.). This section provides an overview of the sonar-based mine hunting sonar systems used to search for and classify mines, as well as a description of the technologies that are applied to this task. Fig. 2 shows a minesweeper equipped with a mine hunting sonar system.

Target Objects

An underwater mine, which is the type of weapon mine hunting sonars attempt to find, works by exploding after it detects either the noise or fluctuations in geomagnetism or water pressure caused by ship movement, thereby damaging the hull of a passing ship. A mine's external form is a small spherical or cylindrical shape, and inside the mine is explosive material, multiple ship detection sensors, and detonators. Mines are covertly dispersed in shipping lanes throughout the vast sea, and since they are tiny objects that wait motionlessly underwater or on the seafloor for ships to ambush, they are extremely difficult to find.

Main Functions of Applied Technologies

The development and manufacturing of mine hunting sonars requires technologies in a wide range of fields, including operational analysis, system engineering, marine acoustic engineering, piezoelectric materials, high-speed computing, optical transmission, signal image processing, and mechatronics control, as well as human-machine interfaces for the sake of operability, maintainability, and upgradeability. The key components and technologies applied to functions are described below.

Fig. 2—Minesweepers Equipped with Mine Hunting Sonars.
A minesweeper guards the safety of the ocean by removing mines laid underwater and on the seafloor.

(1) Transducers

A transducer is an electrical acoustic converter that is equipped at the bottom of the ship, transmits ultrasonic waves underwater, and receives the reflected sounds. A large number of broadband transmitting and receiving elements are in an array in the transducer module, which is included along with the electronic circuit module in a watertight stainless steel case. The transducer internally converts received signals to light and transmits them to the on-ship processor for front-end processing to reduce the effects of signal degradation and noise, in order to convert the received ultrasonic waves into high-definition images.

(2) Drive stabilizers

A minesweeper is a small ship with a standard displacement of approximately 500 t, and is easily destabilized by ocean waves. In order to deal with this problem, data from the motion sensors in the ship's hull is used to control multiple watertight hydraulic cylinders and rotation and elevation devices in a three-axis parallel link system. This makes it possible to correct for the oscillation of the transducer in realtime, so that mines can be searched for in a stable fashion even in rough seas.

(3) Signal processing and display

When ultrasonic waves are transmitted, other sounds are picked up as well, including the various noises caused by the moving ship, and underwater echoes from the seafloor, reefs, and other objects that are not mines. Noise/echo reduction signal processing and signal accumulation functions are used to accumulate multiple signals received and corrected based on the speed of the ship's own movement, thereby removing extraneous noise signals. This makes it possible to clearly display just the shape of the seafloor and other underwater objects, thereby improving the visibility of picked up images.

(4) Automatic support functions

An automatic detection function is used to automatically superimpose a detection marker over any signal that appears to be a mine in the underwater images shown on the display. Two algorithms are available for selection based on hydrographic conditions, the attributes of the ocean area, and other environmental characteristics. When the "multiping" signal detection process algorithm reaches a threshold after receiving and accumulating multiple signals that appear to be the search target from the same position, it determines that the search target has been detected. The phase-error variance process is an algorithm that quantifies the stability of phase differences, and detects a mine if the stability of the signal is less than the threshold. This algorithm was created to analyze the attributes of echo signals by taking data measurements of the actual ocean surface.

The automatic classification function extracts the image region from search target images that appear to indicate the detection of a mine, and applies image processing to automatically measure and display dimensions. The sonar crew then determines the type of mine based on these measurement results.

(5) Search target depth measurement function

Reflected sounds from the mine are used to automatically compute the depth of the search target based on the calculation of the vertical orientation of the phase difference between the transducer's upper and lower layers of reception elements. Since the propagation path taken by the sound waves is bent according to the temperature of the seawater, by automatically correcting based on sound speed data measured in advance at each depth, it is possible to calculate the correct depth. Based on this result, the sonar crew determines whether or not the mine moored under the water is a ground mine.

(6) Others

Defense systems exist in a "sword and shield" relationship. On the mine's side, development is aimed at preventing detection through research into shapes and materials with acoustic stealth capabilities. On the sonar side, research and development must continuously focus on how to detect signals with a weak reflection echo, and on sensors for unmanned underwater vehicles and other areas. The development and manufacturing of these systems in the field of defense involves specialized engineers, various types of specialized facilities such as large cisterns and fixtures, and secret maintenance engineering facilities that satisfy the standards of the Japan Ministry of Defense.

Track Record

The mine hunting sonars manufactured by Hitachi have helped contribute to international efforts such as minesweeping in the Persian Gulf after the war of 1991, in the search and rescue operations after the Great East Japan Earthquake of 2011, and in the various missions of the Japan Maritime Self-Defense Force. Minesweepers also include an acoustic minesweeping apparatus that imitates the sound of a moving ship in order to cause mines to explode through sympathetic detonation, a non-magnetic crane and capstan to deploy and recover this apparatus from the water, and a degausser and various electrical devices designed to prevent the mines from detonating due to the magnetism of the ship's hull. Many different products built by Hitachi are contributing to the safety of the ocean in this way.

CONTRIBUTION TO MARINE PUBLIC INFRASTRUCTURES

A description of Hitachi's track record of using sonar technology to participate in the security of public marine infrastructures follows.

The demand for strengthened security against various types of terrorism has been increasing in recent years, starting with the September 11, 2001 terrorist attacks in the USA. In addition, a large number of crucial social infrastructures are located along Japan's seafront and in the coastal region, including various types of power plants, oil reserve facilities, and offshore airports. If these facilities are hit by a terrorist attack, Japan's society and economy may suffer damage.

Terrorist acts aimed at essential facilities based on covert infiltration from the sea are envisioned in the design of the various advanced security systems in the geographical environment of the seafront and coast, and there have been kidnapping problems and cases of suspicious vessels in the past as well. During an incident that occurred in the marine area off the southwestern coast of Kyushu in 2001, a covert operation vessel was sunk in a gun battle with the Japan Coast Guard, and a large number of weapons were discovered in the vessel along with equipment used in underwater infiltration including small boats, rafts, diving gear, and underwater scooters.

Underwater Infiltration Monitoring: Research into Underwater Security Sonar Systems

Together with the Underwater Technology Research Center, Institute of Industrial Science, The University of Tokyo, Hitachi participated in joint research into an underwater security sonar system between 2005 and 2007. The objective of this research is to build a monitoring system that can prevent acts of terrorism against all types of coastal public infrastructure facilities, and to contribute to the achievement of a safe and secure society by establishing various technologies based on operation and evaluation in an actual harbor. A conceptual diagram of these operations is shown in Fig. 3.

