System for Prediction of Environmental Emergency Dose Information Network System

● Makoto Misawa ● Fumio Nagamori

(Manuscript received May 28, 2008)

The System for Prediction of Environmental Emergency Dose Information (SPEEDI) network system is a computer system capable of rapidly predicting the effect that radioactive materials will have on the surrounding environment if there is a massive release of radioactive materials from a nuclear facility. The Ministry of Education, Culture, Sports, Science and Technology consigns the operation of the SPEEDI network system to the Nuclear Safety Technology Center (NUSTEC). NUSTEC has developed the main functions of the SPEEDI network system and Fujitsu provided continuous support with regards to the system construction, operation and maintenance, such as the introduction of servers and improvement of networks. This paper describes the current status of the development and operation of the SPEEDI network system and Fujitsu's approach to supporting this system.

1. Introduction

While nuclear power generation is beneficial from the standpoint of preventing global warming through eliminating carbon dioxide emissions during the power generation, it has a risk of affecting a wide area in the event of an accident. The Chernobyl disaster in the former Soviet Union in 1986 is the worst accident that has occurred so far, and resulted in a large amount of radioactive material being released into the atmosphere. Partly because the Soviet government at that time was slow in handling the accident, its effects covered a wide range and caused enormous damage. In Japan, a criticality accident of the Japan Nuclear Fuel Conversion Corporation (JCO) in Tokai Village (1999) resulted in the deaths of two people because of radiation exposure, residents in the vicinity had to evacuate, and railways and roads were closed. To prevent such accidents, nuclear facilities including nuclear power stations implement thorough safety measures and, in the event of an accident, countermeasures to minimize the damage are enforced.

In addition to these measures implemented by nuclear facilities, national and local governments have made it mandatory to enforce prompt and appropriate protective measures to ensure the safety of residents in the event of an accident in a nuclear facility that causes a large amount of radioactive materials to be released, through legislation (December 1999) and enforcement (June 2000) of the Special Law of Emergency Preparedness for Nuclear Disaster.[1]

The System for Prediction of Environmental Emergency Dose Information (SPEEDI) network system[2),3)] operated by the Nuclear Safety Technology Center (NUSTEC)[4)] based on the consignment of the Ministry of Education, Culture, Sports, Science and Technology (MEXT)[5)] is an essential system for preventing nuclear disasters by developing protection strategies in Japan. The objective of this system is to provide national and local governments with useful data for formulating effective protection measures by promptly calculating how radioactive materials released into the environment will be diffused (profile of concentration in the atmosphere) and exposure dose.

Since the SPEEDI network system started to be operated in NUSTEC, Fujitsu has continuously supported its development, infrastructure improvement, operation and maintenance. This paper describes the development processes and gives an overview of the system's functions together with Fujitsu's approach to supporting this system.

2. Processes of SPEEDI network system development

Being aware of the serious effects of the accident that occurred in Unit 2 of the Three Mile Island Nuclear Generating Station in 1979, the Japan Atomic Energy Research Institute (currently, the Japan Atomic Energy Agency) started designing the SPEEDI network system. Currently, this program is operated by NUSTEC as a consignment project of MEXT, and further improvement of its functions is being promoted.

In the 1980s, all its functions were concentrated on a single vector computer (Fujitsu's VP2100), by which NUSTEC carried out all the operations such as entering computation parameters and running computations. Based on this system, national and local governments had access to estimates distributed by NUSTEC via a display terminal called Terminal II. In the second half of the 1990s, the functions that had been centralized on the vector computer (data collection functions, system control functions and drawing functions) were split up and assigned to multiple workstations with the purpose of decentralizing the load and improving the availability of data. The vector computers (two units of Fujitsu's VX) were dedicated to calculating the estimates.

Since 2005, new functions have been introduced. The functions enabled national and local government users to directly access the system by using Terminal II. The functions are called "direct acquisition function of estimated results" and "direct calculating function". As a result, using Terminal II lets the users directly input the computation parameters, run the computation, and get the estimated results. Through these modifications, national and local government users became able to interactively access the system.

Key milestones of the SPEEDI network system are shown below:

1) 1980-1984

Design, prototype development and basic system development (Japan Atomic Energy Research Institute)

2) 1985-1992

Transfer of the system to NUSTEC and connection of local government networks

3) 1993-1996

Renewal of local government terminals (integration of workstations)

4) 1997-1999

Decentralization of the system (from VP to workstation)

5) 2000-2001

Expansion of the scope of the facilities (research reactor and nuclear fuel facilities), connection of off-site centers (base facilities for emergency countermeasures)

6) 2002-2004

Update of local government terminals (introduction of PCs)

7) 2005-2006

Introduction of advanced SPEEDI computation model, development of functions to directly obtain estimates and direct computation functions

If a large amount of radioactive materials are released from a nuclear facility, or if the environment is at risk of the foregoing, national and local governments need to promptly take appropriate protective measures. To achieve this target, the SPEEDI network system is in opera-

