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Science and Technology Trends relating to Fire and Disaster Management
— Toward Innovations of Fire and Disaster Management —

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1 Introduction

Japan was formerly considered a safe country. However, deterioration of facilities due to aging etc. and unsafe conditions are progressing in many aspects of the society, as evidenced by the rapidly increasing trend in the annual death toll due to residential fires in recent years. Particularly worrisome trends include the increasing combined occurrence of 2 or more disasters such as the combined occurrence of earthquake and landslide disasters in Niigata Prefecture at the time of the Niigata Chuetsu-oki Earthquake in 2007 and increasing number of natural disasters such as typhoons and tornadoes. In addition, new factors that threaten the safety of the society and the citizens' sense of safety and security are now emerging, as seen in the new overcrowded urban spaces being created by urban development, which had languished until recently after the bursting of the Japanese economic bubble.

Against this background, the need for science and technology for achieving a safe society in which people can live with a sense of safety and security is becoming greater than ever. In the area of “Science and Technology in the Field of Fire and Disaster Management” (which contributes toward achieving such a society), too, policies and measures which make it possible to return the fruits of research to society in a more practical manner are needed now more than ever. To achieve a safe society in which people can live with a sense of safety and security, it is essential to make research outcomes available to the society both in the area of utilization of science and technology in preventing disasters, including the identification of potential hazards and establishment of safety requirements (including the incorporation of S&T outcomes in legal requirements) and in the area of utilization of science and technology in coping with disasters after they occur (including upgrading of firefighting equipment). Efforts to utilize S&T outcomes in the field of fire and disaster management in developing legal requirements have already started and have borne some fruit, but the utilization of R&D outcomes in coping with disasters after they occur, such as the utilization of R&D outcomes in science and technology in the field of fire and disaster management in improving firefighting activities, has not necessarily been pursued sufficiently.[1]

This article analyzes the current situation and issues to be addressed, particularly the issues to be addressed in order to achieve innovations in science and technology in the field of fire and disaster management, with an emphasis on the idea of utilizing science and technology in coping with disasters after they occur and minimizing damage and casualties, which has not been given sufficient consideration, and will present suggestions for innovations (Figure 1).

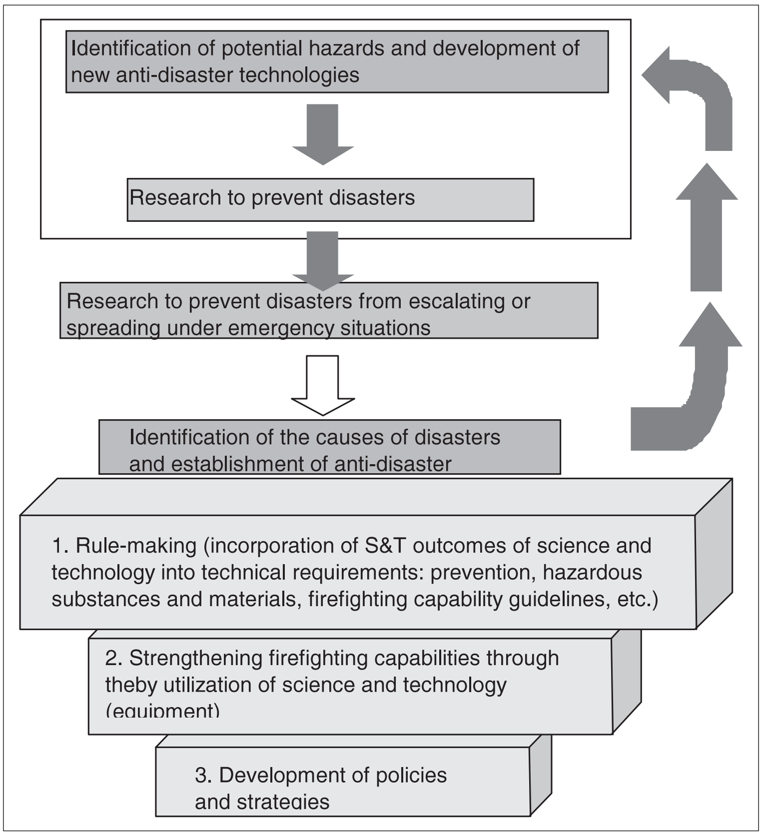

Figure 1 : Returning research outcomes in fire and disaster management to society

2 Recent trends in fire and disaster management and changes in circumstances surrounding disasters

The "Firefighting White Paper"[2] published by the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications provides a wide range of general information about accidents and disasters that have occurred in Japan, including not only fires but also disasters at facilities in which hazardous substances/materials are used or stored and petroleum complexes, natural disasters including wind and flood, volcano and earthquake disasters, and special disasters, including nuclear disasters. According to the White Paper, the annual death toll due to residential fires and the annual number of accidents at facilities in which hazardous substances/materials are used or stored have generally been on the increase in recent years. In particular, the highest number ever of leakage accidents at facilities in which hazardous substances/materials are used or stored occurred in 2006, as shown in Figure 2.

With regard to residential fires, the development and implementation of measures to protect the so-called disaster-vulnerable population (which include senior citizens, infants, and physically handicapped people) from disasters has been considered an important task. However, as a recent trend, the results of a fire statistics analysis show an increasing annual death toll of unemployed elderly people due to residential fires, as shown in Figure 3.[3]

The trend of increasing leakage accidents at facilities in which hazardous substances/materials are used or stored is considered to be attributable mainly to corrosion and general deterioration of facilities due to the aging and the recent trend to reduce maintenance expenditures. However, this assumption must be verified by detailed analyses. Although not reflected in the statistical figures, facility damage of types that were not observed in the past have occurred in recent years, including damage to the floating roofs of floating roof-type petroleum tanks due to strong winds such as those during typhoons. There is also concern that the number of traditional type accidents (such as the explosion that occurred in 2007 at a chemical factory in Joetsu City of Niigata Prefecture) may

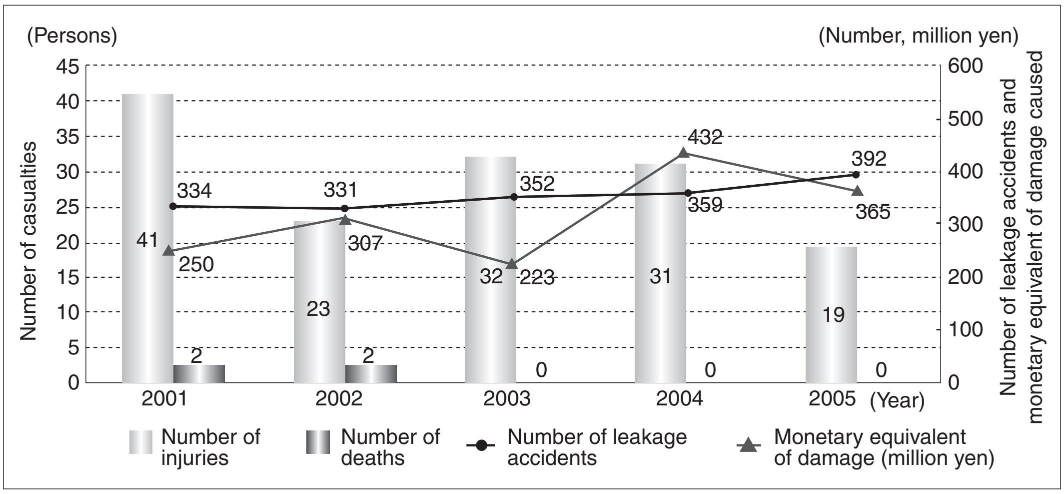

Figure 2 : Number of leakage accidents at facilities where hazardous substances/materials are used or stored and damage and casualties caused by accidents

Source: Reference [2]

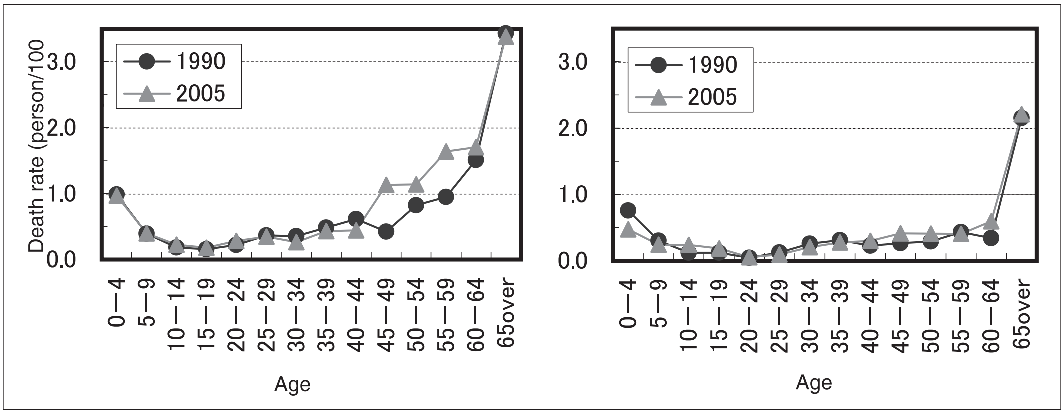

Figure 3 : Death rate due to residential fires by gender and age

Source: Reference [3]

continue to increase, as they have in recent years.

