Science & Technology Foresight Center of NISTEP

Science & Technology Trends

Quarterly Review

No.11
April
2004

Foreword

This is the latest issue of "Science and Technology Trends — Quarterly Review".

National Institute of Science and Technology Policy (NISTEP) established Science and Technology Foresight Center (STFC) in January 2001 to deepen analysis with inputting state-of-the-art science and technology trends. The mission of the center is to support national science and technology policy by providing policy makers with timely and comprehensive knowledge of important science and technology in Japan and in the world.

STFC has conducted regular surveys with support of around 3000 experts in the industrial, academic and public sectors who provide us with their information and opinions through STFC's expert network system. STFC has been publishing "Science and Technology Trends" (Japanese version) every month since April 2001. The first part of this monthly report introduces the latest topics in life science, ICT, environment, nanotechnology, materials science etc. that are collected through the expert network. The second part carries insight analysis by STFC researchers, which covers not only technological trends in specific areas but also other issues including government R&D budget and foreign countries' S&T policy. STFC also conducts foresight surveys such as periodical Delphi surveys.

This quarterly review is the English version of insight analysis derived from recent three issues of "Science and Technology Trends" written in Japanese, and will be published every three month in principle. You can also see them on the NISTEP website.

We hope this could be useful to you and appreciate your comments and advices.

TERUTAKA KUWAHARA
Director
Science and Technology Foresight Center

Contact us: Science and Technology Foresight Center
National Institute of Science and Technology Policy
Ministry of Education, Culture, Sports, Science and Technology (MEXT)
2-5-1, Marunouchi, Chiyoda-ku, Tokyo 100-0005, Japan
Telephone +81-3-3581-0605 Facsimile +81-3-3503-3996
URL http://www.nistep.go.jp/index-e.html
E-mail stfc@nistep.go.jp

Executive Summary

Information and Communication Technologies

1 Next-Generation Content Distribution Technology in the Broadband Age

p.11

In Japan, the broadband environment is quickly coming into widespread use as a result of the communications infrastructure built under the e-Japan Strategy.

At the same time, the demand for viewing high-quality motion pictures through the Internet (content distribution) is rapidly growing. However, there are a number of hurdles to be overcome before motion pictures or other types of large-volume data can be smoothly distributed. These hurdles include not only the issue of the network bandwidth but also problems concerning content servers located upstream in networks, such as the need for greater server capacity and for server load balancing.

In the area of content distribution, firms are having difficulty with "fee-based" business models. Businesses that intend to directly charge fees to consumers for their online purchases (B2C model) have not been successful, except for those involved in e-commerce such as online stores in which purchased products are physically delivered to consumers. As a result, the B2C sector is showing growth smaller than the business-to-business (B2B model) commerce sector. A possible solution to this is to build a new business model that could be called B2B2C, which would be essentially a model embracing the overall online commerce flow, starting from the content sources located upstream in the network.

For content distribution in such a scheme, grid computing could prove useful, because it allows multiple computing resources to be linked together so as to be scalably allocated as required. To construct grids, efforts should be made to promote the research and development of its constituent technologies, including grid middleware and application software, as well as hardware technologies such as optical interconnection and optical wiring.

(Original Japanese version: published in October 2003)

2 Toward the Improvement of Quality and Reliability in Information Systems Construction

– A Study of "Business Rules" and Requirements Engineering in the Upstream Process –

p.19

At a time when information systems assume a critical role as a social infrastructure, technologies to construct safe and reliable information systems promptly and inexpensively are the source of general industrial competitiveness as well as the basis of research and development. The key to improving quality and reducing cost in systems construction is to identify required functions and to ensure quality in the upstream phase of systems construction. Imperfections in the upstream process may lead to substantial problems or an enormous cost in operation and maintenance of the system. However, rather little emphasis has been placed on improving upstream environments, including the aspects of technological development and human resources fostering, particularly in Japan.