The system is built around an integrated monitoring system, and is comprised of fixed location sonar

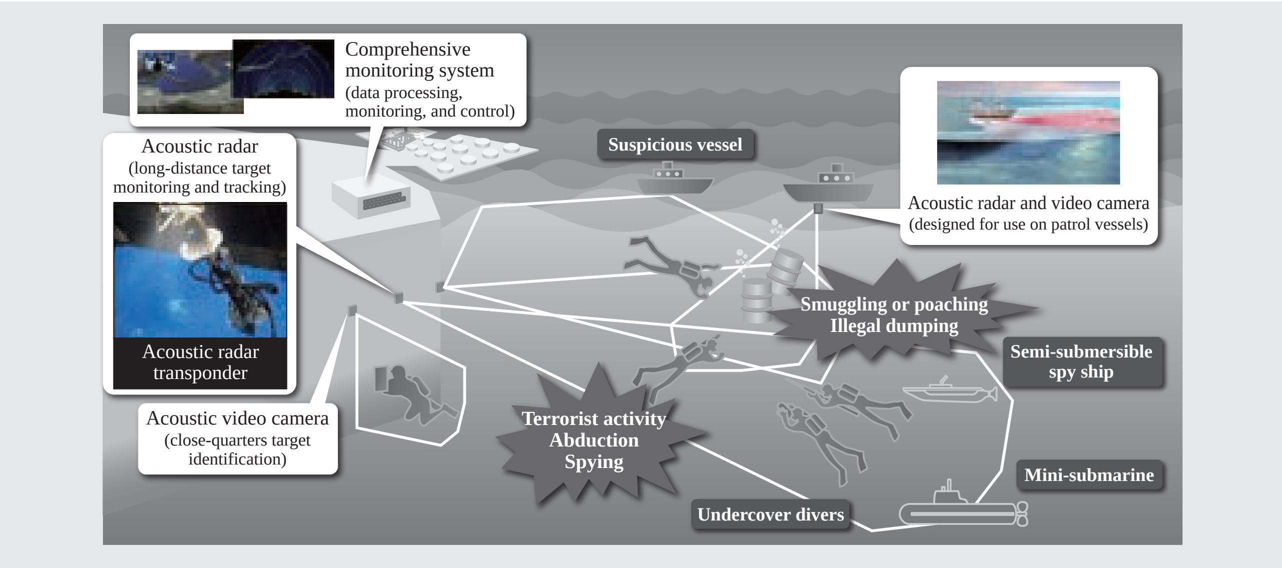

Fig. 3—Conceptual Diagram of Underwater Security Sonar System Operation.
This diagram illustrates the concepts behind the underwater security sonar system.

devices installed on quays and the seafloor, as well as sonar devices installed on ships. Of this research, Hitachi was responsible for general consideration and support of the research project as a whole, the integrated monitoring subsystem that is central to operation, sonar signal processing, and the rotation and elevation mechanism installed on the ships. In addition, Hitachi provided technologies in a wide range of fields, including system engineering, sonar signal processing software, mechatronics, and others.

During this three-year research project, after numerous test evaluations conducted on the actual ocean surface, integrated operations were tested over a period of approximately 10 days in November 2007. These tests showed that the system resulting from this research and development is effective in the monitoring of actual underwater infiltration. Fig. 4 shows an example of how the various types of data are integrated, with ship sonar images superimposed over geographical data.

Underwater Construction

In 2009 fiscal year, Hitachi participated in the development of an ultrasonic three-dimensional image acquisition device aimed at underwater surveying and the verification of construction for the Port and Airport Research Institute. The purpose of this device is the verification of the state of the underwater bridge supports of Haneda Airport's runway D, and it is contributing to the streamlining of construction verification for underwater civil engineering work in an environment affected by Tama River's tidal currents and poor underwater visibility, as well as to improvements in safety for underwater operations. This device is also being used to verify the underwater state of harbors affected by the Great East Japan Earthquake.

CONCLUSIONS

This article provided an overview of sonar systems and applied technologies, and described Hitachi's track record of participating in research regarding marine infrastructure security.

The relative merits of a defense system are determined by its balance between the need for operators and the viability of its engineering. The sensor technology used to search for enemies is the most important technology, and research institutions in Europe and the USA are fiercely competing in the research and development of this technology.

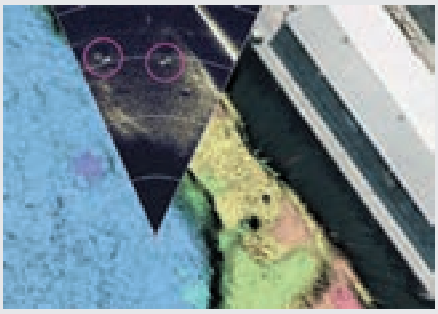

Fig. 4—Example of Superimposition of Acoustic Sensor Images.
This example shows ship sonar images superimposed over geographical data.

At present, Hitachi has begun considering an integrated sonar system for use on next-generation minesweepers, and is starting development on an acoustic imaging sonar system that can acquire video at an even higher resolution in a small and lightweight form (see Fig. 5).

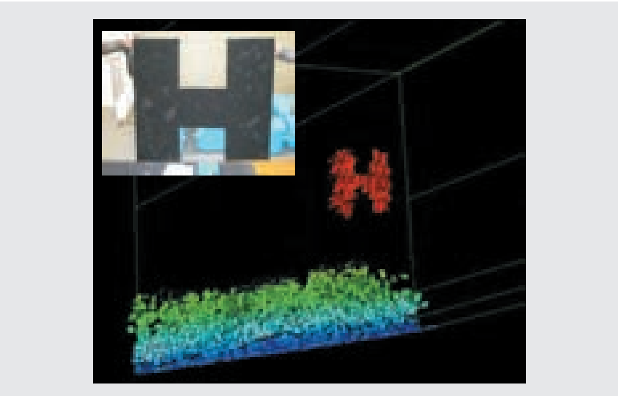

Fig. 5—Example of Acoustic Imaging Sonar Images.
An acoustic imaging sonar system is being developed that is expected to have applications in public marine infrastructures, including ocean exploration, search and rescue operations, underwater civil engineering, harbor restoration, and other areas.

In the future, Hitachi will continue to work aggressively to contribute to the safety and security of public marine infrastructures and society, including not just defense and security, but also applications in ocean exploration, search and rescue operations, underwater civil engineering, harbor restoration, and underwater unmanned vehicles.

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Prefabricated Supporting Bridging Systems

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Tomio Nakamura
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OVERVIEW: As a nation with many rivers and ravines, Japan relies on a large number of bridges to ensure the delivery of essential services. Hitachi supplies two different prefabricated supporting bridging systems to the Japan Ministry of Defense for use when bridges are destroyed by natural disasters such as earthquakes or floods. The two bridges are suitable for different situations, with the Type 92 floating bridge (a prefabricated temporary floating bridge) being designed to float on a river and support vehicle traffic, while the Type 07 mobility support bridge (a prefabricated temporary span bridge) can span rivers or ravines without requiring piers. The Japan Ground Self-Defense Force uses these products for purposes that include civil defense training drills conducted by regional governments. In the Great East Japan Earthquake, a Type 92 floating bridge was used in ferry configuration to transport construction machinery to an island that had become isolated. With the prospect of civilian applications in mind, Hitachi intends to continue developing supporting bridge systems that can contribute to recovery work during disasters.

INTRODUCTION

JAPAN has many rivers and ravines, and bridges are constructed to allow the movement of traffic. Prefabricated supporting bridges are needed to restore essential services rapidly after a bridge has been destroyed by an earthquake, flood, or other disaster. Hitachi supplies prefabricated bridging systems to the Japan Ministry of Defense for use as mobility support equipment to enable the passage of heavy vehicles.

This article describes two prefabricated bridging systems supplied to the Japan Ministry of Defense that are currently in use, and also their civilian applications: the Type 92 floating bridge that floats on a river and supports vehicle traffic, and the Type 07 mobility support bridge that can span rivers or ravines without requiring piers.

OVERVIEW OF PREFABRICATED SUPPORTING BRIDGING SYSTEMS

Prefabricated Temporary Floating Bridge

Prefabricated temporary floating bridges are used to cross rivers that have become impassable because, for example, an existing bridge has been destroyed. They are made from special-purpose trucks for transporting the floats, which float on the river and form part of the bridge structure, and boats, which push the floats on the water (see Fig. 1 and Fig. 2).