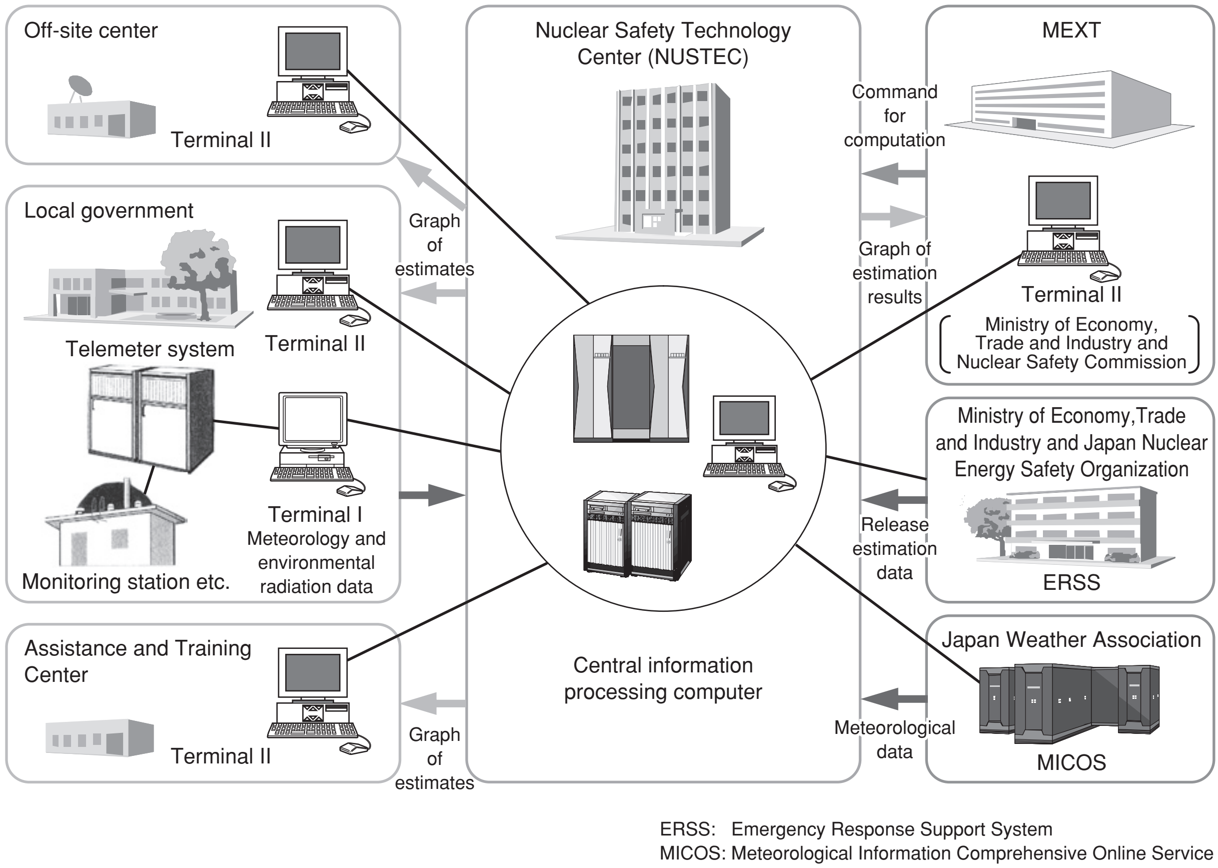


Figure 1
Concept of SPEEDI network system.

tion 24 hours a day, all year round.

3. Configuration and functional overview of SPEEDI network system

Based on the meteorological conditions in the vicinity of a nuclear facility, released source information that estimates the source of a radioactive release from that nuclear facility and predetermined geographical data, the SPEEDI network system performs a radioactivity dispersion model computation to estimate how radioactive materials would disperse, their concentration in the atmosphere, and the exposure dose in human beings. These estimates are expressed in terms of contour-line data on a map showing the vicinity of the nuclear facility, and are supplied via networks. The concept of the SPEEDI network system is indicated in **Figure 1**.

Data on meteorological conditions in the vicinity of nuclear facilities are automatically collected from each local government and the Japan Weather Association and gathered on the central computers of NUSTEC. These computers are always ready to run computations to make estimates.

Upon receiving a command to execute the estimation from MEXT, NUSTEC carries out computations to make estimates, and transmits the results in the form of graphic data to local governments and national disaster prevention organizations.

The main functions of the SPEEDI network system are described below:

1) Data collection, monitoring and registration

Meteorological data necessary to estimate how radioactive materials will disperse are collected and accumulated on a continuous basis. The following pieces of meteorological data are collected: i) Grid Point Value (GPV) data (i.e. numerical prediction data) and observational data of the Automated Meteorological Data Acquisition System (AMeDAS) that are supplied by the Japan Weather Association, and ii) monitoring data supplied by local authorities where nuclear facilities are located.