This article focuses on requirements engineering and "business rules" as technical elements for the upstream process. Requirements engineering deals with "requirements" for the system and aims to acquire, analyze, and specify these requirements so that they can be managed in all processes across the system life cycle. "Business rules" describe the business structure of the information systems to be constructed and identify the expected and required functions of the systems within that business structure.

While the U.S. and Europe have formulated frameworks to discuss "business rules" since 1995, there exists no such scheme in Japan, with little research activity ongoing at present. Requirements engineering is established as part of system engineering or software engineering. However, of 376 presentations delivered at IEEE international conferences in the past 10 years, only nine was from Japan, a fact that indicates the need for boosting research and develompent in this field.

The author proposes the following three approaches to improve the upstream processes in Japan.

(1) Create environments that make "business rules" and requirements specifications to be identified during system development

Possible solutions include the enactment of legislation and the auditing of systems purchase specifications.

(2) Foster human resources who can develop "business rules" and requirements definitions

This refers to providing education as part of MBA (Master of Business Administration) curriculums or in the purchasing/user departments in companies and government organizations.

(3) Encourage research and development in the upstream process

Specifically, this embraces: (a) formal methods and mechanical verification; (b) technologies for requirements acquisition from stakeholders; and (c) quantitative evaluation of technologies and methods (by collecting and publishing data for public use).

(Original Japanese version: published in November 2003)

3 Technological Trends in Internet Routers
– Toward Construction of Next-Generation Communications Infrastructures –

p.30

The infrastructure for data communications consists of transmission lines, such as optical fibers and copper wire, and switching devices represented by Internet routers. Technological trends in data communications infrastructures are now about to see the next turning point, which emerges about every 10 years. We could see this from the following evidences: (1) further growth in user traffic (volume of communications) toward the future; (2) demand for sophisticated and diverse network management capabilities such as security protection; and (3) the need for new research-and-development directions in response to the evolution in hardware as seen in optical switching.

The Internet has been developed on the basis of the "best-effort" concept, in which controls required for communications are implemented in a distributed manner. In the meantime, standardization activities aiming at "de facto standards" contributed to the success of rapid technological accumulation within a short time. However, current technological trends suggest that the traditional approaches that have been adopted to develop the Internet should give way to new concepts in terms of R&D in communication infrastructure.

Now, in a time of transition, the national government should take the decisive initiative, based on its strategy, in setting the course for long-term technological accumulation in the area of communications infrastructures. The reason is that the past national strategy on technological accumulation, which functioned primarily through the operations of NTT Public Corp., significantly changed after the privatization of the company in the process of the growth of the Internet. For example, take the case of network management technology, research on which has recently been increasing in importance. This is a technological field that has an impact on the entire communications infrastructure and, therefore, requires a universal direction of research.

Since there has been a tendency among Japanese communications equipment manufactures to scale down the functions of their central research laboratories, the academic sector is expected to assume an increasingly significant role in the communications infrastructure field. Universities should emphasize, in particular, practical R&D, including the development of equipment that is intended for commercial use. Aside from delivering research papers, they should focus more on research projects that can potentially contribute to industrial competitiveness, such as a project for developing a chip that will embody a new technology and prove competitive in the communications equipment market.

(Original Japanese version: published in December 2003)

Environmental Sciences

4 Water and Sewer Treatment Technology in the World and Trends in the Privatization of Public Water Utilities

p.38

There has been a growing interest in water as well as in air pollution and global warming. As “water” in this particular case refers to water sources, tap water, sewer, wastewater, industrial water, well water, seawater, lake water, river water, etc., with each involving its unique environment, debates over “problem-solving” are increasingly complex. While upgrading and replacement of aging water/sewer lines are being discussed in the industrialized countries, severe water shortages and the lack of water infrastructures are looming large in the developing countries.