On arriving at the river, each truck reverses down to the river's edge, and then a hydraulic cylinder tips

Photo courtesy of Japan Ministry of Defense

Fig. 1—Bridge Construction and Vehicles Driving over Type 92 Floating Bridge.
The Type 92 floating bridge consists of floats that float on the river and form part of the bridge structure, and boats that maneuver (push) the floats on the water.

Fig. 2—Floats and Boats in Transit.
Special-purpose trucks are used to transport the floats and boats used by the Type 92 floating bridge.

up a special frame installed on the truck so that the float (which is attached to this frame) can be released to slide off onto the surface of the river.

The floats are designed to fold up into a compact arrangement compatible with road widths when carried on the truck, and then to use the balance between their own weight and the force of floatation to unfold by themselves once deployed onto the water.

The boats are also launched by sliding off the special-purpose trucks used to transport them.

As the floats do not have any motive power and would float away if not restrained, the boats are used to push them into position and link them together to form the floating bridge. As the floats are designed to be linked together in a chain, floating bridges spanning several hundred meters can be constructed.

In addition to being used as a conventional bridge, the floating bridge can also be used as a ferry capable of transporting vehicles or goods to the opposite shore by linking a number of floats together and using the boats to push them along.

The floating bridge needs to be made small and light so that it can be installed quickly during an emergency, and its design must also allow for factors such as vehicle width, height, and gross weight to ensure that the trucks will be able to carry the floats on conventional roads. Similarly, the floating bridge must have sufficient strength to carry heavy vehicles (such as tanks) both when used as a floating bridge and as a ferry. To satisfy these requirements, the floating bridges are built using a welded structure of high-tensile aluminum.

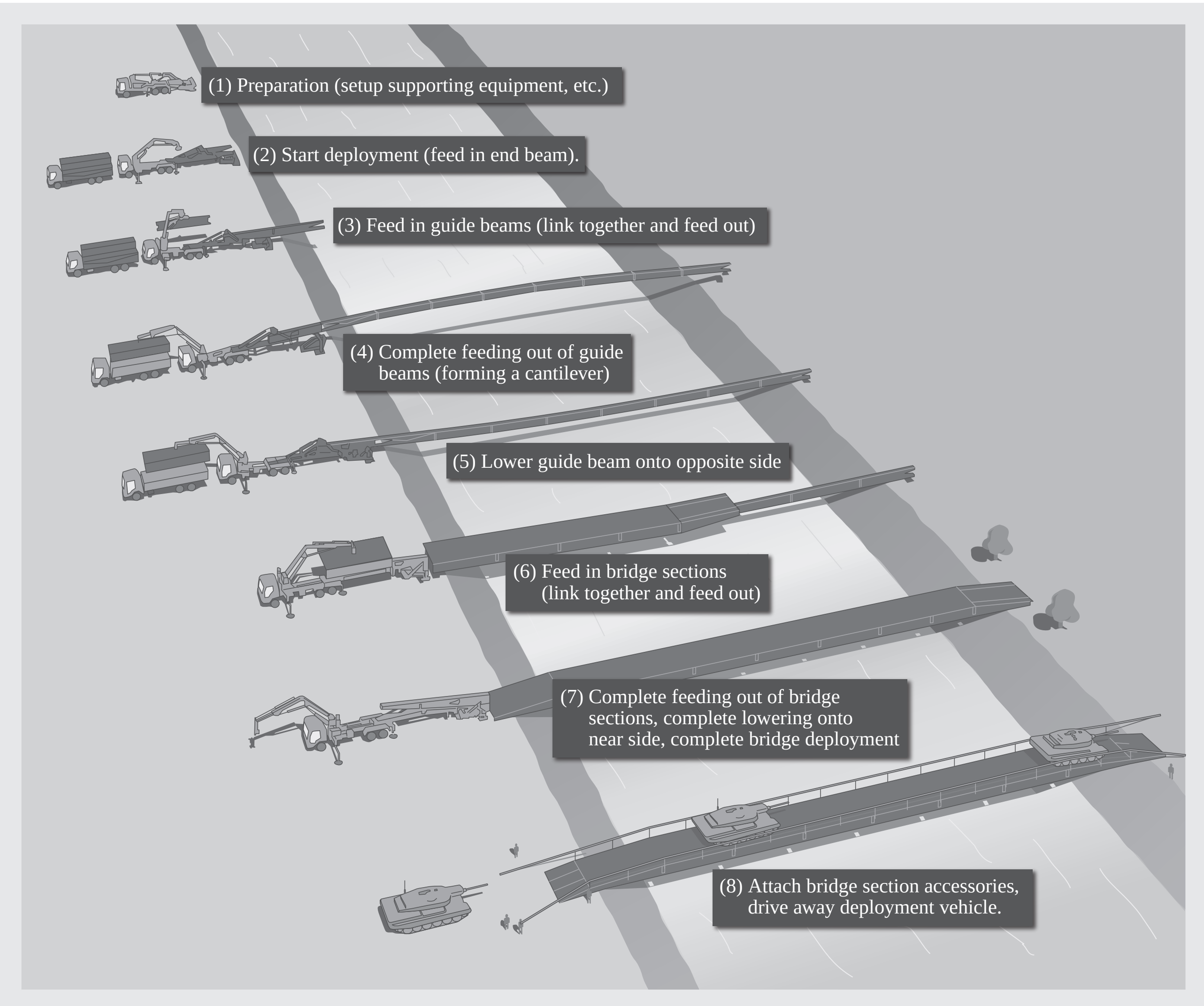

Fig. 3—Deployment Procedure.
First the guide beams are fed out as a cantilever and then lowered onto the opposite side. Next, the bridge sections are unloaded from the transporter and placed on the guide beam where they are linked together and slid along until the bridge is completed.

Fig. 4—Guide Beams during Deployment Process.
The guide beams have a welded structure of high-strength aluminum.

Prefabricated Temporary Span Bridge

Prefabricated temporary span bridges are used to cross rivers or ravines in situations such as when an existing bridge has been destroyed. Compared to previous prefabricated temporary span bridges that have used piers (trestles or other bridge supports), the benefits of not requiring piers include eliminating restrictions on the depth of the terrain being bridged and shortening the amount of preliminary work required to level the bottom of the river and erect piers.

The bridge is constructed using a special vehicle fitted with the equipment needed to deploy the bridge, guide beams that guide the deployment process together with the vehicle used to transport them, and bridge sections that form part of the bridge together with the vehicle used to transport them.

Fig. 3 shows the procedure for deploying a bridge. First, a special crane on the construction vehicle unloads the guide beams from their transporter. Next, the guide beams are linked together on the back of the construction vehicle and feed out to form a cantilever. To minimize the weight of the guide beams that form the cantilever, they have a welded structure of high-strength aluminum. Unfortunately, aluminum is more prone to bending than steel and therefore the more guide beams are linked together, the greater the amount of bending. To deal with this, a support is located between the guide beams being fed out and the equipment on the construction vehicle. This support can be raised or lowered to ensure that the far end of the guide beam reaches the opposite side correctly even if a high degree of bending occurs (see Fig. 4).

After feeding out the guide beam, the end is lowered onto the opposite side. Next, the special crane on the construction vehicle unloads the bridge sections from their transporter, places them on the guide beam, links them together, and slides them out along the guide beam to construct the bridge (see Fig. 5).