Besides meteorological data, observational data for environmental radiation are also collected from local authorities with the purpose of continuously monitoring whether the observed values of environmental radiation remain within a specific level. If they exceed a certain level, that information is communicated automatically to the people concerned within NUSTEC and in MEXT via voice messages and E-mails sent via mobile phones.

2) Computations for meteorological estimates

Changes in meteorological conditions (such as wind direction and speed) surrounding a nuclear facility are estimated through an atmosphere dynamics model calculation based on GPV data. AMeDAS data and monitoring data are used to correct the estimated value for improved accuracy.

3) Computation for dispersion estimation

This function estimates the time-dependent dispersion of radioactive materials that are released and their level of effect on the human body and the environment, based on the results of the computations for the meteorological estimates.

4) Formulation of graphics depicting the estimates

This function formulates graphics (graphics depicting the estimates) to express the computation results of the dispersion estimates on maps. The graphics are displayed in the form of contour lines. The graphics that can be shown include those depicting the atmospheric concentration of radioactive materials, graphics showing the air-absorbed dose rate (the dose from radioactive materials), a surface-deposition graphic representing the level of radioactive material that falls on the ground, and external and internal exposure graphics that represent the effects of the radiation on the human body. The computation results of meteorological estimates are also represented as wind-field graphics.

5) Transmission of graphics depicting estimates

This function transmits the graphics to national and local Nuclear Emergency Response Headquarters[note)] and local governments via networks. The graphics can be displayed on dedicated terminals in the Nuclear Emergency Response Headquarters and local governments.

Figure 2 shows an example of graphics depicting estimates (effective dose of external exposure).

4. Components of SPEEDI network system

The SPEEDI network system is comprised of a group of central computers at NUSTEC in Bunkyo-ku, Tokyo, a group of terminals installed at national and local governments, and the networks that connect each element, to embody the above-mentioned functions. The networks

note) Establishment of Nuclear Emergency Response Headquarters (Special Law of Emergency Preparedness for Nuclear Disaster: Article 15).
In the event where a Declaration of Nuclear Emergency is issued by the prime minister, the Nuclear Emergency Response Headquarters should be located in the prime minister's official residence based on Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster. Further, Local Nuclear Emergency Response Headquarters should be located in off-site centers so as to facilitate the handling of the accident under the initiative of the national government. In the event of any nuclear disaster, or if there is a risk of a nuclear disaster, local governments should set up Nuclear Emergency Response Headquarters at local levels to organize the necessary systems for disaster countermeasures.