Japan, too, is saddled with a variety of problems related to water : contamination of well water with organic chlorine compounds and arsenic, aging water lines resulting in contamination with foreign materials, soil pollution associated with groundwater pollution, etc. In addition, appropriate measures should be adopted to address and solve other problems such as tightening water quality standards, the need for efficient management and information transparency, expanding service areas due to the consolidation of smaller municipalities, and sluggish revenues from water sales due to the ongoing recession. Meanwhile, the recent accident involving cryptosporidium (in which as many as 9,000 residents suffered from diarrhea caused by cryptosporidium in tap water) spurred consumers to buy drinking water or install water purifiers. Naturally, water suppliers are taking a series of measures to ensure the safety of water - e.g., review of conventional treatment methods, introduction of advanced water treatment that incorporates biological, UV, ozone and activated carbon treatment into conventional treatment, and conservation of water sources.

Water treatment technology has been making headway, involving technological innovation - which is symbolized by improved water quality due to the introduction of advanced water purification techniques. In response to a suggestion made by France about ISO standards, there have been active discussions in Japan on the possible adoption of international standards - the spotlight centers on water utility services. The introduction of ISO standards could further improve Japan's water quality control, which in itself is beneficial from the viewpoint of ensuring the supply of safe water.

An increasing number of public water utilities in European countries are being privatized, each of which is striving to improve services and reduce costs - the time will come soon when Japan needs to address this vital issue. When opting for privatization, however, there is a need to have a clear picture of the circumstances surrounding the domestic public water utilities, as the example of the U.S. shows.

On the other hand, the growing demand for mineral water in Japan indicates that public requirements for drinking water are becoming more stringent, from "potable water" to "safe and tasty water."

In view of all these factors, what is required for water treatment technology in the future is not only to produce potable water and treat wastewater but also to improve water quality and establish technology best suited for Japan's unique nature and culture. Technological innovation should also be promoted to improve services as a whole. In solving the problems mentioned above, therefore, there is a need to monitor water sources and introduce overseas expertise in addition to adopting advanced water treatment systems. In this context, it is desirable that due attention be given to both domestic and international trends and appropriate approaches be adopted, taking into account a water cycle as necessary.

(Original Japanese version: published in October 2003)

5 Trends in Earth Monitoring and Observation Satellites

– Advances in Monitoring and Observation with Satellites in File-formation Flight –

p.47

The need for data obtained through earth monitoring and observation satellite to protect Japan from natural disasters and to determine policies for that purpose is increasing. At this time, NASA and others are proposing that small satellites be loaded with one or a few sensors and flown in formation rather than loading large satellites with multiple sensors. This system involves multiple satellites following the same orbit at set intervals, much as train travels on the ground. From the perspective of the ground under that orbit, satellites pass overhead in succession at intervals of a few seconds to a few minutes. The result is that the multiple sensors loaded on the satellites in a formation can monitor or observe a single point or area on the ground from a variety of perspectives, obtaining more valuable data.

From the perspective of launch costs, earth monitoring and observation utilizing satellites in formation is at a disadvantage compared to the conventional method of multiple sensors on a single satellite. On the other hand, formations offer greater flexibility in policy development by avoiding interruptions in observation, spreading budgets over longer periods, and enabling easier participation in satellite observation projects. Furthermore, once a formation of satellites has temporarily formed, increased flexibility in sensor development and operation plans, gradual increases in the value of monitoring and observation data obtained by satellites, and concentration of satellite formation operation and data collection and distribution can be expected. This may result in a major impact on overall earth monitoring and observation utilizing satellites.

Japan has successfully developed outstanding earth observation sensors such as the Global Imager (GLI), the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), and the Precipitation Radar (PR). In formations of satellites, these sensors can be key instruments that obtain data that increase the value of other types of sensors. With its outstanding key sensors, Japan's planning and operation of its own groups of satellites in formation would respond to social needs, particularly those for safety and peace of mind. From the perspective of space policy development as well, it should be engaged in for the sake of the development of space transport systems and satellites.