Like the floating bridge, the span bridge must also be made small and light, taking account of factors such as vehicle width, height, and gross weight to ensure that the vehicles can drive on standard Japanese roads. While the bridge sections used for the bridge must be wide enough for the vehicles passing over the bridge, they must also be narrower than the road when loaded on the transporter. To achieve this, both sides of the bridge sections are designed to fold out, and the special crane on the construction vehicle uses an attachment that automatically folds these extensions out or in when deploying or dismantling the bridge.

Fig. 5—Completed Bridge.
The bridge sections have sufficient strength to carry heavy vehicles.

The bridge sections must be strong enough to carry heavy vehicles (such as tanks) when deployed while also being light enough to be carried on conventional roads when loaded on the transporter. Accordingly, they have a welded structure of high-strength aluminum, like the guide beams.

USE IN GREAT EAST JAPAN EARTHQUAKE

The bridge linking Miyato Island to the mainland at Higashi Matsushima City in Miyagi Prefecture was destroyed in the Great East Japan Earthquake, leaving the island isolated. The Japan Ground Self-Defense Force was involved in the recovery work, which included use of a Type 92 floating bridge in ferry configuration to transport construction machinery and other supplies to the island (see Fig. 6).

The Type 92 floating bridge and Type 07 mobility support bridge are valuable tools for disaster recovery, and have been used in civil defense training drills conducted by regional governments (see Fig. 7).

Photo courtesy of Northeastern Army, Japan Ground Self-Defense Force

Fig. 6—Use of Type 92 Floating Bridge in Recovery Work.
The floating bridge was used to transport construction machinery needed for recovery work to an island cut off by the Great East Japan Earthquake.

Fig. 7—Type 07 Mobility Support Bridge in Deployed Configuration.
The photograph shows the civilian Type 07 mobility support bridge deployed as part of the FY2010 general civil defense drill of Kitaibaraki City in Ibaraki Prefecture. The vehicle in the rear is the construction vehicle.

These prefabricated supporting bridging systems are increasingly being recognized as a very effective means for keeping essential services operating during times of disaster.

SAFETY AND SECURITY MEASURES

Disasters such as earthquakes and floods have been increasing in recent years in countries around the world. Hitachi aims to supply products that provide the means to make an international contribution to safety and security, and that utilize its technology for prefabricated supporting bridging systems that has been built up over many years.

As defense equipment is designed for rapid deployment and withdrawal, product features include automation using special-purpose vehicles. When repurposing these products for civilian and other uses, general-purpose trucks, trailers, and cranes are used so that they can be supplied as a lower price (see Fig. 8).

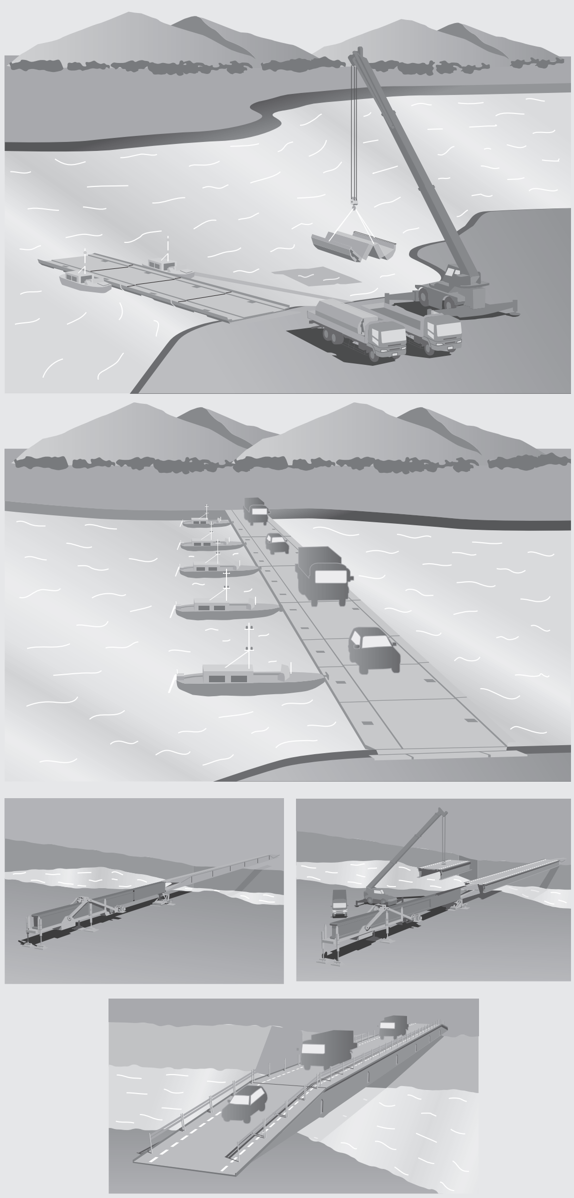

Fig. 8—Example Civilian Uses of Prefabricated Temporary Floating Bridge and Prefabricated Temporary Span Bridge.
Hitachi believes it can supply these bridges for civilian use at low cost by using general-purpose trucks, cranes, and other equipment.

CONCLUSIONS

This article has described the Type 92 floating bridge that floats on a river and supports vehicle traffic, and the Type 07 mobility support bridge that can span rivers or ravines without requiring piers, and also their civilian applications.

Hitachi develops prefabricated supporting bridging systems and supplies them to the Japan Ministry of Defense. In the future, Hitachi intends to contribute to the creation of a safe and secure society by supplying prefabricated supporting bridging systems that can be used to respond to interruptions to essential services caused by disasters and other events.

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Mine-clearing System for Use in International Peacekeeping

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OVERVIEW: The laying of landmines during the wars and civil conflicts of the 20th century has left somewhere between 60 and 110 million of these devices buried in the ground in different parts of the world (according to figures from a FY1998 U.S. Department of State report), and even now they result in injuries to around 20,000 people each year. It was against this background that Yamanashi Hitachi Construction Machinery Co., Ltd. established a project team to contribute to international peace through humanitarian aid, and in 1995 set about developing demining equipment based on functions from hydraulic excavators. This development got underway in earnest after the Japanese government signed the Ottawa Treaty in 1997. Currently 86 machines are being used for landmine clearance in nine different countries (as of April 2012), and Hitachi is actively working to develop and supply demining equipment that is even more efficient and easy to use. To supply equipment to the Japan Ministry of Defense for use in international aid, Hitachi, Ltd. has also used demining equipment as a base for developing a landmine clearance machine with a remote control function that can withstand anti-tank mines. A prototype was delivered in 2010.

INTRODUCTION

WITH the aim of contributing to the international community, Hitachi's demining business supplies an anti-personnel landmine removal machine that commenced development at Yamanashi Hitachi Construction Machinery Co., Ltd. in 1995.

When the situation in the Kingdom of Cambodia was discussed with staff from the Cambodian Mine Action Centre (CMAC), which is supported by the United Nations agency and the Cambodian government to undertake landmine clearance, they reported that the biggest problem was the clearance of reeds, bamboo, and other brush, and that this took up 70% of the time spent on landmine clearance. In response, Hitachi embarked on the development of a combined brush clearance and anti-personnel landmine removal machine that would be capable of dealing efficiently with this type of vegetation.

Although anti-personnel landmine removal machines were still subject to export controls at that time, Hitachi decided on humanitarian grounds to start the development anyway. Subsequently, development was spurred on by the Japanese government signing the Ottawa Treaty (officially known as the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction) in 1997, followed by the exclusion of anti-personnel landmine removal and detection machines from the "Three Principles on Arms Exports."

This article describes a landmine removal machine that is intended to help promote international peace.

DIFFERENT TECHNIQUES DEPENDING ON MINEFIELD CONDITIONS

At the time development first started, approximately 54% of the world's minefields were in the Middle East or North Africa, 21% in Asia, 18% in Central Africa, and 5% in Central or South America.