Amid the trends of increasing accidents and disaster hazards described above, the development of underground spaces in metropolitan areas, such as the construction of the Shinjuku Route of the Tokyo Metropolitan Expressway Network (Figure 4), and the construction of high-rise and large-scale buildings, which had languished until recently after the bursting of the Japanese economic bubble, are rapidly intensifying. This means that changes in conditions which increase the vulnerability of overcrowded urban spaces to disasters are progressing.[4]

With regard to natural disasters, a recent trend is that earthquake and landslide disasters occur nearly simultaneously, thereby increasing damage and casualties, as evidenced by the Niigata Chuetsu Earthquake in 2006, the Noto Hanto-oki Earthquake in 2007, and the Niigata Chuetsu-oki Earthquake in 2007.

In addition, there seems to be a recent trend in other countries toward increasing natural disasters, including giant earthquakes, Tsunamis, tornadoes, typhoons, and landslides. Examples of such disasters are the Indian Ocean Earthquake and Tsunami in 2004, Hurricane Katrina in 2005, and the South Leyte landslides in the Philippines in 2006. In recent years, large-scale flood disasters have occurred frequently around the world, including the storm surge disaster in the United States caused by Hurricane Katrina in 2005. To better prepare the country for large-scale flood disasters, the Cabinet Office has established a "Technical Investigation Committee for Countermeasures for Large-Scale Flood Disasters." In Japan, as in many other countries, there has been a recent trend toward increasing local torrential downpours (Figure 5). The Technical Investigation Committee has stated

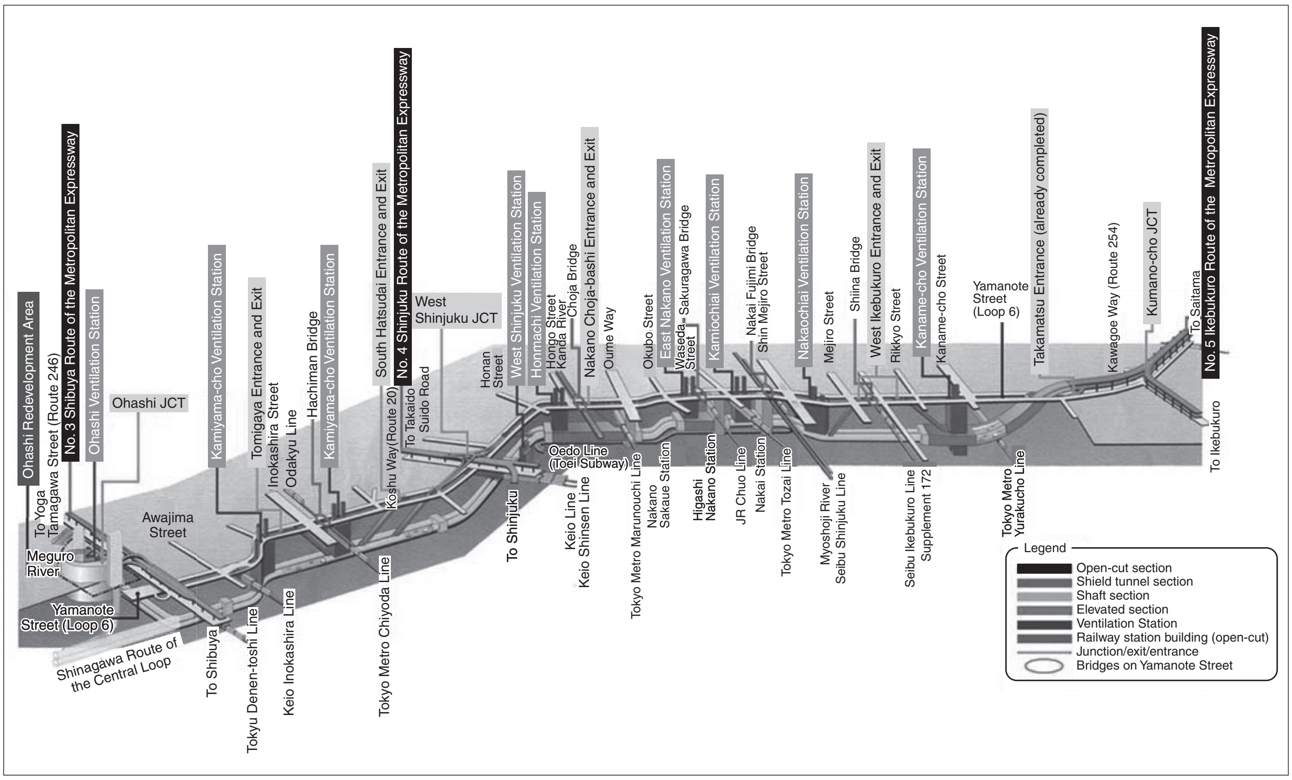

Figure 4 : Overview of project to construct the Shinjuku Route of the Central Loop of the Tokyo Metropolitan Expressway Network

Source: Reference [4]

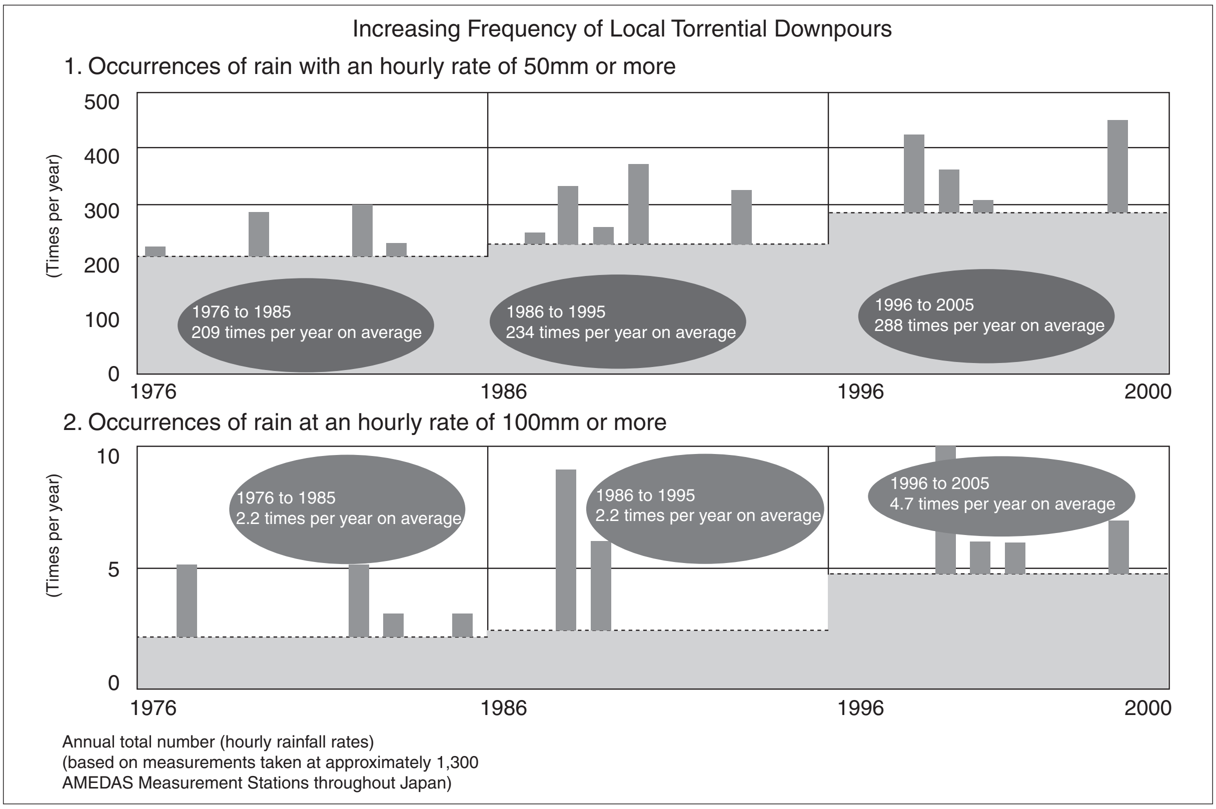

Figure 5 : Increasing frequency of local torrential downpours

Source: Document prepared by the Ministry of Land, Infrastructure and Transport that the development and implementation of countermeasures to minimize damage in the event of a large-scale flood disaster is an urgent task for the country.[5]

3 Research and development in science and technology in fire and disaster management

This chapter provides an overview of research and development in science and technology in the field of fire and disaster management being conducted in Japan by local government firefighting organizations, the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications (FDMA, MIAC), and other organizations, either individually or jointly.