(Original Japanese version: published in November 2003)

Nanotechnology and Materials

6 New Measurement Technology: Multi-probe System
– Toward Direct Measurement of Functions of Nanomaterials and Biomaterials –

p.53

Progress of many scientific technologies often proceeds together with the development of new measurement technologies. It would not be an exaggeration to say that new apparatus is indispensable for discovering new phenomena and to elucidate them, and this fact has been proven by many researchers who have received the honor of the Nobel Prize.

In the fields of nanotechnology and biotechnology, which are considered to be important for Japan who advocates a technology nation, development of completely new technologies and products are being sought by utilizing the characteristic functions of newly developed bio-materials and nano-materials. In the research and development of such materials, the first thing to be done is to know the functions of these new materials and it is impossible to measure the functions using conventional apparatus. In this case, the Multi-probe System is expected to play an important role in the measurement of such functions. The Multi-probe System is a device that uses a plural number of micro probes that directly touch bio-materials or nano-materials to measure functions such as electrical characteristics including signal transmission, and chemical and mechanical characteristics. Since the Multi-probe System is able to elucidate various phenomena such as antibody antigen response and ion transmission with a high spatial resolution, it is also expected to play an important role in medical applications.

The basic technology of the Multi-probe System lies in the scanning probe microscope (SPM), which has a resolution of the atomic level. It is not an exaggeration to say that the SPM opened the road to nanotechnology, and the inventor of the SPM was awarded the Nobel Prize.The Multi-probe System is, from a mechanical point of view, a device equipped with a plural number of scanning probe microscopes (SPMs) and that enables direct measurement on the nano scale by integrated control of the plural probes, which is not possible with the SPM. Therefore, it is expected that the Multi-probe System will create new methods of research and, consequently, create new research fields in the nanotechnology and biotechnology areas. It is also expected that the Multi-probe System will contribute much to enhancing the competitiveness of the semiconductor industry. This is because the Multi-probe System enables the evaluation of the performance characteristics of devices during the production process, making it possible to significantly reduce the period required for the development of devices, which is one of the most important factors in the commercialization of products.

The development of this device, which is just in the initial stage, is mainly being carried out by research institutes in Japan and overseas. This indicates that the development was started by researchers themselves in order to carry out the most advanced research and development. At present, only Japanese research institutes have succeeded in obtaining measurement data and reported the data, which means that Japan is one step ahead in the competition of the device's development.

In the present Japan, there is a tendency that the more advanced the target of research is, the more devices of foreign make are used. To use foreign equipment in research work not only leads to the outflow of budget but also may directly lead to the defeat in the fields of research and development. In order to lead the world in the fields of research and development, it is indispensable to develop the most advanced devices independently, and the Multi-probe System surely is one of the devices that must be developed independently.

The key to the success of the development of the Multi-probe System lies in the development of methods to perform integrated control of a plural number of probes including the development of measuring methods. In the development of the Multi-probe System, therefore, it is required for researchers, the users, and the device makers to closely cooperate more than in any other cases of conventional devices. For Japan to overwhelm other nations in the fields of nanotechnology and biotechnology taking advantage of the present lead, it is strongly desired to take national measures that promote such research and development activities.

(Original Japanese version: published in December 2003)

Science and Technology Policy

7 The Expanding Percentage of Women among Corporate Science and Technology Human Resources
– EU Policies and Japanese Issues –

p.62

For Japan to continue as a country based on science and technology, a sustainable supply of human resources is required. With the advent of a graying society in which families are having fewer children, however, Japan is moving along a path in which the labor force includes fewer young people. The nation thus faces the necessity of utilizing women as science and technology human resources, something it has not done sufficiently in the past.

The EU is already paying attention to women as science and technology human resources, and has worked out policies to increase the utilization of women in science and technology fields. Numerous research programs for the development and utilization of women in science and technology are being carried out by the Women and Science program of Science and Society under the EU's Framework Program 6 (FP6, 2002-2006).