Removal methods differ depending on circumstances in each region, including the soil type, how the mines have been laid, the types of mines, and the presence of other unexploded ordnance. Cambodia and other Southeast Asian nations have a high proportion of anti-personnel mines that can be difficult to locate because of the tendency for buried landmines to be carried to different positions during the rainy season. It is also common for minefields to be overgrown with grass or brush, which impedes the removal of anti-personnel mines. In contrast, while minefields in places like the Middle East or North Africa commonly have little vegetation that needs to be cleared first, they often contain large numbers of anti-tank mines and unexploded ordnance. Mines can be broadly divided into anti-tank mines (containing 6 to 10 kg of explosive) designed to damage tanks, and anti-personnel mines (containing 50 to 250 g of explosive) designed to injure human beings. Some minefields also contain unexploded ordnance.

Amid all these different considerations, the major issue was the development of a cutter able to deal with the brush that grows on Southeast Asian minefields.

PRODUCT DEVELOPMENT

The two types of anti-personnel landmine removal machines in current use are the swing type based on hydraulic excavators and the newly developed self-propelled push flail type based on past research and development. The removal methods are the rotary cutter type and the more explosion-resistant flail hammer type.

Swing Type Anti-personnel Landmine Removal Machine

In surveys of Cambodian minefields since 1995, what the people on the ground have requested has been machinery capable of efficiently clearing brush prior to mine removal, a task that consumes 70% of the time required for demining. Products on the market at that time included a Canadian-made brushcutter and locally produced grass cutters, but none had the capacity to cut the type of brush found in Cambodia. Hitachi decided that it needed to develop its own combined brush clearance and anti-personnel landmine removal machine to overcome this problem, and that it was also necessary to be able to clean up the brush after cutting. With operator safety and machine durability obviously being the overriding requirements, the first prototype anti-personnel landmine removal machine based on a hydraulic excavator was completed in 1998.

Minefields in Cambodia have reverted to jungle. In addition to the potential for landmine explosion, cutting and removing this jungle brush by hand also puts people at risk of poisonous snakes and mosquito-borne diseases such as malaria and dengue fever.

Rotary cutter machines are one solution to this problem. The cutters rotate at high speed to pull out brush by its roots, and these same cutters can be used to explode any mines in the soil. An advantage of swing type machines based on hydraulic excavators is that they can cope with the different terrains in which landmines are buried. In addition to the hill-climbing capabilities of a hydraulic excavator, the end of the arm can follow the topography in situations such as steep or rugged terrain with severe undulations. The machine can also be used for digging by changing the attachment at the end of the arm to a bucket, for example. A swing-type combined brush clearance and anti-personnel landmine removal machine was supplied in 2000 following explosion resistance testing in Cambodia that confirmed the safety and explosion resistance of the cab, the durability and explosion resistance of the rotary cutter, and the blade strength. This machine is still in active service (see Fig. 1).

Fig. 1—Swing Type Anti-personnel Landmine Removal Machine Able to Deal with Brush Efficiently Using Rotary Cutter.
The rotary cutter is used to clear the brush to make the landmines easier to find. The unit can swing backwards and forwards to follow the lie of the land and perform clearance work even on sloped or other uneven terrain.

Flail Hammer Type Demining Equipment

The way landmines are buried in minefields varies widely, and these fields often also contain unexploded ordnance and anti-tank mines. Because of the risk of encountering these, it is essential that equipment development place a priority on maintaining the safety of the operator and machine. With the aim of developing demining equipment with better explosion resistance, and with support from the New Energy and Industrial Technology Development Organization (NEDO), Hitachi started developing flail hammer type demining equipment in 2002 based on research and development conducted between 1995 and 2000. Unlike rotary cutter machines, flail hammer type demining equipment has a slimmer rotating shaft and works by rotating a chain with a hammer (weight) on the end at high speed to destroy the mines by blowing them up. The machines are more blast resistant because of the large number of gaps in the rotating flail.

This problematic explosion resistance testing was conducted in cooperation with the Japan Ministry of Defense. Hitachi also participated in practical trials in places such as the Islamic Republic of Afghanistan and

Fig. 2—Explosion Resistance Testing in the Islamic Republic of Afghanistan.
Stringent explosion resistance testing is conducted, with the safety of the operator having top priority.

Fig. 3—Flail Hammer Type Demining Equipment.
After landmines are cleared by the highly explosion-resistant flail hammer fitted to the front of the machine, the soil is plowed by rippers fitted to the rear to help restore it to agricultural use.

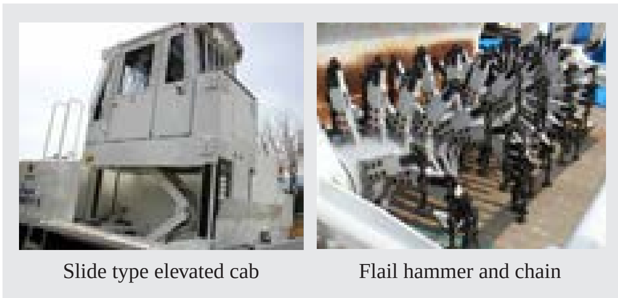

Fig. 4—Slide Type Elevated Cab, and Hammer and Chain.
The cab is located at the rear of the machine for safety, and the hammers and chains are designed to allow refurbishment by local technicians to repair any wear or damage.

Cambodia in cooperation with the Ministry of Foreign Affairs of Japan prior to the machine entering practical use in February 2007 (see Fig. 2). It is currently used in Cambodia and the Republic of Angola.

In 2006, Hitachi started developing new demining equipment that will be better suited to clearing flat land. Equipped with a flail hammer at the front that covers a width of 3 m (twice that of the previous machine), the machine uses chains with 90 hammers attached to pummel the surface of the ground, and moves forward under its own power detonating mines as it goes. It is also fitted with nine large rippers at the rear of the machine that can plow the soil and help restore it to agricultural use. The machine provides an efficient way to clearing landmines with a capability of 1,700 m^2 per hour, which is more than 100 times faster than using manual labor.

The main features of the machine are as follows (see Fig. 3 and Fig. 4).

(1) Level plates (which function like sleds) fitted to the bottom of both flail hammer units provide an automatic control mechanism that can adjust the flail depth based on the terrain and detonates anti-personnel mines by reacting to uneven ground and keeping the excavation depth constant.

(2) Rippers are fitted to the rear of the machine to help rehabilitate the land for agricultural use.

(3) The cab is located at the rear of the machine to improve safety. Use of a slide type elevated cab also improves visibility.

(4) The shape and material of the hammers and chains were developed through repeated testing. To reduce maintenance costs, they are designed to allow refurbishment by local technicians.

LANDMINE CLEARANCE MACHINE BUILT USING TECHNOLOGY FROM DEMINING EQUIPMENT

In 2010, Hitachi, Ltd. supplied a prototype landmine clearance machine that used the rotary cutter and flail hammer technology from the swing type anti-personnel landmine removal machine based on a hydraulic excavator. The main features of the machine are as follows (see Fig. 5).

(1) The attachment mechanism allows the machine to swap between the rotary cutter, flail hammer, and landmine detector. This means that the same machine can perform each of the steps required for landmine removal, with the rotary cutter used to clear and pile up the brush, the landmine detector used to detect landmines and unexploded ordnance, and the flail hammer used to clear the landmines.