3-1 Research and development by local government firefighting organizations

Currently, a total of 9 local government firefighting organizations in Japan have a dedicated department for research and development in science and technology in the field of fire and disaster management, namely, Sapporo City Fire Department, Tokyo Fire Department, Kawasaki City Fire Department, Yokohama City Safety Management Bureau, Nagoya City Fire Department, Kyoto City Fire Department, Osaka Municipal Fire Department, Kobe City Fire Bureau, and Kitakyushu City Fire Department. The fire and disaster management-related research and development departments of these 9 organizations have a total (officially prescribed) of 74 researchers and total R&D budget of approximately ¥100 million. The R&D budgets for the 9 individual fire and disaster management-related research and development departments vary widely, ranging from ¥1.8 to 50 million.

The fire and disaster management-related research and development departments of the 9 local government firefighting organizations conduct technological development and applied research to improve firefighting and other activities conducted at disaster sites, including research to improve firefighters' firefighting activities (such as research to improve/upgrade firefighting equipment and materials) and fire behavior-related research, as well as research to improve and upgrade disaster management equipment and materials and investigations, analyses and tests to identify the causes of fires.

The main recent R&D projects at the fire and disaster management-related research and development departments of the 9 local government firefighting organizations include:

- A study on the physiological load on firefighters during firefighting (Sapporo City Fire Department)
- Development of a safety management system for firefighters and a chemical analysis system for use at disaster sites (Tokyo Fire Department)
- Development of a water mist fire extinguisher nozzle (Yokohama City Safety Management Bureau)
- Development of an improved fire-retarding door (Kyoto City Fire Department)
- Development of a new fire extinguishing agent that uses a natural surface-active agent (Kitakyushu City Fire Department)

The 9 firefighting organizations jointly hold an annual "Conference of Organizations for Research for Fire and Disaster Management in Large Cities" to exchange information and opinions relating to science and technology in the field of fire and disaster management.

3-2 Research and development at the national level

A Firefighting Technology Policy Office was established in FDMA in April 2006. The FDMA and its National Research Institute of Fire and Disaster (formerly an incorporated administrative agency) conduct research to address the common challenges for all prefectures of Japan, including development of equipment for emergency firefighting assistance teams and development of an information system for coping with large-scale natural disasters including earthquakes. As of August 2007, the National Research Institute of Fire and Disaster (NRIFD) employed 26 researchers and had an annual budget of approximately ¥300 million. The main R&D projects currently being conducted are as follows.

(1) Research and development of robots

Development activities to develop practical high-performance robots that are affordable to fire headquarters have been implemented with the objective of developing robots for NBC terrorism by 2006. NBC disasters are special disasters including Nuclear disasters caused by nuclear radiation and radioactive substances, Biological disasters caused by pathogenic microorganisms such as viruses, rickettsia and microbes, and Chemical disasters caused by toxic chemicals. Building upon the robot technologies that have been developed, a new robot called "FRIGO-M",[6] which is capable of autonomously recognizing and following a firefighter wearing firefighting clothing etc., automatically recognizing and memorizing the path of movement taken, and autonomously transporting disaster victims found by the firefighter to safety by retracing the path, is currently being developed as firefighter support equipment to alleviate the physical and psychological burdens on firefighters. As shown in Figure 6, the FRIGO-M robot has a main body that is highly waterproof, dustproof, explosion-proof, and shock-resistant.

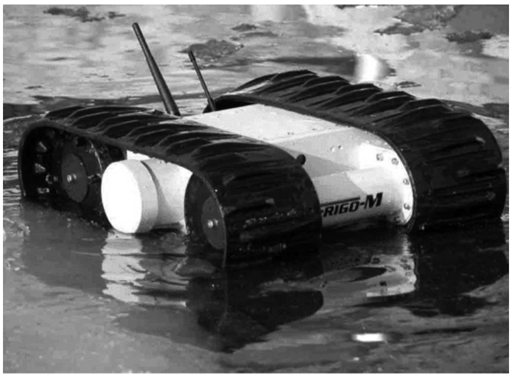

Figure 6 : FRIGO-M small crawler robot

Figure 7 shows conceptual diagrams of firefighter support equipment for special disasters such as NBC disasters.

(2) Research to develop earthquake countermeasures for petroleum tanks

During the Tokachi-oki Earthquake in 2003, 2 petroleum tanks in Tomakomai City ignited and many floating roof-type petroleum tanks were damaged. To prevent future occurrence of accidents and damage of this type, research is being conducted to develop countermeasure technologies and efforts are being made to revise the requirements of the Fire Defense Law relating to the structure of petroleum tanks. In addition, technologies to predict how floating roofs behave during earthquakes are being developed. This work includes sloshing (liquid surface movement) experiments using actual

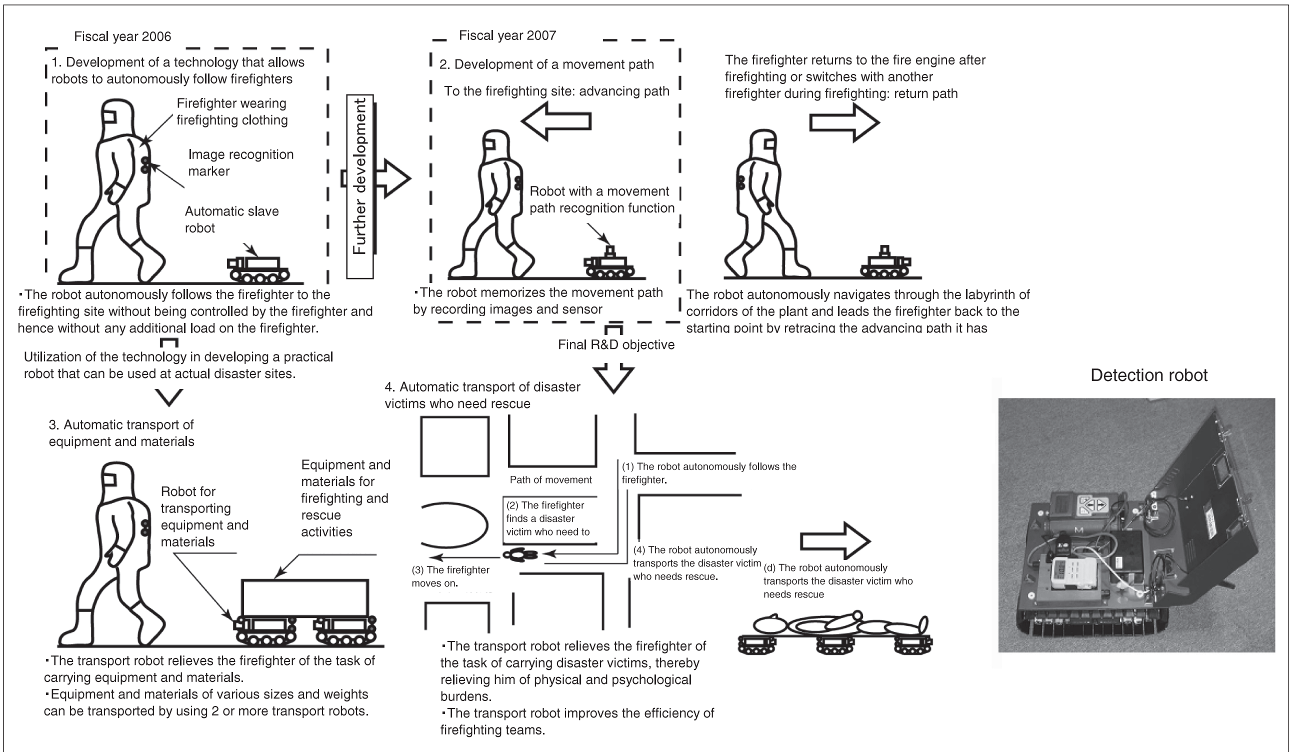

Figure 7 : Conceptual diagrams of support equipment for firefighters

petroleum tanks with diameters of up to 30m (Figure 8).

Other development which is now underway includes a method of predicting how seismic waves propagate during an earthquake and a system for predicting earthquake damage to petroleum tanks in real time immediately after the earthquake and reporting the prediction results to the organizations concerned, including the local fire headquarters. Figure 9 shows an outline of the real-time prediction system.

Figure 8 : Sloshing experiment using a model tank

Vibration generator installed in National Research Institute for Earth Science and Disaster Prevention

(3) Research relating to fire countermeasures for overcrowded urban spaces

Research relating to prediction of the spread of fires in complex, large urban spaces such as underground facilities and skyscrapers is being conducted. Specifically, R&D topics include research to establish methods of predicting the spread of fires in overcrowded urban spaces (including firestorm phenomena that occur while a fire is spreading in an urban area (Figure 10)), R&D to develop firefighting support technologies for more effective firefighting, and development of firefighting clothing for harsh firefighting environments (Figure 11).