The EU is actively trying to utilize women as science and technology human resources because securing outstanding science and technology personnel and introducing diversity into them will strengthen its competitiveness and vitalize its economy. The plan to increase the number of researchers (engineers) in the whole of the EU by 500,000 by 2010 is driving policies to utilize women as science and technology human resources. Concrete policies to increase the percentage of researchers who are women are being implemented, not only at the EU and the European levels but at the corporate level as well.

In Japanese corporations, there is a perceived shortage of scientific and technical personnel and of researchers in particular. Signs of an increase in the number of female researchers have become visible in recent years. However, the percentage of researchers in Japan who are women has remained at about 10 percent for several years, and is only 6 percent in corporations. Rather than continue the status quo, some sort of policy is required if the utilization of women as science and technology human resources is to be expanded.

The major issues in Japan are as follows. 1) The percentage of women in science and technology fields among university graduates and PhD recipients is low. 2) Carry out survey research regarding women who do research in corporations and analyze factors that become career obstacles. 3) Clarify the agency responsible for “women and science” and implement various types of programs. 4) Focus on women as science and technology human resources in the Third Basic Plan and clarify their position in science and technology human resources policy.

(Original Japanese version: published in December 2003)

1

Next-Generation Content Distribution Technology in the Broadband Age

ATSUSHI OGASAWARA *(Affiliated Fellow)*

1 Introduction

In recent years, Japan saw the rapid development of its communications infrastructure under the e-Japan Strategy. As a result, ADSL (Asymmetric Digital Subscriber Line) and fiber-optic communications have become widely available, making Japan the country where a broadband network environment is available at prices lower than anywhere else in the world and where more than half (54.5% as of the end of December 2002) of the total population have access to the Internet.

These changes are leading to a sharp growth in the demand for viewing streaming video or other types of motion pictures through the Internet. It is expected that as the fusion of communications and broadcasting advances, this demand will further increase and so will the demand for the distribution of large-volume, high-resolution images (rich content) such as high-definition video. To meet such demands, clearing technical hurdles is an urgent necessity.

This is particularly important to Japan, which owns the world's first-class broadcasting and video technologies as well as world-renowned image content ranging from films to animations to video games.

The e-Japan Strategy II, announced on July 2, 2003, and the e-Japan Priority Program, published on August 8, 2003, also emphasize the importance of the utilization of content, along with digital home appliances, as one of the key elements that will enable Japan to assume the leadership in the forthcoming network society. There are, however, problems that Japan needs to resolve before it can take advantage of its comprehensive strength covering from distribution technologies used upstream in the network to terminal devices located downstream.

While mentioning the possibility that such innovation in content distribution could transform the traditional concept and structure of the network, this article discusses how Japan could buildup technical and industrial competitiveness through this possible transition.

2 Problems in large-volume data distribution

The major problem in distributing information-rich content, or rich content, such as high-resolution motion pictures is the bottlenecks in large-volume data traffic.

In the past, the problem did not draw much attention since the gap in speed between the Gbps-level backbone networks and the "last one mile" to households was extremely wide. However, the gap narrowed as household computers became more sophisticated with the advent of CPUs with up to 3 GHz processing power, and as the communications speeds of the last one mile increased to a range of a few to 100 Mbps, thanks to the widespread availability of ADSL and fiber-to-the-home (FTTH). As a result, the relatively low capacity on the content server side has become highlighted.

Figure 1 is a conceptual image of the bottleneck problem. It shows that attention has mostly been paid to improving the situation in the last one mile, while the server-side bottleneck, which exists upstream in the networks, has been neglected.

The major causes of user complaints in the current network environment are an absolute insufficiency in the performance of servers, a superficial lack of server capacity due to the poor network infrastructure around servers, and the fluctuation of server capacity caused by varied access volume. Internet users are also frustrated even when viewing streaming videos, which are, unlike broadcast programs, accessible whenever they like, because people tend to find spare time during the same time periods of a day, resulting in an overload on the servers and thus an unsatisfying viewing experience for many. This server overloading issue, along with the problem concerning poor access speeds due to insufficient capacity, has emerged as a serious challenge.