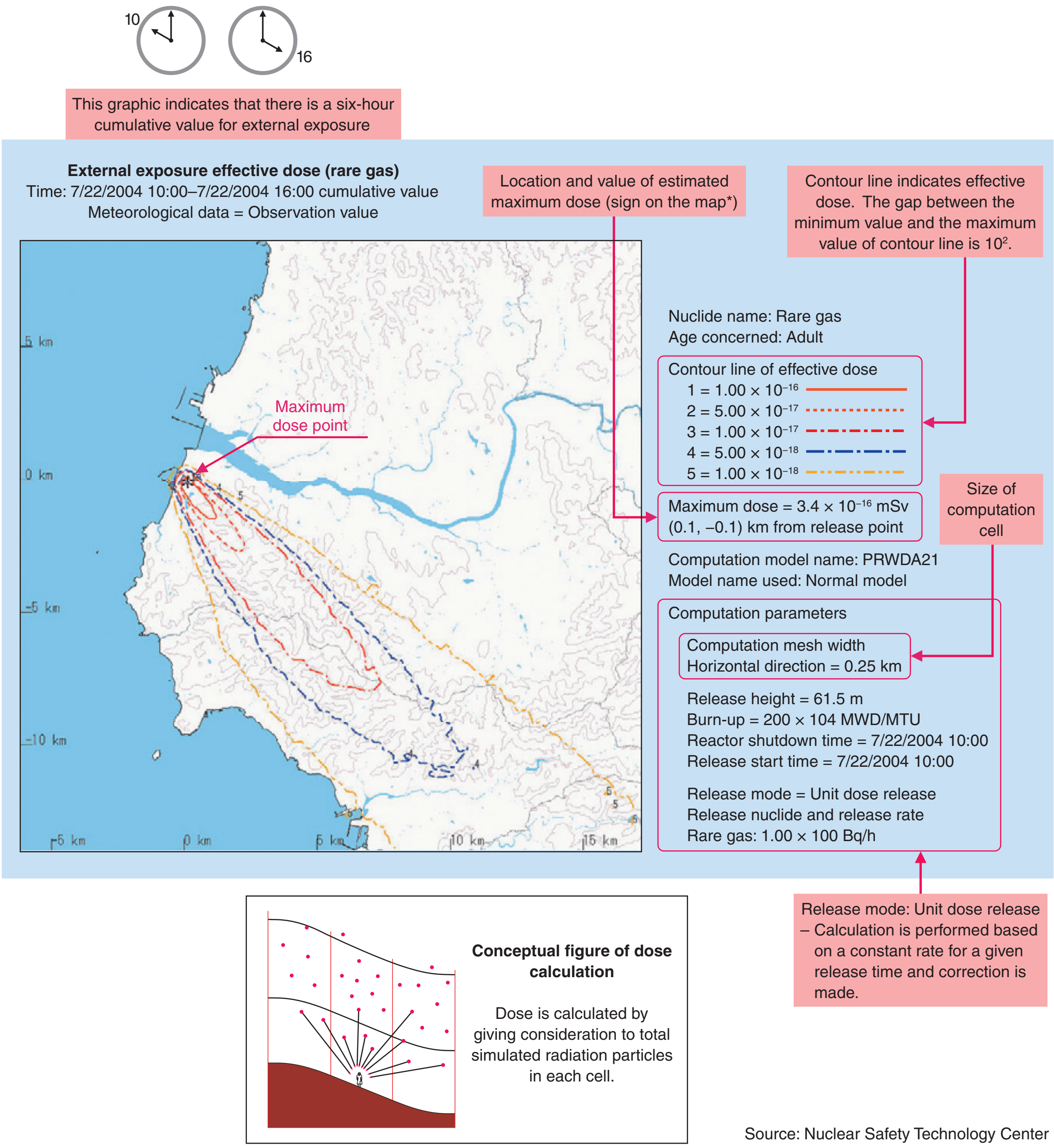


Figure 2
Prediction results of external exposure dose.

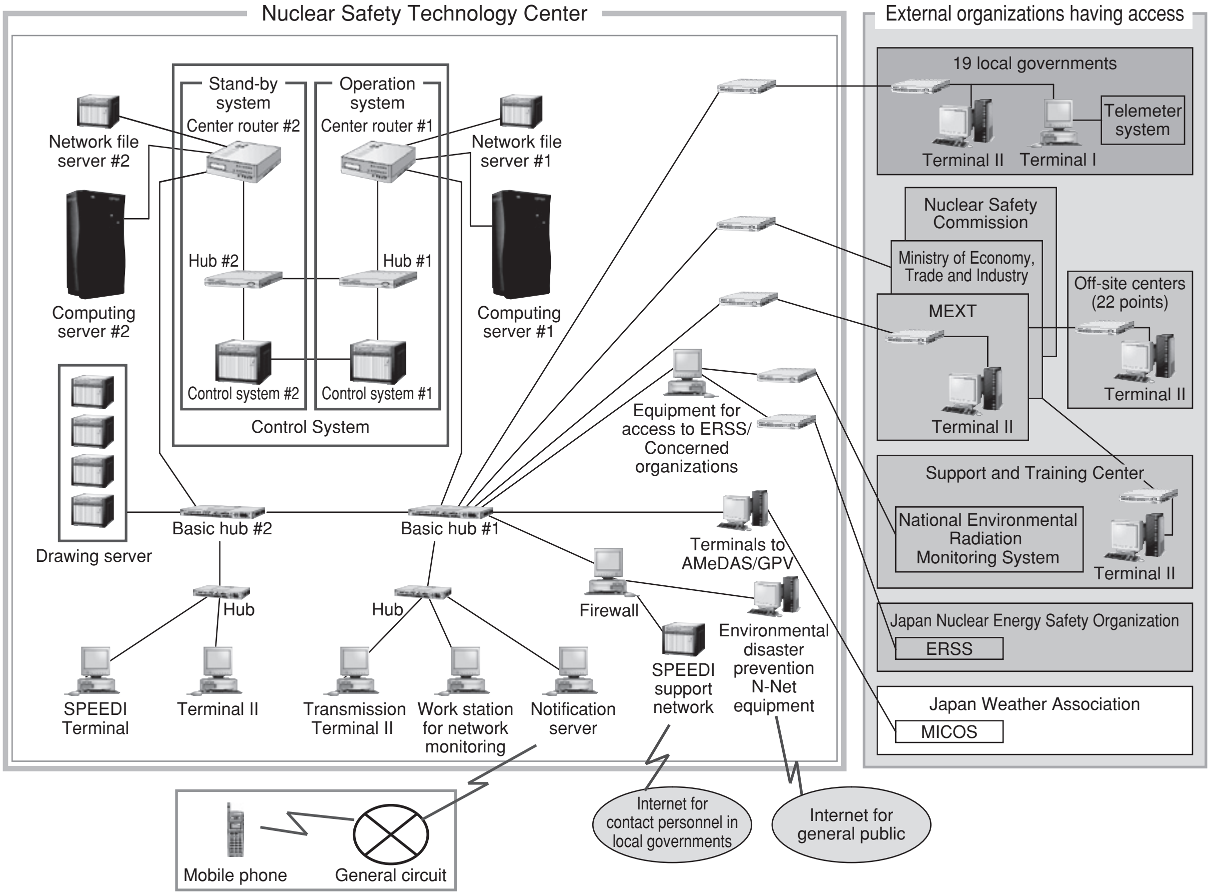


Figure 3
SPEEDI network system structure overview.

connecting NUSTEC and the Nuclear Emergency Response Headquarters or local governments are ensured by using dedicated lines instead of using the Internet or public lines, in order to ensure security and to avoid congestion in the event of an emergency.