Flail hammer

Landmine detector

Rotary cutter

Photo courtesy of Japan Ministry of Defense

Fig. 5—Prototype Landmine Clearance Machines.
The attachment mechanism allows the machine to swap between the rotary cutter, flail hammer, and landmine detector.

(2) By using different materials and thicker plate to improve its strength, the machine has been made capable of withstanding anti-tank landmines as well as anti-personnel landmines.

(3) For safety, a remote control function has been provided to allow work to proceed without an operator on-board. In this case, a camera is fitted in the cab where the operator's head would be and the images from this camera are used to operate the landmine clearance machine and perform landmine detection and removal work remotely. A camera is also fitted on the rear to check the safety of the area behind the machine.
(4) The machine is designed to allow disassembly so that it can be shipped by air as well as by land or sea.

CONCLUSIONS

This article has described a landmine removal machine that is intended to help promote international peace.

Landmine clearing does not end when the mines are removed from the minefield. The actual benefits are realized when the land from which the mines have been removed is reused for a school or farm, for example, so that the local people can become more independent and self-reliant. In the Republic of Nicaragua, land from which mines had been cleared is now used to grow oranges, producing 600,000 cases a year and about 1.5 million dollars in exports. Other crops included coffee and highland vegetables.

In Cambodia, two schools have been built on former minefields to provide the infrastructure for children's education. Working through a non-profit organization, "Good Earth Japan," Hitachi is also actively participating in measures that support self-reliance, including providing local people with agricultural education, the construction of wells and reservoirs, and the provision of roads. For safe and secure communities, Hitachi's aim is to contribute to international peace by restoring land to peace and prosperity so that children can play barefoot.

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topics

Driverless Antarctic Tractor System

Kenichi Nagashima Koji Yamada Akiko Tadano

OVERVIEW: A driverless Antarctic tractor system was developed in response to a request from the National Institute of Polar Research (an Inter-University Research Institute Corporation Research Organization of Information and Systems) for a vehicle that could be used to transport supplies from the coast to the interior of the Antarctic continent. In addition to conventional operation by a driver, the system is also capable of automatically trailing another vehicle using a combination of autonomous driving and positioning information from a variety of sensors, including gyroscopes and GPS positioning data transmitted from the driver-operated vehicle. The aim for the future is to improve the efficiency of goods transportation in the Antarctica through the adoption of fully automatic systems, such as operating a number of tractors automatically in a convoy, or converting driver-operated vehicles to driverless operation.

TRANSPORTATION EFFICIENCY ENHANCEMENT

ON the Antarctica, sleds pulled by driver-operated snowcats are used to transport supplies from coastal to inland bases. The trip to the inland base takes about three weeks of driving 10 hours a day, and forces staff to put up with the vibration and other discomforts of travelling across snow and ice. The driverless Antarctic tractor system was developed to make life easier for staff and to improve transportation efficiency by giving the tractor the ability to follow another vehicle automatically.

SYSTEM OVERVIEW

The driverless Antarctic tractor system consists of a driver-operated snowcat, a driverless tractor, and the electronic equipment mounted in each of these vehicles (see Fig. 1).

The driverless tractor uses its own global positioning system (GPS) position and orientation information together with the GPS position information on the driver-operated snowcat as the basis for automatic trailing. Images from the monitor cameras installed on the front and rear of the tractor can be displayed on a panel personal computer (PC) located in the driver-operated vehicle. Also, to prevent collisions, image recognition is used on the images from the tractor's front-end camera to detect and calculate the distance to a target mounted on the rear of the sled pulled by the driver-operated snowcat.

The panel PC on the driver-operated snowcat is also used to display information and issue commands to the tractor, such as initiating or cancelling automatic trailing. The information includes the status of the driverless tractor and waypoints along the route being traveled by the vehicles (target coordinates set at roughly 2-km intervals).

TRAILING METHOD

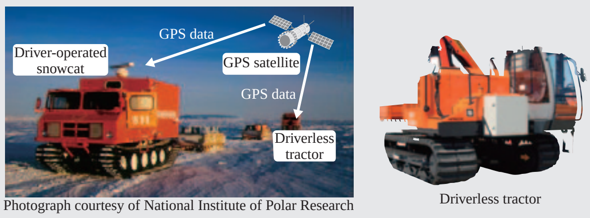
The automatic trailing function of the driverless Antarctic tractor system calculates the direction (θ) of the target point based on GPS position information from each vehicle, and calculates the angle to turn (ω) from the distance (d) and speed (v) of the driverless tractor at 1-s intervals (see Fig. 2).

TRAILING PERFORMANCE

The position provided by GPS can vary from the actual position due to a variety of factors. To cope with this, work was done on the two objectives described below to improve the trailing performance of the system.

(1) Reduce positioning error.

When trailing another vehicle, the most important variable is the relative position of the driver-operated



Photograph courtesy of National Institute of Polar Research

GPS: global positioning system

Fig. 1—Driverless Tractor System.

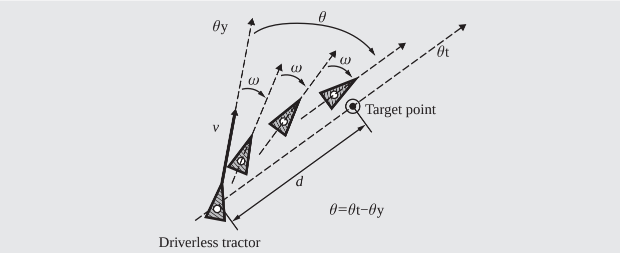


Fig. 2—Vehicle Turn Calculation.

and driverless vehicles. To obtain this, an electronic reference point (which would normally be located on the ground) is positioned on the driver-operated snowcat, and realtime kinematic (RTK) GPS*1 is used to determine its distance and direction. This reduces the relative positioning error to about 20 cm or less.

(2) Minimize impact of positioning errors.

Rather than always pointing directly toward the driver-operated snowcat, the driverless tractor sets target points along the trajectory of the driver-operated snowcat. This means that any variation in the GPS positions has a greater effect the shorter the distance (*d*) to the next target point, causing the trailing error to increase (see Fig. 3). A human driver typically looks a certain fixed distance ahead of the vehicle. In the same way, the driverless tractor progressively switches to new target points as it moves along, always using a measurement point located more than a certain minimum distance ahead as its next target point.

By using this forward-directed model, which sets the turning angle in proportion to the horizontal deviation from the target point, the trailing operation can be performed in a way that minimizes the influence of measurement variation. Table 1 lists the results of simulation for different values of distance (*d*). Using target points located 20 m ahead reduces the trailing error compared to a target distance of 5 m.

ACTUAL PERFORMANCE

To approximate conditions in Antarctica, the system was tested on a snowfield that was free of obstacles. The tests demonstrated that the driverless tractor could follow the driver-operated vehicle without significantly deviating from its path, including around sharp corners with a 20-m turning radius. Additional tests were conducted driving up a snow-covered slope to simulate driving over the sastrugas*2 found in Antarctica. This demonstrated that the driverless tractor could successfully follow the lead vehicle up and down slopes with an incline of approximately 20°.

In addition to proposing systems for making transportation even more efficient, including operating a number of tractors in convoy or converting driver-operated vehicles to driverless operation, Hitachi intends to contribute to a safe and secure future society by supplying control solutions for a wide variety of applications, including automatic control systems.