For example, in the jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the National Space Development Agency of Japan (NASDA, or Japan Aerospace Exploration Agency (JAXA) since October 1, 2003) has been offering live pictures of the H-II rocket launches through the Internet. Visitors to their website have been experiencing difficulty accessing the images because of extreme congestion, and even those who did gain access were only given low-frame-rate images that were far from satisfactory. While this is an exceptional case where the overwhelming peak in access number occurs at the moment of the launch, it shows the need for efficient techniques to provide for the required server capacity and to balance the load on servers.

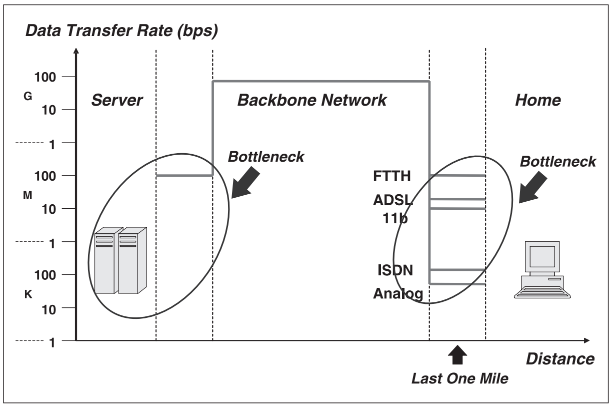
These two issues will become increasingly critical in years to come, when content to be distributed will be larger in volume and higher in resolution.

If the issues of insufficient server capacity and fluctuations in server load were to be resolved solely by installing servers with large enough capacity and scale, only a limited number of businesses that could afford such a large investment would be entitled to enter the content distribution market.

If Japan wants to develop the content business as a new pillar of the Japanese industry, it must encourage the entry of venture firms and small to medium-sized companies. In addition, reducing their investment requirements is yet another critical factor of the development in this area.

One of the reasons that the initial Japanese IT business, which had been emerging in the latter half of the 1990s, burst like a bubble is that

Figure 1: Network bottlenecks (conceptual image)



fluctuations in server load required companies to build facilities beyond their investment capacity. This is another hurdle that must be overcome.

3 Technologies to eliminate the bottlenecks

3.1 Enhancing server performance

(a) Increasing the processor's speed and memory bandwidth

The most essential approach to improving server performance is to increase the speed and memory bandwidth of the processor. Compared with general-purpose processors used for regular PCs, the processors for 3D graphics are required to provide higher operating frequency, wider memory bandwidth, and additional vectorization capability. Japan's vector processor technologies are superior to those of the U.S., as demonstrated in the Earth Simulator, the world's fastest supercomputer. Furthermore, current Japanese video game systems incorporate processors that operate at as high as the 128-bit level (as opposed to 32-bit level Intel Pentium processors for standard PCs), with some even enabled for vector processing. Japan is probably the most advanced country with respect to processor technologies applicable for 3D graphics.

Japan could further advance these technologies and leverage them to construct servers at affordable costs.

(b) Parallel/distributed processing

Another feasible approach to enhancing server performance is the introduction of parallel/distributed processing.

Although increasing the parallel/distributed processing power of a single processor is a possible strategy, there is a more cost-efficient method in which multiple processors are connected to form a cluster that provides greater processing power.

3.2 Coping with load fluctuations

(a) Content delivery network (CDN)

Content delivery network (CDN) services have been developed as one of the technologies that help businesses cope with fluctuations in server load, a problem as serious as the issue of sever performance. As described by Naoki Nishikado of Mitsubishi Research Institute, Inc. in the September issue of Science & Technology Journal, a CDN consists of cache servers (usually mirror servers) that serve as geographically-distributed content sources, and controls them to route users to the nearest server to ensure faster access. This technology is advocated by Akamai Technologies, Inc. of the U.S.