Other R&D includes “development of information communication and decision making assistance systems to support fire and disaster management activities, including the operation

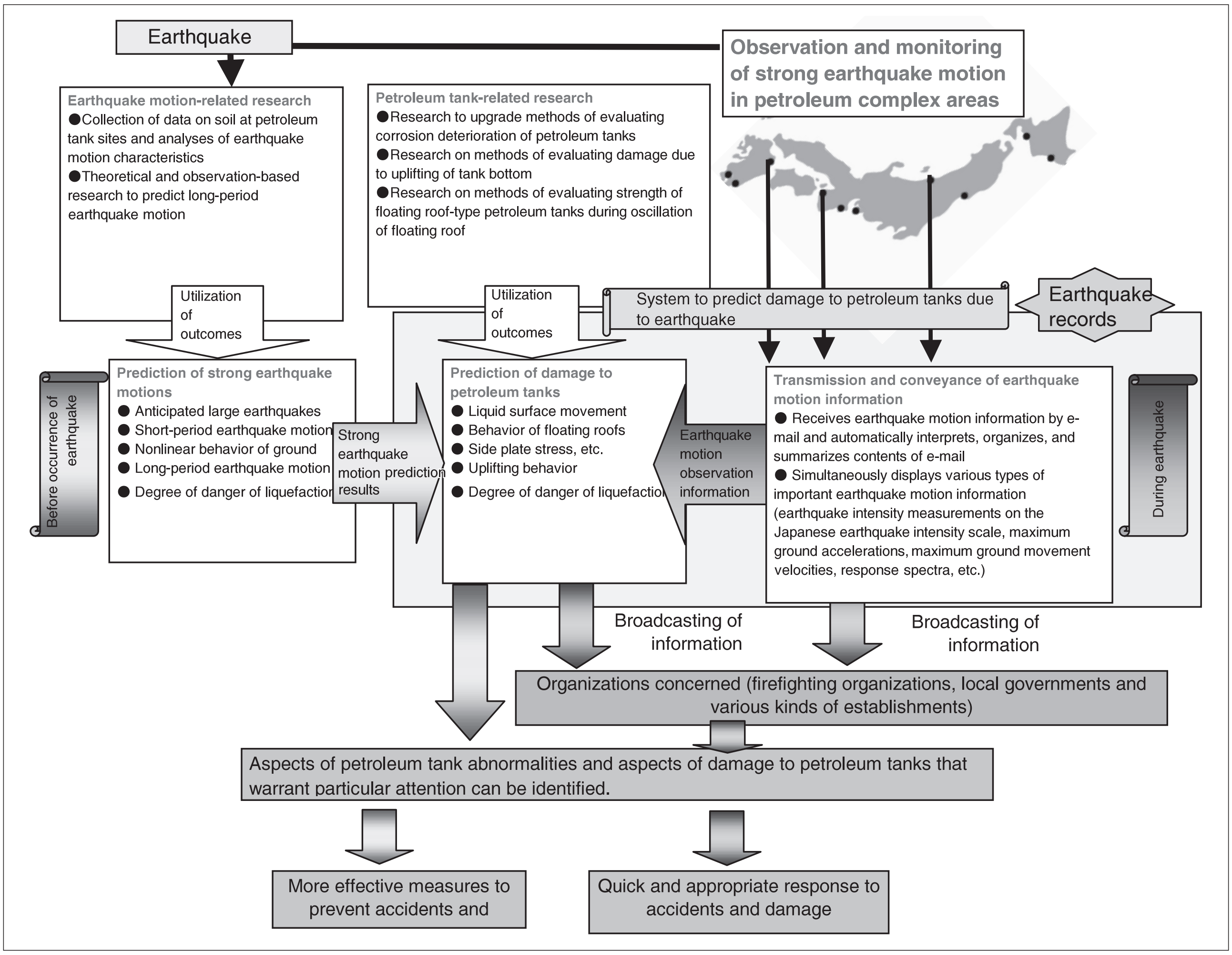

Figure 9 : Overview of real-time earthquake damage prediction system for petroleum tanks

Figure 10 : Example of firestorm phenomena downwind of fire sites

(see also the color diagram on the cover)

of emergency firefighting assistance teams during large-scale natural disasters," "research on technologies to assess the degree of danger of explosion during fires of materials newly coming into widespread distribution/use and firefighting- and re-ignition prevention-related technologies," and "research on technologies to identify the characteristics and behavior of fires, etc. in special facilities and environments such as nuclear facilities, and technologies to ensure the safety of firefighters and reduce their physical and psychological burdens."

3-3 Research and Development under "Programs to Promote Research and Development in Science and Technology in Fire and Disaster Management"

In FY 2003, a new competitive grant program (¥350 million/year) was established to promote joint industry-government-academia research in science and technology in fire and disaster management. During the 4-year period ending at the end of FY2006, a total of 48 joint industry-government-academia research projects jointly undertaken between private sector companies, universities, local governments, etc. were selected as funded projects, including "Development of a Water Loss Reduction Type 2-Fluid Fire Extinguisher Nozzle," "Evaluation of the Effects of Tsunamis on Petroleum Tanks," and "Large-Capacity Underwater Pump with Reduced Weight and Enhanced Functionality." Two of the 48 projects, namely, "Firefighting Water Ejector Equipment Based on a Fire Extinguishing System Using a Mixed Spray of 2 Fluids (Water and Air)" and "Development of a Fire Extinguishing

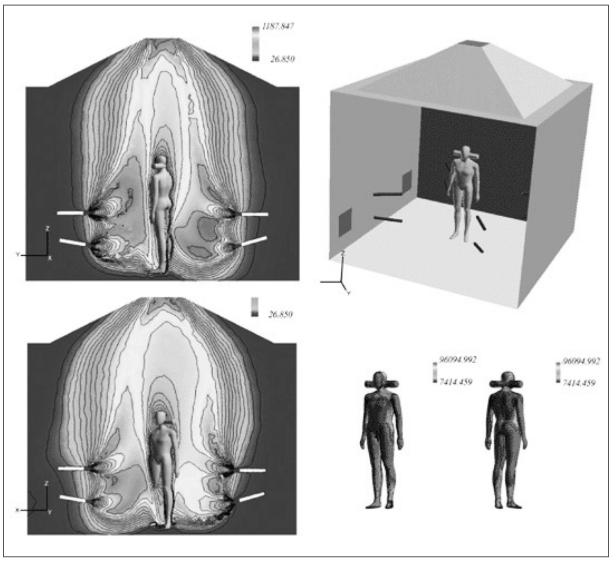

Figure 11 : Simulation of effects of heat on firefighter working in fire environment

(see also the color diagram on the cover)

Agent that Uses Less Water and New Firefighting Tactics," won the Internal Affairs and Communications Minister's Award of the Joint Industry-Government-Academia Research Promotion Contributor Awards of the Council for Science and Technology Policy, Cabinet Office.

In FY2007, a "Field Needs-Oriented Research Grant Program" was established. This is a grant program for joint research projects involving firefighting organizations, and is an attempt to motivate organizations to give priority to "exit-oriented research," that is, research that places emphasis on meeting the needs of people in the field and at disaster sites. Candidate projects include "Development of Next-Generation Firefighting Clothing," "Molecule Recognition-Based Ultra-High Sensitivity Fire Detection Sensor," and "Feasibility Study for the Development of a Raft to Assist in Activities to Extinguish Full-Surface Tank Fires."

4 Priority research areas in science and technology in fire and disaster management

In order to utilize limited research resources effectively so as to obtain S&T outcomes that contribute to realizing a safe society in which people can live with a sense of safety and security, it is essential to identify the important research areas and intensively allocate research resources to them. This chapter provides an overview of the priority research areas designated by the Council for Science and Technology Policy and the FDMA of MIAC.

4-1 Priority research areas in science and technology in fire and disaster management under the Third Science and Technology Basic Plan

Under the Third Science and Technology Basic Plan established by the Council for Science and Technology Policy, "Achieving a Safe Society in which People Can Live with a Sense of Safety and Security" is designated as one main objective. Some of the research and development areas in S&T in the field of fire and disaster management have been designated as priority research areas under the research area-specific promotion strategy.[7] The designated research areas are as follows:

(1) Materials that help achieve a safe society in hich people can live with a sense of safety and security and technologies to utilize those materials

The development of materials for protective clothing and equipment that protects people from unexpected disasters and accidents, as well as the development of technologies to utilize those materials, is needed. For example, the development of materials technologies relating to materials such as highly heat resistant nano-fiber materials that can be used to produce comfortable-to-wear firefighting clothing for harsh fire environments, including fires in underground facilities and skyscrapers, and allows firefighters to work safely and effectively, and the development of technologies to evaluate such materials, have been designated as a priority research area. The required performance levels will be identified by 2008, research relating to methods to evaluate performance and functions will be conducted, including methods for evaluating the performance of nanotechnology-based firefighting clothing in terms of heat resistance, wearer's comfort, and kinematical characteristics against established requirements, and advanced firefighting clothing will be developed.

(2) Ensuring human safety during fires in various types of buildings and facilities

A database of the combustion characteristics of materials used in buildings and facilities will be constructed by FY2010 and a computer simulation-based prediction method for predicting the spread of fires in various types of spaces, including ordinary buildings, underground facilities, and skyscrapers, will be developed. In addition, the developed prediction method will be utilized to enhance evacuation and warning systems. Fire prevention measures will be strengthened and effective firefighting tactics that take into consideration the characteristics of buildings and facilities will be established.