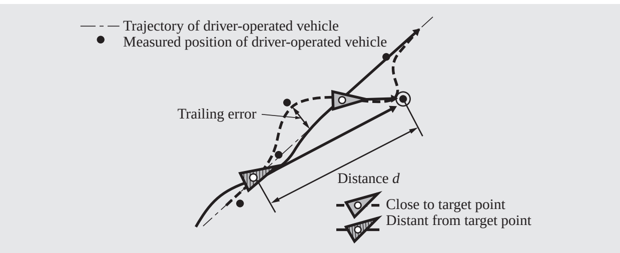


Fig. 3—Effect of Variation.

TABLE 1. Results of Simulation at Different Distances (*d*)

Distance *d* (m)	5	10	15	20
Trailing error (m)	10.1	9.7	2.5	1.7

*1 A realtime method for measuring the position of a moving vehicle that works by transmitting information for correcting measurements to the vehicle from an electronic reference point (known location). To improve positioning accuracy, the distance between the electronic reference point and moving vehicle needs to be kept within about 10 km.

*2 Ridges formed on the surface of snow in Antarctic continent that can reach up to nearly 2 m in height.

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topics

Electric Propulsion Systems for Ships

Yoshifumi Ajioka Kiyoshi Ohno

OVERVIEW: The number of electric propulsion ships being built is expected to rise due to their ability to do an excellent job in meeting societal demands such as simplifying the running of a ship, increasing fuel efficiency during travel, and reducing CO_2 emissions. Hitachi is applying power converter and electric motor-driven control technology to its development of an electric propulsion system for ships, which was adopted for use in the icebreaker "Shirase."

INCREASING USE OF ELECTRIC PROPULSION SYSTEMS ON SHIPS

AS is the case with general automobiles that are driven on land, the main type of engine used on ships is the internal combustion engine (motors such as diesel engines and gas turbines). It is a well-known fact that as a societal demand for reductions in carbon dioxide (CO_2) emissions has arisen, electric motor-driven systems have been introduced for use in automobile engines, thereby greatly improving fuel efficiency in hybrid or electric vehicles (which decrease CO_2 emissions by reducing the consumption of fossil fuels). For the same reason, the number of electric propulsion ships being built has also been increasing (based on research by Hitachi, Ltd.), and this trend is expected to continue accelerating in the future.

The introduction of electric propulsion systems for use in ships offers the following four advantages:

(1) Simplification of the propulsion system, including the complicated reduction gear used to run the ship (frequent shifts between forward and backward movement or acceleration and deceleration; crush astern)

(2) In the case of ships that consume extremely large amounts of power, a reduction in the financial burden of maintenance and repair including life cycle costs, due to the integration of propulsion motors with power generation motors for use in supporting general internal electrical load

(3) Silencing of onboard noise

(4) Improved fuel efficiency during travel due to the ability to constantly maintain a rotational speed that offers good fuel efficiency in the motors used for producing propulsive electric power

Disadvantages include a higher initial cost when compared to propulsion systems based on internal combustion engines, increased energy conversion loss from fuel to propulsion, and a larger system volume due to the large number of component parts.

Electric propulsion systems are often used on ships such as icebreakers or oceanographic research vessels that take advantage of the aforementioned operational benefits, or large passenger cruise ships and others that emphasize cost and silent operation.

Hitachi is working to develop electric propulsion systems for ships based on these advantages and disadvantages.

SOLUTIONS FOR PROBLEMS AFFECTING ELECTRIC PROPULSION SYSTEMS ON SHIPS

The utilization of industrial technology is being pursued as a strategy for conquering the initial cost disadvantage of electric propulsion systems. The electric propulsion system for icebreakers described below had to have a high-power electric motor that offers load characteristics that can provide a great deal of torque at low speed, and so it was developed by applying electric motor technology for industrial steel mills, which provide similar torque characteristics. Hitachi is also considering size-reduction solutions that apply smart grid technology, an area in which it is focusing a great deal of product development efforts.

EXAMPLES OF ACTUAL USE OF ELECTRIC PROPULSION SYSTEMS

Icebreaker "Shirase"

Since icebreakers must repeat a process of breaking ice then moving forward, their propulsion systems must be able to support sudden movements both forward and backward. This is why the icebreaker Shirase uses an electric propulsion system with electric motor variable speed control. This electric

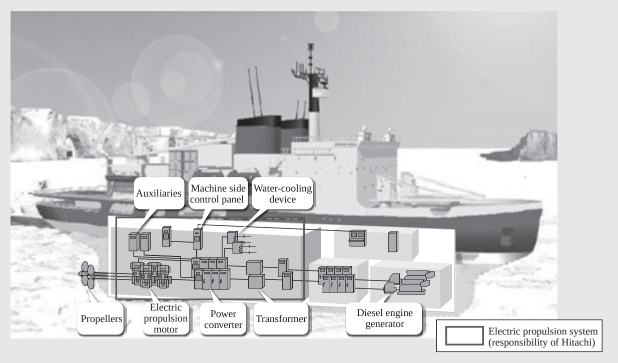
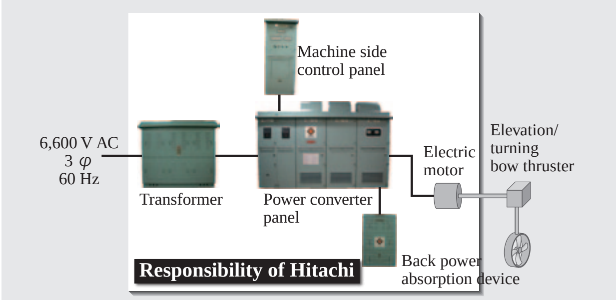


Fig. 1—Devices Related to Icebreaker Electric Propulsion Systems.



AC: alternating current

Fig. 2—Configuration of Elevation/Turning Bow Thruster Drive System.

propulsion system is comprised of an electric motor, power converter, transformer, initial charging panel, back power absorption resistor, water-cooling device, machine side control panel, and other parts (see Fig. 1). During icebreaking, a steep torque curve (around 170%) is required so that the chunks of ice are smashed as they come into contact with the propellers, and since generator power and electric motor power are around the same level, if there is a precipitous change in load on the propeller, the generator may have trouble keeping up, which can cause the generator's motor to cease up. This electric propulsion system, on the other hand, prevents the motor from ceasing up by outputting the large amounts of torque necessary for icebreaking while maintaining a maximum torque limit, thereby satisfying two conflicting requirements at the same time.

A water-cooled power converter was adopted from a unit used in steel mill motor drives and the environmental resistance required for use on a ship (vibration resistance, shock resistance, heat and cold resistance, humidity resistance, and so on) was achieved through means such as reviewing parts, changing part support structures, and using a rigid structure for chassis.

Bow Thruster Devices for New Cable-laying Ships

Cable-laying ships lay cables on the seafloor. Since this cable-laying work requires a fixed location to be maintained by the ship, in addition to the main propulsion system at the stern, a small propulsion system is also installed on the bow of the ship (bow thruster). This small bow thruster is an elevation/turning bow thruster drive device with electric motor variable speed control, and is comprised of an electric motor, a power converter panel, a transformer, a back power absorption device, and a machine side control panel (see Fig. 2). Since this small bow thruster offers superb responsiveness to rotation speed commands, it is used to maintain the ship's position by changing the running speed of the electric motor based on factors such as the state of ocean currents.

The air-cooled power converter was adopted from a unit used in steel mill motor drives and repurposed by equipping it with the environmental resistance required for use on a ship (shock resistance, heat and cold resistance, humidity resistance, stabilization, and so on) by reviewing parts and chassis.