An overview of the SPEEDI network system configuration is indicated in **Figure 3**.

4.1 Overview of central computer group

Because the objective of the SPEEDI network system is to address accidents that might occur at an unexpected timing, the main components are designed in a redundant structure, so that estimates can be calculated at any moment. To be specific, the control system has a cluster configuration and the computing server and drawing server are arranged in a multiple number of units.

1) Control system (two units of Fujitsu's PRIMEPOWER650)

With its function to control the whole central computer group, this system represents the core of the SPEEDI network system. Its main functions are the reception, monitoring and accumulation of data from local governments, execution control for calculating estimates at computing servers, storage of various parameters to be used in calculating estimates, storage of computation results and control of drawing servers. The control system consists of two servers based on a cluster system.

2) Computing server (two units of Fujitsu's VPP5000U)

Calculations of meteorological estimates and dispersion estimates are executed under the control of control servers. By using three types of computation codes, i.e. local meteorological estimates (PHYSIC), wind field computation (WIND21), and concentration and dose computation (PRWDA21), the dispersion of radioactive materials is estimated. Configuration of the computing server is based on two identical units of a machine.

3) Drawing server (four units of Fujitsu's PRIMEPOWER450)

Managed by the control system, graphics depicting estimates are formulated based on the computation results that are output from computing servers. The formulated graphics are sent to Terminal II which is a display terminal.

Configuration of the drawing server is based on four identical units of a machine with the purpose of enhancing the continuity of operations in the event of a hardware disturbance, while minimizing the time necessary for formulating graphics.

The control system monitors the job progress of drawing servers and assigns the drawing job to the server with the least workload.

4) SPEEDI terminal (Fujitsu's FMV)

It is the operation terminal that assumes most of the operational work of the SPEEDI network system. Most of the main operations for the SPEEDI network can be carried out from the SPEEDI terminal including a display of the system status of the control system, input of parameters for computing estimates and monitoring of the data collection status.

5) Transmission Terminal II (two units of Fujitsu's GP400S/M60)

This terminal has the function of storing the formulated estimate graphics and transmitting them to Terminal II, which is installed in the national and local governments. Besides the transmission function, it has a graphics display function in the same way as the ordinary Terminal II.

6) Notification server (third-party brand)

All the system logs of the SPEEDI network system are accumulated in the control system. The notification server monitors the logs in the control system and, in the event of a specific incidence, makes notifications via voice messages and E-mails sent via mobile phones.

7) Network monitoring terminal for SPEEDI (one unit of Fujitsu's GP400S/M60)

This terminal performs the centralized monitoring of the operational status of each computer and network component connected to the SPEEDI network system.

8) Terminal to AMeDAS/GPV (installed in the Japan Weather Association)

This terminal is connected to the Meteorological Information Comprehensive Online Service (MICOS) System of the Japan Weather Association and receives GPV data and AMeDAS data.

9) Emergency Response Support System (ERSS) and component for connection with related organizations (two units of Fujitsu's GP400S/M10)

This system and the components are connected to the ERSS of the Japan Nuclear Energy Safety Organization (JNES) and they receive the released source information. In addition, they have a function to transmit the data collected from local governments to Assistance and Training Center of the Japan Atomic Energy Agency.

4.2 Overview of systems of national and local governments

1) Terminal I (two units of Fujitsu's GP400S/M10)

This terminal is connected to the telemeter system of local governments, and it receives and stores meteorological observation data and environmental radiation data from the telemeter system. The stored data are collected by the control system every 10 minutes. To prevent any interruption in the reception of data related to a hardware abnormality, most of Terminal I is based on two identical units of a machine so that either unit can continue to collect data even if the operation of the other one is interrupted.

2) Terminal II (Fujitsu's FMV)

Terminal II displays the graphics showing estimates that are transmitted from the central computer group. Terminal II is arranged in the related facilities of national and local governments. While it was used solely to display graphics of estimates in the past, it started to assume a role as an input terminal as a result of the development of its direct acquisition and direct computation functions, which we will describe later.

5. Approach by Fujitsu

The basic part of the SPEEDI network system developed by the Japan Atomic Energy Agency was transferred to NUSTEC in 1986 as a result of a consignment by MEXT. At the same time, the network system connected to local governments and the Japan Weather Association has been improved and is being operated.

Among the SPEEDI network system, the element that calculates estimates of the dispersion of radioactive materials was developed by the Japan Atomic Energy Agency. Fujitsu has been involved in the collection and storage of various pieces of data; formulation of input data for calculating estimates; control of computation jobs; development of functions to use the system, such as function to visualize computation results; introduction and structuring of various servers; improvement of the environment for monitoring the network; and maintenance and support to smoothly promote the use and operations of the system.