(3) Minimizing earthquake damage to facilities where hazardous substances/materials are used or stored

In FY2006, floating roof oscillation experiments using real-scale petroleum tanks were conducted and a standard method for repairing floating roofs was developed. By FY2010, research and development will be conducted aimed at minimizing damage to facilities in which hazardous substances/materials are used or stored during large earthquakes. Research and development to develop disaster prevention measures including R&D on petroleum tanks with high resistance to long-period earthquake motion, as well as R&D to develop methods for predicting earthquake damage to petroleum tanks as a result of oscillation during an earthquake immediately after the earthquake and predicting tsunamis, will be conducted. In addition, methods for evaluating the condition of petroleum tanks that are directly relevant to their earthquake resistance characteristics will be developed, including methods of determining whether deterioration due to corrosion has occurred and the degree of deterioration without opening the tank. Figure 12 shows an overview of the development of technologies to provide accurate, real-time predictions of damages to petroleum tanks due to the oscillation of the tanks caused by earthquakes.

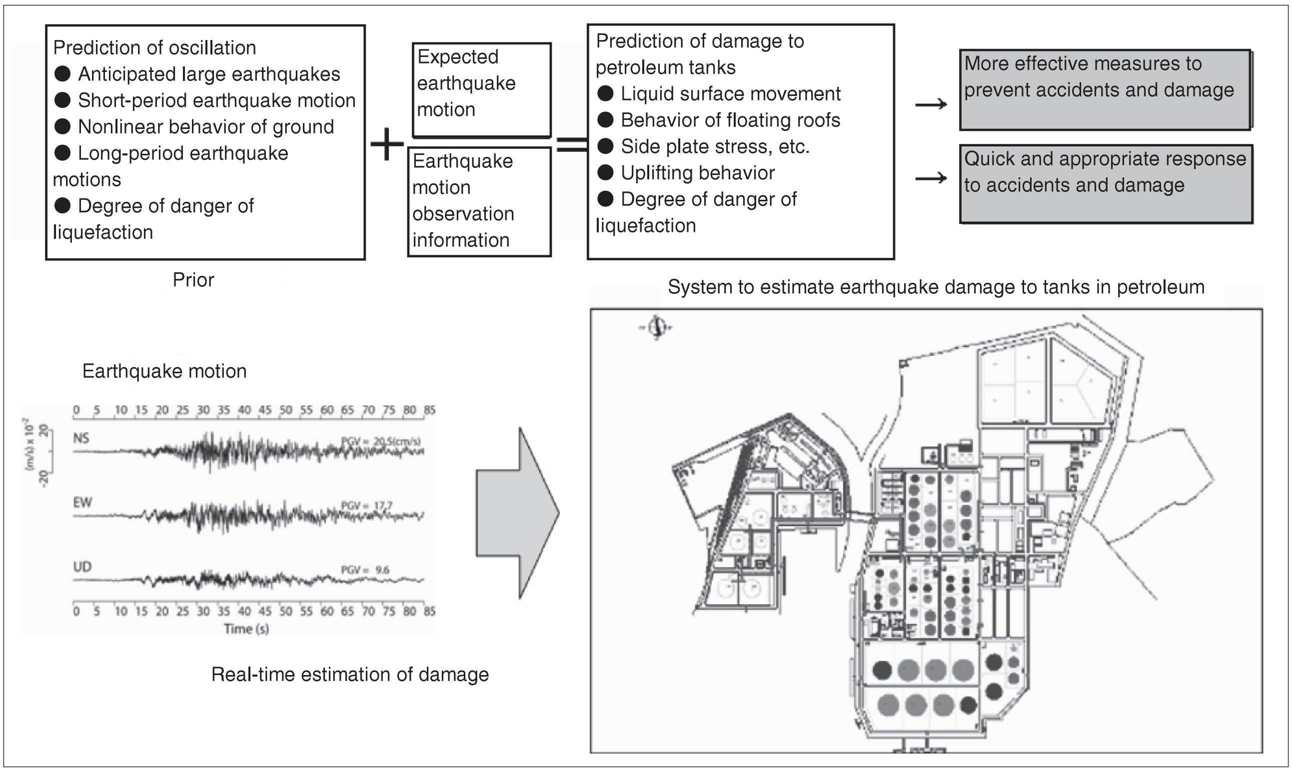

Figure 12 : Development of technologies to predict and minimize earthquake damage to facilities where hazardous substances/materials are used or stored

(4) Information systems to assist fire and disaster management activities during large-scale disasters, etc.

To minimize the damage caused by large-scale earthquakes, it is necessary to respond to disasters in a quick and appropriate manner. To appropriately respond to disasters, it is essential to collect, convey, and analyze disaster management information quickly and accurately, regardless of the type of the disaster. Systems that optimize the operation of firefighting capabilities on the assisted side (in disaster sites) will be developed by utilizing a system to simulate the spread of fires in real time, taking into account the availability of assistance teams in the prefecture and emergency assistance teams, with the objective of optimizing the operation of firefighting capabilities during simultaneous occurrence of multiple fires due to an earthquake, etc. On the assisting side, programs to assist in achieving optimal deployment of firefighting capabilities which are capable of presenting information about the appropriate assistance teams and their compositions, as well as the optimal deployment of the teams, will be developed. Specifically, assistance systems and information and communications systems that allow the national and local governments to perform effective disaster management activities will be developed by FY2010, and advanced technologies to collect, convey, and analyze information during disasters will be developed. Figure 13 provides an overview of an information system to assist in fire and disaster management activities.

(5) Ensuring human safety during special disasters and developing firefighting methods for special disasters

By FY2010, the characteristics of fires in special facilities and environments and fires due to special causes will be identified and firefighting methods for such fires will be established. Building on the results of these studies, firefighting methods for special fires will be put into actual use by FY2015. In addition, assistance equipment to ensure the safety of firefighters and reduce firefighters' physical and psychological burdens will be developed.

(6) Preventing Chemical Fires and Explosions and Fighting Chemical Fires

By FY2010, new hazardous substances (such as recycled resources) will be assessed with regard

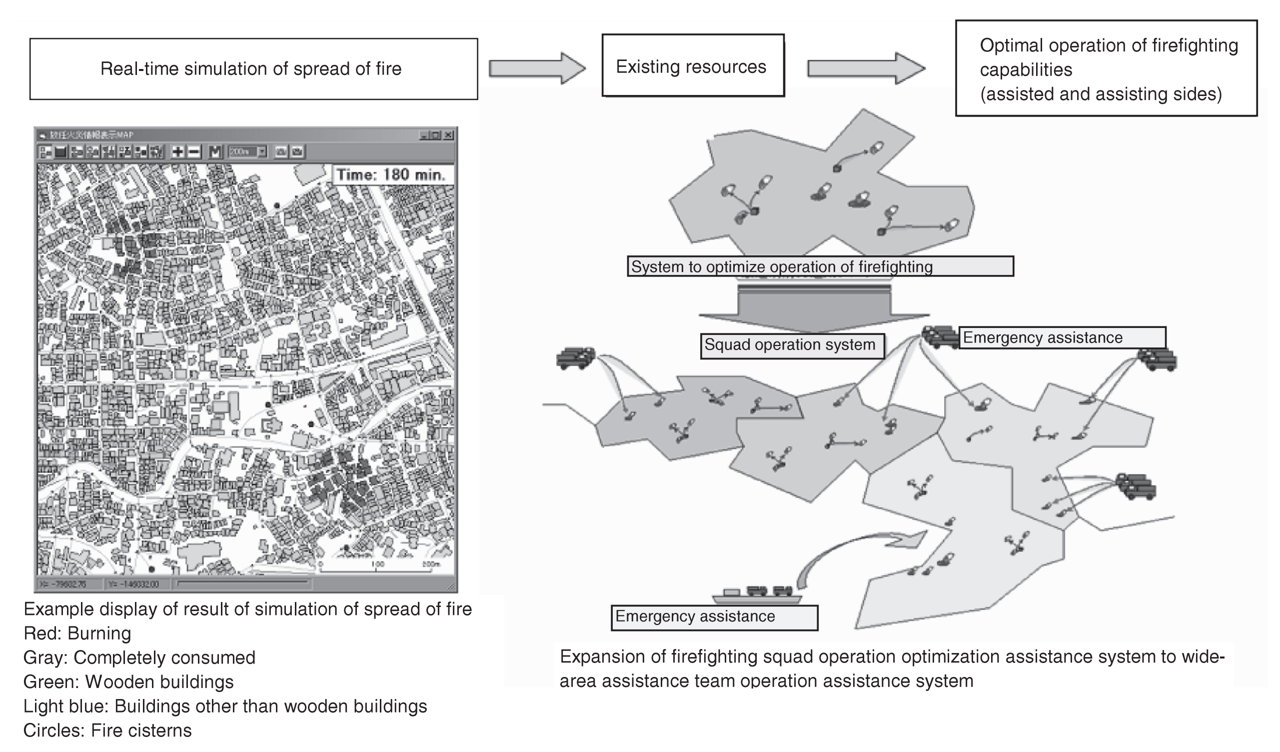

Figure 13 : Development of an information system to assist fire and disaster management activities (see also the color diagram on cover)

to their degree of danger of ignition/explosion. Methods for assessing the degree of danger of heat accumulation, danger of spontaneous ignition, danger of explosion, etc. will be developed, and relevant data will be accumulated. In addition, to better prepare for chemical leakage accidents and accidents that result in fires, technologies to fight tank fires and fires involving oil leaks will be developed, including technologies to prevent re-ignition.