UTILIZATION OF INDUSTRIAL TECHNOLOGIES

Electric ship propulsion is an effective means of helping to achieve the low-carbon society required by global societal needs. Hitachi is promoting systemization for the same purpose by developing technologies that utilize information systems and other basic technologies that are applied in smart grids and electric vehicles, and these technologies are used to support the ship power network control technology necessary as internal ship power requirements increase, as well as other implementation technologies. Hitachi will continue contributing to the spread of electric propulsion systems for ships by utilizing these technologies.

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topics

Gamma Camera Radiation Measurement Device

Eiji Moro Kaori Asai

OVERVIEW: Hitachi Consumer Electronics Co., Ltd. has developed a radiation measurement device that can measure amounts of radiation over a wide range and show them in a color-coded display. Ever since sales began in March 2012, Hitachi has listened to and reflected the opinions of specialists and other parties involved in the decontamination of municipalities and other locations while also taking actual radiation measurements itself. As a result, Hitachi started taking orders for an improved model in August of the same year. This device features highly sensitive and precise measurements as well as excellent usability, and can be easily operated by just setting up a camera and laptop PC, and then launching measurement software.

TOWARDS STREAMLINING DECONTAMINATION ACTIVITIES

THE decontamination of radioactive material has been carried out in various locations ever since the Great East Japan Earthquake occurred in March 2011. If a general-purpose dosimeter (survey meter) is used during decontamination activities, although doses can be measured, locations that should be decontaminated are not displayed. There is an urgent need for the ability to visualize hot spots that have received high doses, in order to improve the efficiency of decontamination.

It is against this background that Hitachi Consumer Electronics Co., Ltd. developed and began selling the gamma camera radiation measurement device, which can measure amounts of radiation all at once over a wide area, while showing results in an easy-to-view color-coded display (see Fig. 1).

OVERVIEW AND FEATURES

This device is used together with a laptop personal computer (PC) to superimpose the results of gamma ray (radiation) dose measurement over images shot with the camera in a color-coded display on the PC screen (see Fig. 2). In addition, the types of radiation measured (cesium-134, cesium-137, or iodine-131) can also be identified. The gamma camera can also be used for a wide range of applications other than decontamination activities, such as the measurement of radiation in hospitals, research centers, and other facilities that handle radiation.

High Sensitivity and Precision

This device includes a semiconductor radiation detection sensor module developed by Hitachi Consumer Electronics that features high energy resolution and sensitivity. Highly sensitive radiation detection is implemented by placing elements on each

Fig. 1—External Appearance of Gamma Camera Radiation Measurement Device and Example of Usage.

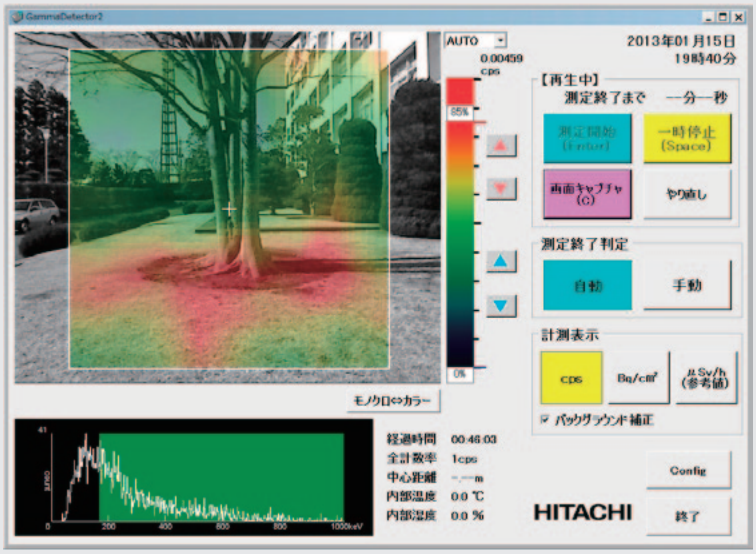

Fig. 2—Example of Measurement Result Screen Display.

of the 256 pixels of the radiation detection area.

Thanks to this design, it is possible to measure amounts of radiation in a wide area from a location that is separated from the measurement target (viewing angle at a point 10 m away is 8 m × 8 m). This allows high-dose locations to be identified without approaching the measurement target, which makes it possible to streamline measurement work while securing the safety of workers.

Furthermore, this device uses multiscanning to measure the distance to the measurement target using each of the 256 measuring pixels, and displays the surface dosage rate after applying a correction process based on Hitachi's unique technology. This method results in highly precise radiation measurements at each pixel.

REFLECTING DEMANDS OF PARTIES INVOLVED IN DECONTAMINATION AND SPECIALIZATION

Hitachi Consumer Electronics has been conducting radiation measurements in and around Fukushima Prefecture, Japan ever since it began selling radiation measurement devices. At the same time, it has been listening to the demands, product improvement ideas, and other suggestions of the decontamination personnel and radiation measurement specialists working for municipalities and other organizations regarding the radiation measurement device, and has reflected the opinions gathered at numerous hearings in further development.

Specifically, the graphical user interface (GUI) was improved in a number of ways, including the automatic display of the end time of measurement based on the measurement environment, and the display of remaining battery power. These improvements have increased usability, and the device is easily operated even without specialized knowledge. Also, by attaching a global positioning system (GPS) receiver using the universal serial bus (USB) connection [National Marine Electronics Association (NMEA) product, should be obtained separately], it is possible to append GPS information to the measurement data, which helps with data management both before and after decontamination activities.

Hitachi will continue development efforts that contribute to the improvement of efficiency in decontamination activities and the containment of decontaminated debris and other waste materials.

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topics

Contribution of Mine-clearing Machines to Land Restoration

OVERVIEW: Minefields are still found in many different parts of the world, and mine-clearing machines developed by Yamanashi Hitachi Construction Machinery Co., Ltd. are being used to restore this land to a safe and peaceful condition. In the Kingdom of Cambodia, former minefields have been transformed into farms or even used for building elementary schools.

ACHIEVING GENUINE SELF-RELIANCE

IN addition to developing and providing maintenance training for mine-clearing machines, Hitachi Construction Machinery Group also provides comprehensive support for Good Earth Japan, a non-profit organization. In the Kingdom of Cambodia, Good Earth Japan provides a variety of assistance aimed at helping the local people achieve a self-reliant way of life, including building roads, providing agricultural training, and establishing farms on former minefields.

In the Banon District of Battambang Province, the organization built a village road for Russei Ro village that has become an essential part of the infrastructure for daily life and agricultural activity. At the request of the village inhabitants, they also established an elementary school in 2009. It was built with financial assistance from Hitachi Construction Machinery Co., Ltd. and Kiesel GmbH, a German sales agent for Hitachi Construction Machinery.

Measures such as the provision of farms and roads and the construction of wells to improve drinking water are of immediate benefit to local living standards. The construction of educational facilities, on the other hand, can be seen as an important form of long-term assistance that helps nurture the people on whom the progress and future of Cambodia depends. Nherk Sinoun, a teacher who supervises the children at the Russei Ro Kiesel Primary School, has passed on a message about this initiative.

Russei Ro Kiesel Primary School

Anti-personnel Mine-clearing Machine

Photograph courtesy of Good Earth Japan

The civil war left Russei Ro village with impoverished returnees and a large number of landmines. Nevertheless, poverty eradication and the utilization of human resources in what once were minefields is now underway in the Kingdom of Cambodia, and these plans have been advanced by Hitachi Construction Machinery's mine-clearing machines. The children at this primary school now study under the public education program and live happily with the other people of the village. I hope that the children at this school will grow up to make a major contribution to the progress of our country. I also hope that the children will never forget what Hitachi Construction Machinery and Kiesel have done for us.

Nherk Sinoun