Particularly, since the JCO accident in 1999, a series of reinforcements have been made to the SPEEDI network system functions to supply information necessary to develop protective measures for residents in the vicinity of nuclear facilities more effectively and more efficiently, while giving consideration to the increased importance of nuclear emergency preparedness. The improvement and addition of main functions in recent years are described in the next section.

5.1 Reinforcement of estimation and monitoring functions

1) Expansion of facilities in the scope of estimation

In the initial stage, the scope specified for calculating estimates of radioactive material dispersion to be conducted by the SPEEDI network system was limited to nuclear power plants (including the Monju Nuclear Power Plant and the Fugen Plant) and reprocessing plants. Then, since the JCO accident in 1999, the scope of estimation was expanded to include research reactors of universities and research institutes as well as nuclear fuel facilities. As a consequence, the number of facilities in the scope was increased from 34 sites in 14 local governments to 43 sites in 19 local governments. In addition, based on the national policy, 22 off-site centers (base facilities for emergency countermeasures) were arranged nationwide as base sites for protective countermeasures in the event of a nuclear disaster. Along with the expansion of the facilities in the scope, improvement of the system utilization environment and addition of functions were implemented. In this framework, Terminal II was installed in all the off-site centers, and functions to transmit and display graphics depicting estimates were added.

The data communication network of the SPEEDI network system is indicated in **Figure 4**.

The SPEEDI network system connects MEXT; the Nuclear Safety Commission; the Ministry of Economy, Trade and Industry; off-site centers; local governments and the Japan Weather Association with the central information processing computer in NUSTEC as a core facility by using a dedicated circuit. The central information processing computer collects meteorological

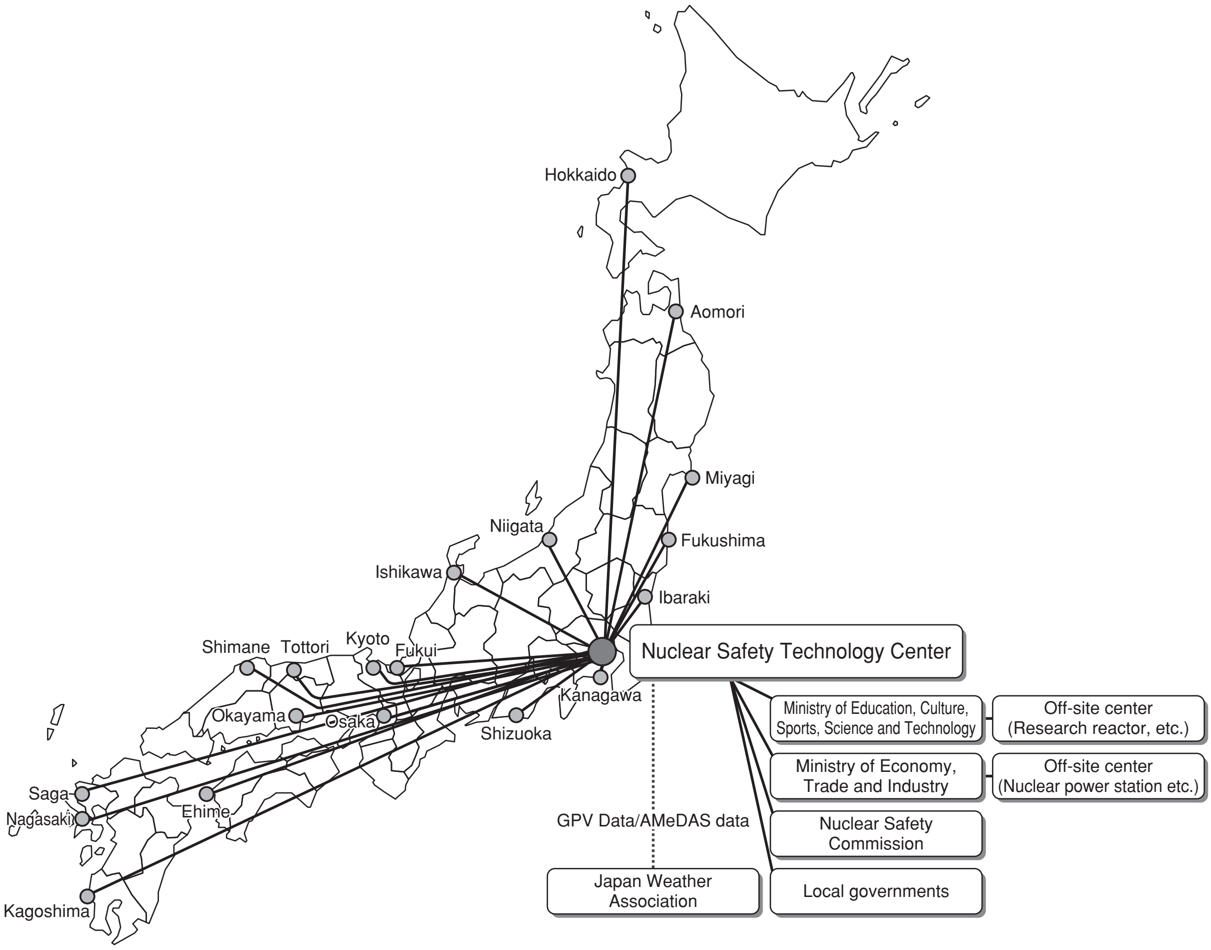


Figure 4
Data communication network of SPEEDI network system.