4-2 Second Strategic Plan for Advancing Science and Technology in the Field of Fire and Disaster Management[8]

The Forum for Discussion on Science and Technology in the Field of Fire and Disaster Management (comprising external knowledgeable persons and chaired by Professor Emeritus Yoichi Uehara of Yokohama National University) was charged with the task of establishing, by FY2005, a plan for the future of science and technology in the field of fire and disaster management. Based on discussions of the subject, the body established the First Strategic Plan for Advancing Science and Technology in the Field of Fire and Disaster Management.[9] The First Strategic Plan was subsequently revised, taking into consideration the necessity of achieving compatibility with the Third Science and Technology Basic Plan as well as recent changes in the circumstances surrounding disasters, including fires, and general trends in science and technology. The revised plan was announced by the FDMA in February 2007 as the 2nd Strategic Plan for Advancing Science and Technology in the Field of Fire and Disaster Management.[10]

A questionnaire survey comprising 10 items and 76 sub-items concerning the urgency of introduction and practical application of technologies was conducted among fire headquarters in 100 Japanese cities (Major Cities designated under a Government Ordinance, consisting of prefectural capital cities and other cities that are considered to be equivalent thereto) prior to the establishment of the Second Strategic Plan, and the results of the survey were reflected in the Plan. The 10 items are as follows:

(1) Development of more advanced disaster management systems through utilization of information and communications technologies
(2) Development and implementation of measures to prevent and fight residential fires

(3) Qualitative improvement of disaster management capabilities
(4) Development of more advanced facilities to assist in firefighting activities and more advanced equipment and materials for firefighting activities
(5) Strengthening of measures to prevent and respond to special disasters
(6) Enhancement of measures to prevent and respond to disasters at facilities where hazardous substances/materials are being used or stored
(7) Development and implementation of more advanced rescue and lifesaving services
(8) Environmental protection considerations
(9) Internationalization-related needs
(10) Development and improvement of mechanisms for protecting the citizens of Japan

The priority R&D areas designated under the Plan are as follows:

- Research and development toward ensuring the safety of the citizens of Japan, particularly people who are likely to need rescue in the event of a disaster, such as senior citizens, and providing them with a sense of safety and security
- Research and development toward enhancing preparedness for large-scale disasters
- Research and development toward developing and implementing advanced fire and disaster management activities that utilize advanced technologies
- Research and development toward meeting the increasing lifesaving needs and developing and implementing more advanced lifesaving services

The Plan states that policies and measures must be developed and implemented to (1) enhance education and training systems so as to nurture future researchers in science and technology in the field of fire and disaster management, (2) promote the sharing of scientific and technological information in the field of fire and disaster management and (3) enhance and strengthen promotion systems based on cooperation and coordination between the national and local governments and interested organizations and industries.

5 Achieving innovation based on science and technology in fire and disaster management

5-1 Cooperation in exit-oriented research and development

This chapter outlines examples of research and development being conducted in S&T in the priority research areas described in Chapter 4 in the field of fire and disaster management with the objective of achieving innovation. All of the R&D activities described below are activities in research areas that were selected by the national government from the standpoint of the needs of the people engaged in fire and disaster management activities at the field level, from items for which certain outcomes have been obtained but no exit to practical application is envisioned. The national government has been attempting to assist R&D organizations develop R&D outcomes into scientific and technological innovations for people working at the field level by developing frameworks for cooperation and coordination between industry, government, and academia, between government organizations, and between the national and local governments.[11]

(1) R&D on nanotechnology-based firefighting clothing

Figure 14 shows the research and development being conducted to develop nanotechnology-based firefighting clothing and next-generation firefighting clothing. Under a competitive grant program sponsored by the Ministry of Economy, Trade and Industry, laboratories and research institutes of private sector companies and Independent Administrative Institutions (IAI) are developing materials, and the FDMA is analyzing data on the needs of people engaged in firefighting at the field level and developing evaluation technologies. Figure 15 shows the framework for promoting cooperation and coordination between industry, government and academia and between government organizations.

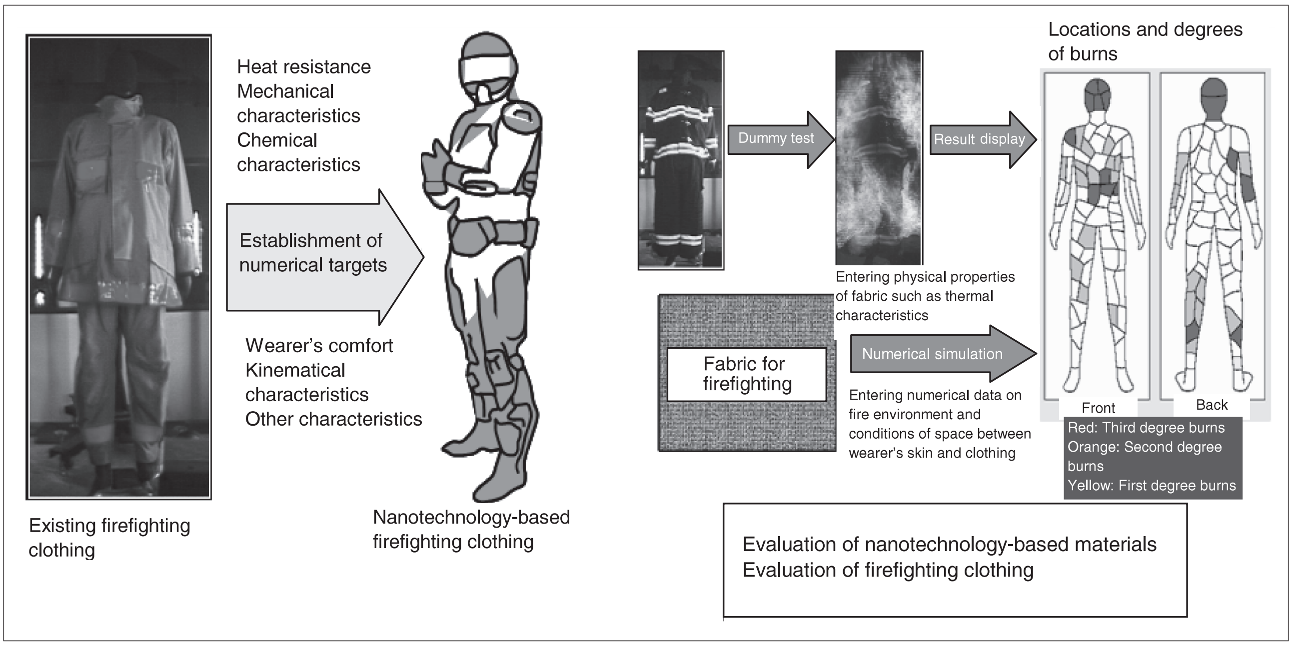

Figure 14 : Development of nanotechnology-based firefighting clothing and next-generation firefighting clothing