and environmental radiation observation data from monitoring stations of the local governments, as well as GPV data and AMeDAS data from the Japan Weather Association, on a continuous basis to be prepared for any emergency.

2) Refinement of data collection and monitoring

The environmental radiation data that the SPEEDI network system collects from each local government were not an essential element for the computing of estimates at the initial stage. However, since the JCO accident, continuous monitoring of environmental radiation data of all the domestic nuclear facilities has been considered to be one of the significant missions of SPEEDI. Along with this change, the frequency of collecting the environmental radiation data on a regular basis was changed from the conventional rate of once every one hour (every 10 minutes in an emergency) to once every 10 minutes. Also, some of the facilities were modified so that they included data on dose rates of neutron beams in the scope of data to be collected, in addition to the conventional data on dose rates of gamma radiation.

In implementing the modifications and improvements described in 1) and 2), NUSTEC asked for development and arrangements to be made within an extremely short period, based on the urgency of implementing countermeasures after the JCO accident. With cooperation from NUSTEC, Fujitsu was able to successfully meet these requirements by consolidating its various know-hows and technologies obtained through its experience.

5.2 Improvement of user environment (function for direct acquisition of estimate data)

Previously, entry of parameters as well as job actuation of computing estimates could be conducted only from the SPEEDI terminal in NUSTEC. This was attributable to the initial assumption of a one-way communication of commands in the event of a nuclear emergency, where execution commands for SPEEDI computing estimates should be issued by MEXT, and the computing of estimates should be carried out by NUSTEC according to those commands, and the estimates should be distributed to local governments. However, an increasing number of local governments started to implement nuclear emergency drills and their need for easy access to the graphics depicting estimates to be used in those drills was heightened. To address those needs, the user environment was improved so that it allowed direct acquisition of graphics depicting estimates, based on the computation of estimates, by directly entering the computation parameters into Terminal II located in each local government.

While SPEEDI terminals were configured as a cluster server system having applications also in the terminal side, the operation system for directly acquiring estimates has been constructed as a web system that can be operated just by using a browser on the terminal side. This configuration was employed to enhance the maintenance efficiency and to be prepared for the future introduction of a Web system in Terminal II.

The concept of the function for direct acquisition of estimates is indicated in **Figure 5**.

To make it more convenient for the users of the function to directly acquire estimate data, the functions were improved by, for instance, simplifying the operation through introducing fixed formatting for complex computation parameters or displaying the estimated completion time when starting a computation job.