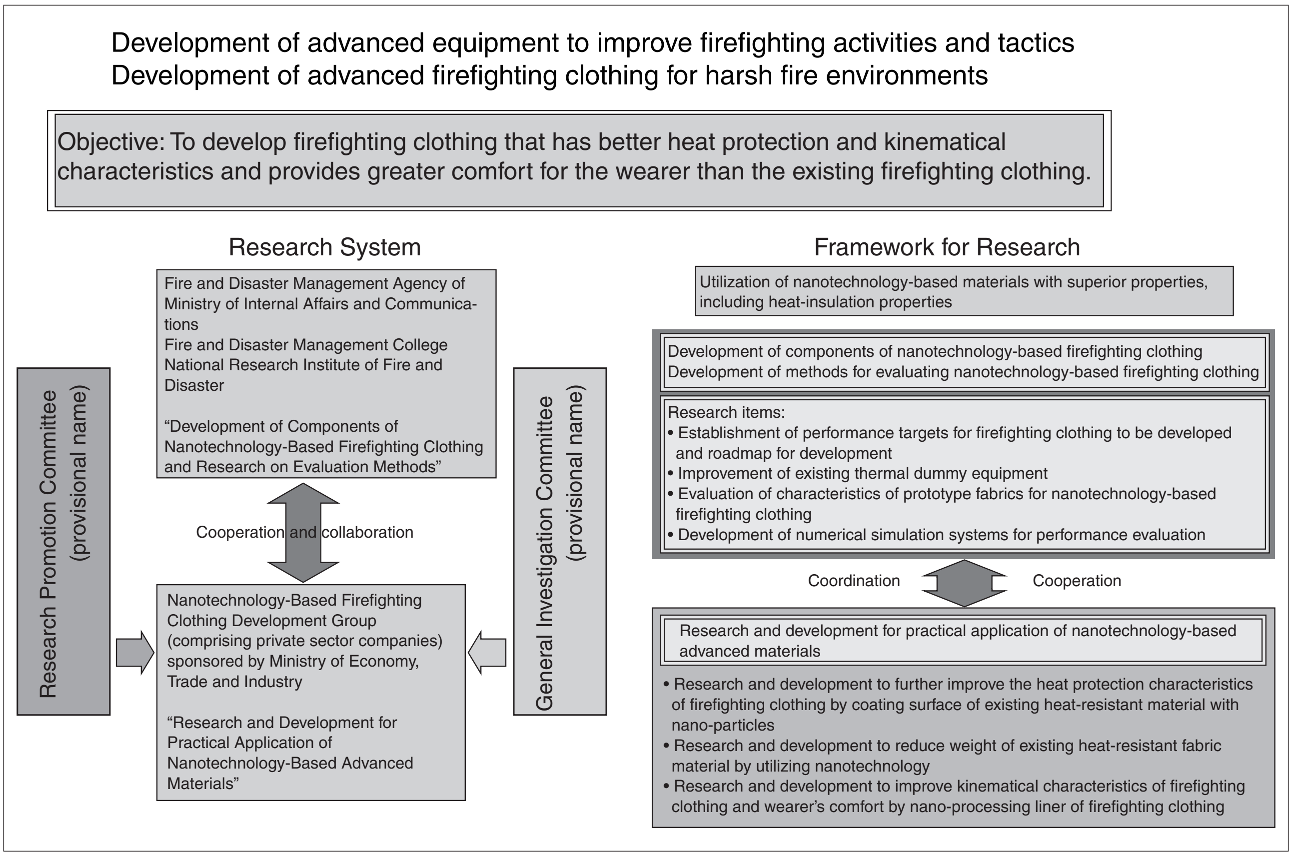

Figure 15 : Overview of system for research and development of nanotechnology-based firefighting clothing

(2) Introduction and deployment of Helisat technology

"Helisat" technology was developed by the National Institute of Information and Communications Technology (IAI) and allows helicopters and communications satellites to communicate directly with each other (Figure 16). Currently, R&D is being conducted to implement this technology in fire and disaster management helicopters operated by the national government. At the time of the Niigata Chuetsu Earthquake in 2004, earthquake damage on the ground made it difficult to relay video data from helicopters in the earthquake-stricken area, revealing the vulnerability of the existing information communication system. This R&D is

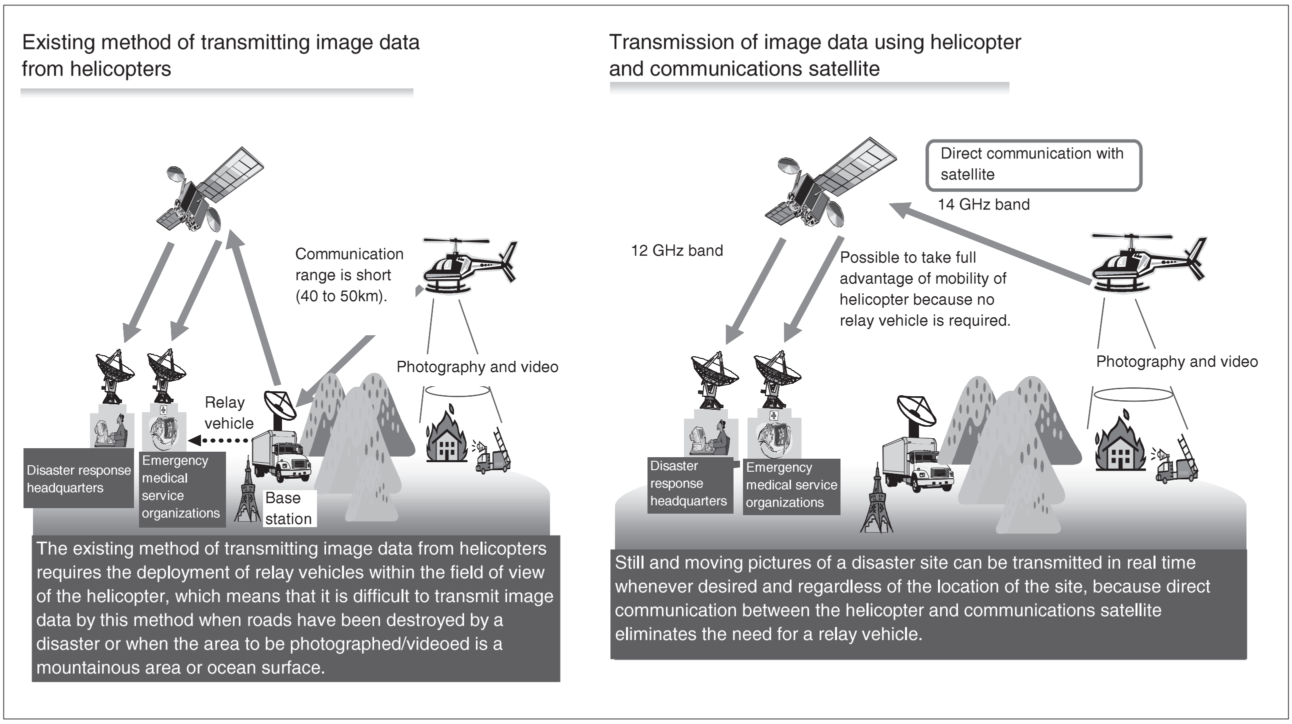

Figure 16 : Introduction of technology for direct communication between helicopters and communications satellites

being conducted with the objective of providing a technological solution to the challenge of developing means of emergency communications that do not fail during large-scale disasters. Expectations that this research and development will attain its objective are high.

(3) R&D to provide emergency assistance teams with reconnaissance and assistance robots

R&D is being conducted to deploy equipment developed with national funding (as equipment for firefighting and emergency assistance teams) at fire headquarters of local governments for practical use on a trial basis. The equipment shown in Figure 17 is being developed based on the lessons learned from exposure to sarin nerve gas of firefighters engaged in rescue work after the sarin attack on the Tokyo subway system in 1995. The target is to make this equipment capable of “moving from above the ground to subway platforms in the Kasumigaseki area and detecting and analyzing toxic substances” (The current specifications do not require that the equipment to be capable of return to the ground. The toxic substances detected are recovered after the incident is resolved). In addition, continuing R&D with national funding is being conducted with the aim of developing a low-cost version of the equipment which would only provide a subset of the functions of the full version but would be affordable to fire headquarters. The companies that have participated in research and development have commercialized the technology and started marketing products of their commercialization efforts.

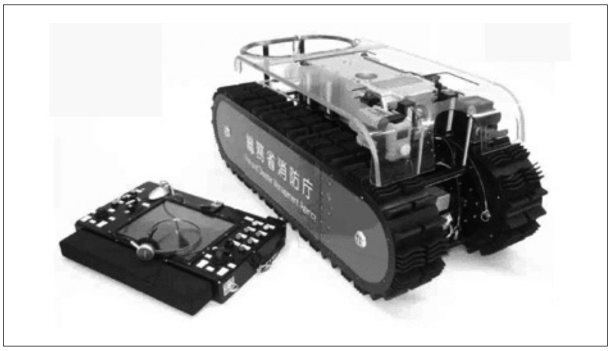

Figure 17 : Detection and exploration robot to assist in disaster response activities deployed at the Tokyo Fire Department

5-2 Efforts to develop R&D outcomes into innovations for society

This section proposes a somewhat general theory of innovation and examines the problem of why R&D outcomes fail to become useful innovations for society.

In “The Prince,” Machiavelli points out the following as reasons why it is difficult to achieve social reform: “The introduction of a new order will antagonize all people who have fared well under the old system. In addition, even those people who accept the new order only do so without eagerness. There are two reasons for the reluctance of people to accept a new order. First is the fear among people who have enjoyed advantages or comfortable lives under the old system that they might lose them, and second is the skepticism among people about the new system."[12] This observation also applies to attempts to achieve innovation for society through utilization of science and technology. That is, attempts to introduce a new technology often encounter two types of objections:

- People who have fared well without innovations tend to say, "What is wrong with being content with the existing system?"
- Because the benefits that will be brought about by an innovation (e.g. cost-benefit ratio) are usually uncertain, people tend to say, "What good will it do?"

The obstacles to the development, commercialization, and industrialization phases to achieving innovations for society through utilization of R&D outcomes are sometimes called the Devil's River, Death Valley, and Darwin's Sea, respectively. Some people argue that the development of technologies for achieving a safe society in which people can live with a sense of safety and security requires a holistic approach, that is, an approach that "grasps the overall picture of the problem," "allows the utilization of knowledge that transcends the boundaries of disciplines," and "allows problem-solving-oriented sharing of knowledge."