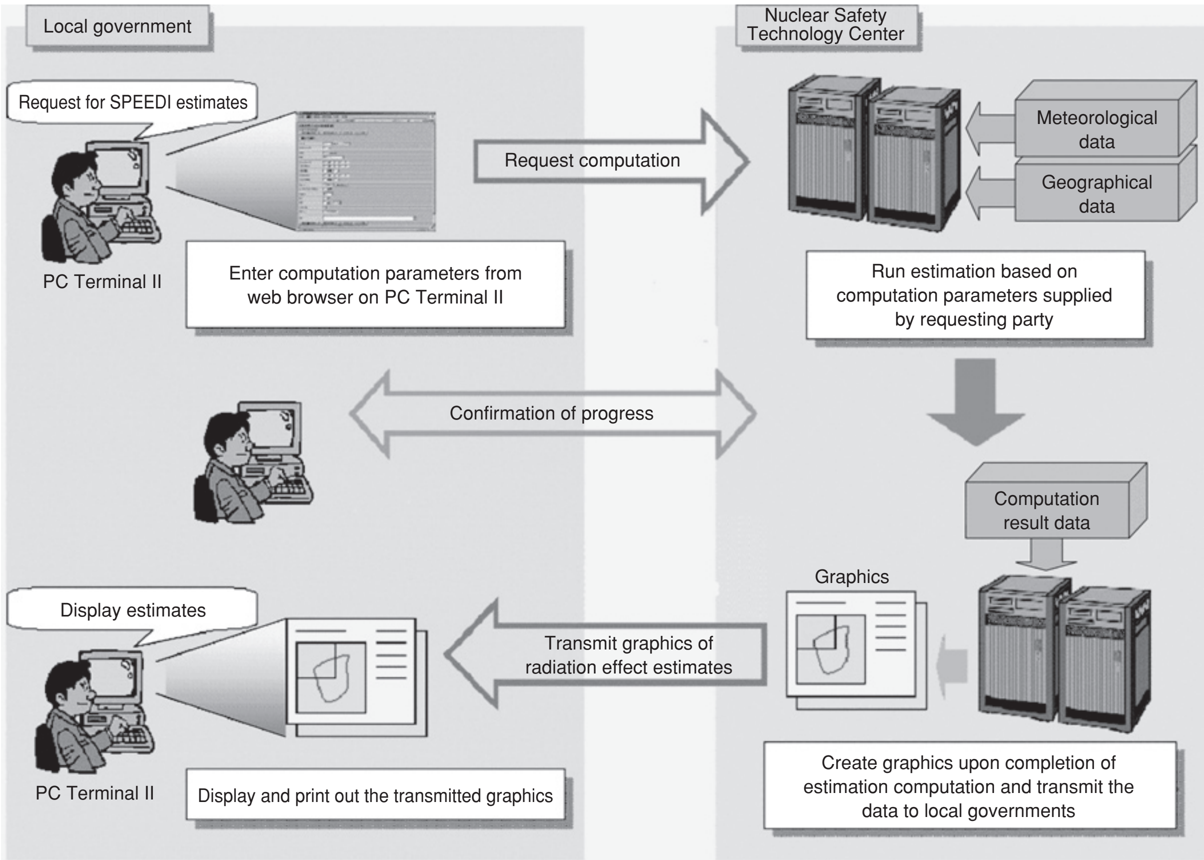
6. Future development

In the current system, the scope of computing estimates by the SPEEDI network system is limited to an area of approximately 100 km square around the nuclear facilities. The introduction of a new computation model developed by the Japan Atomic Energy Agency is in progress, with the purpose of improving the function to make estimates on more comprehensive effects.

MEXT and NUSTEC are planning to transfer the computation model for the comprehensive-effect estimation function from the computer environment of the Japan Atomic Energy Agency to NUSTEC's computer environment (new computing server) in FY2007 to establish an environment where calculations of estimates can be made. From FY2008, efforts are made to improve the environment necessary for operations, such as entry of computation parameters and formulation and transmission of graphics, hoping to be in time for the targeted start of operations in FY2009. In line with this improvement plan developed by MEXT and NUSTEC, Fujitsu is promoting the introduction of new computing servers. In this framework, PC clusters (12 units of Fujitsu's PRIMERGY RX200 S3) have been introduced to replace the conventional vector computers. This approach will contribute significantly to improving cost performance.

Because the period of modification work was very short, while there were drastic changes in the nuclear-related environment after the JCO accident, we were forced to inherit the existing basic design concept of the SPEEDI network system, in which most of the processing was carried out only by a single vector computer.

Giving consideration to the significant changes in the requirements of these systems,



Source: Nuclear Safety Technology Center

Figure 5
Concept of function to directly receive prediction results.

Fujitsu is striving to optimize each system to enable prompt planning of nuclear protection countermeasures as a more advanced goal in future, while coordinating the schedule to be in time for the replacement timing of each piece of hardware. In this framework, Fujitsu will consider the review and rearrangement of main functions such as data collection, data management and computation control. At the same time, Fujitsu plans to promote redundancy of the system through integrating the possibility of a secondary back-up system based on the assumption of an emergency such as an earthquake in Tokyo, i.e. a core site of the current system, and to propose a more solid and efficient system.

7. Conclusion

This paper introduces the current status of the development and operation of the SPEEDI network system and describes Fujitsu's support for this system. Being aware of the significance of this system as a core system in Japan's nuclear disaster prevention, Fujitsu is determined to provide further support to realize its steady operation and expansion of functions.

This paper describes the comprehensive results of "investigation for emergency response comprehensive support system" conducted by NUSTEC, which was a project consigned by MEXT based on the former "Special Account Law for Electric Power Development Promotion (Special Account for Energy Policy)".

References

1) Cabinet Office: Special Law of Emergency Preparedness for Nuclear Disaster (in Japanese). *http://www.bousai.go.jp/jishin/law/002-1.html*
2) System for Prediction of Environmental Emergency Dose Information Network System SPEEDI pamphlet. 2006 (in Japanese). *http://www.bousai.ne.jp/vis/torikumi/030103.html*
3) N. Suda: The Present Status and Future Prospects of the SPEEDI Network System. *Hoken buturi*, vol.41, no.2, pp.88-98 (2006).
4) Nuclear Safety Technology Center: *http://www.nustec.or.jp/english/english.htm*
5) The Ministry of Education, Culture, Sports, Science and Technology: *http://www.mext.go.jp/english/index.htm*

Makoto Misawa
Fujitsu Ltd.
Mr. Misawa joined Fujitsu Ltd., Tokyo, Japan in 1987 and has been engaged in the development of systems for nuclear power engineering.

Fumio Nagamori
Fujitsu Ltd.
Mr. Nagamori joined Fujitsu Ltd., Tokyo, Japan in 1986 and has been engaged in the development of systems for nuclear power engineering.