How, then, can we overcome these obstacles and develop R&D outcomes into innovations for society? The Apollo Program in the United States, which was carried out to send men to the moon, is considered to be an example of success, because it led to the development of the Global Positioning System, Internet, and Kevlar fiber. An analysis of examples of success, including the Apollo Program, leads to the conclusion that the key to developing R&D outcomes into innovations is to break the vicious cycle in which "the tendency that outcomes of advanced technologies and products developed from them are not initially accepted by people on the needs side who have been accustomed to traditional technologies because of a lack of track record" results in "a lack of motivation on the seeds side to invest in the advanced technologies," which in turn "dampens efforts to achieve innovations."

To overcome Devil's River, Death Valley, and Darwin's Sea obstacles, it is considered important to ensure that there will be "sophisticated specification-oriented" users in the initial phases who purchase advanced technologies and products developed from them as "first customers," enabling a virtuous cycle of innovation to begin. For example, the Global Positioning System, Internet, and Kevlar fiber would not have established their footholds if they had not been supported by national defense-related procurement in the United States. These examples suggest the conclusion that it would be easier for R&D outcomes to make their way into private-sector industries and consumer markets if there were "sophisticated specification-oriented" customers in the public sector who take development-related risks in the initial phases and create initial demand. Figure 18 presents a diagram (reproduced from a report of the Ministry of Economy, Trade and Industry) showing an overview of the government's scenario for creating initial demand for nanotechnology-based protective clothing through development and implementation of policies.

Researchers who are engaged in research and development often make the mistake of trying to define the research topic and the direction of research "on the basis of what problems they think they can solve" rather than "on the basis of what problems should be solved to attain the objective." In general, evaluations of the outcomes of a development project differ considerably between "the case where the researchers themselves are users" and "the case where the researchers are not users." The tendency that researchers "highly value technologies which they have developed" and "are critical of technologies developed by others" has also been a barrier to achieving innovations. It can be thought that a combination of these two problems has caused a situation where researchers engaged in research and development say, "We have produced research results, but

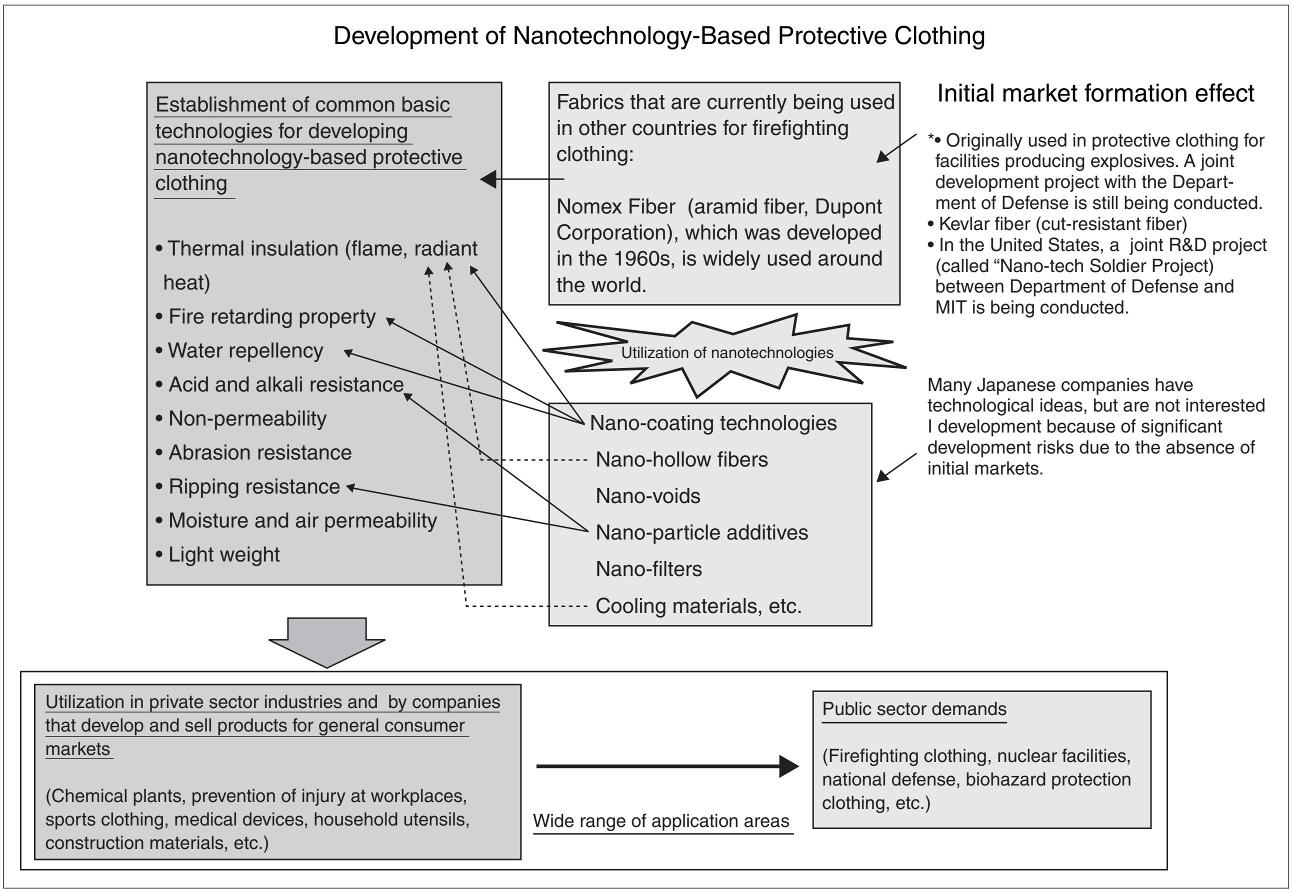

Figure 18 : Scenario for creating initial demands for nanotechnology-based protective clothing through development and implementation of policies

companies and organizations on the user side are not interested in using them for practical purposes," while companies and organizations on the user side say, "There are no research results that can be used for practical purposes." In other words, there is a significant difference between "the perspective of people on the development side" and "the perspective of people on the user side."

In science and technology in the field of fire and disaster management as well, it is reasonable to think that user involvement from the development phase will help in efforts to create initial demand through development and implementation of policies and in solving the problem of differences in perspective. In short, we believe that, in order to create an environment in which R&D outcomes are actively utilized for field level fire and disaster management activities, simply improving R&D systems is not sufficient, and it is important to consider a "mechanism that works, taking into consideration how the R&D outcomes will be valued by the procurement departments of users.[14] Such a mechanism must:

- Be capable of involving firefighting organizations from the development phase;
- Include a method to objectively evaluate the costs and benefits of the introduction of R&D outcomes; and
- Allow development to be conducted in a procurement-conscious manner.

In particular, in the case of creation of initial demand through development and implementation of policies to create demand in the public sector, in order to ensure that this is done in an objective and rational manner, it is necessary that there be sufficient accountability to the taxpayers and financial managers with regard to the new technology being considered for introduction. To that end, it is considered necessary to develop an appropriate evaluation method such as one based on a set of appropriate criteria, like those shown in Table 1.

Table 1 : Evaluation criteria for introduction of new technologies

- Evaluation of the need to introduce the technology
  Isn't it possible to solve the problem without introducing the technology? Is the technology essential to solving the problem?
- Prediction of the results of introduction of the technology and analysis of the advantages of introduction
  What is the problem that can only be solved by using the technology?
  Does it occur frequently or infrequently?
- Losses being incurred as a result of the unsolved problem
  (= How much money is available to solve the problem?)
- How much money is required to solve the problem?
- Comparison with alternative means (for example, cost, expected effects, and ease for users becoming accustomed to the technology)
- Evaluation of the credibility of the R&D researchers' assertion that the technology is "useful"

[Note] The evaluation of a technology in terms of cost requires a decision as to whether to estimate the cost required to purchase the technology in the initial introduction phase or the cost required to purchase the technology after popularization of the technology. (For example, in addition to the direct effects of introduction, the second and subsequent units tend to become less expensive than the first, which may be rather expensive.)

5-3 Major innovation-inhibiting factors unique to S&T in fire and disaster management and the need for S&T coordinators

The major innovation-inhibiting factors unique to science and technology in the fire and disaster management include:

(1) Small overall scale of the market

The total number of firefighters working at firefighting organizations in Japan (i.e., the total number of "users" for the purposes of this report) is approximately one million. Equipment-related expenditures represent no more than 10% of the total national firefighting budget of approximately ¥2,000 billion.

(2) Individual procurement of equipment and materials by more than 800 fire headquarters throughout Japan

Because the current equipment and material procurement system does not have a central command station for introduction of new technologies, researchers tend not to be strongly motivated to develop new technologies.

To solve these problems unique to S&T in fire and disaster management, it is important that the national and local governments work in close cooperation and coordination. For example, the development of standard specifications, identification of important user requirements, and introduction of joint procurement systems under the leadership of the national government can be effective in solving these problems.

For effective functioning of the above-mentioned mechanism for developing R&D outcomes into innovations for society, science and technology coordinators who can objectively understand, evaluate, and explain R&D outcomes are essential. Currently, there is a serious lack of such coordinators in Japan. Nurturing and deploying such coordinators is an important task for the future.

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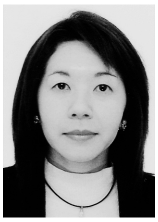

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