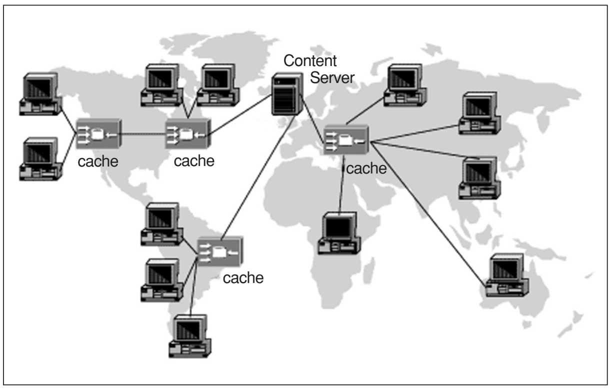
(b) The grid

As compared to content delivery networks, in which data is processed by a group of servers on an independent basis, there is another approach in which multiple computers or processors are connected through a network to scalably perform parallel/distributed processing in accordance with the required computing power. This technology is known as grid computing, an environment in which numerous computers are connected to a network to operate like a single massive-scale computer system through the sharing of CPU resources and memory space. For the successful implementation of a grid computing project, not only computers but also a high-speed network infrastructure is indispensable.

In Akamai's content delivery network, which is based on distributed processing on cache servers, computing resources available to a user will never exceed the cache server's processing capacity, that is to say there are as many independent computing spaces as the number of cache servers located across the world. For example, a network that can simultaneously deliver content to hundreds of thousand of people worldwide is actually divided into independent spaces each accommodating a few thousands of people. In a distributed processing environment created through grid computing, by contrast, the computing resources recognizable to a single user would be exactly the same as the entire network resources, which the rest of the hundreds of thousand of people also have access to.

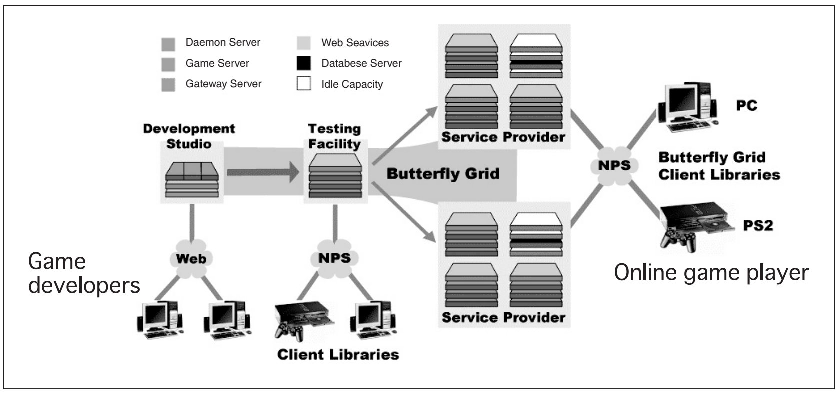
Whether to use cache servers or a grid to distribute content produces a significant difference in the results of load balancing. While the difference may be limited as far as the content is not time-sensitive or interactive, if the content

Figure 2:Content Delivery Network (CDN)



Source: Excerpts from ATT material

Figure 3:Grid server for gaming (IBM)



requires users to participate and substantially interact with each other (e.g., participation in politics in an electronic government, educational applications, and network gaming or other personal entertainment applications), the difference is considerable.

Another advantage of grid computing is that it frees content providers from the need for excessive server investment to ensure accessibility even during peak periods. They can instead purchase computing resources as required in the same way as they purchase electricity. This would also contribute to facilitating the entry of venture or small to medium-sized companies to the content industry.

4 Background of grid computing technology

Grid computing has been developed mainly for the purpose of scientific high-performance computing (HPC), for which mainframes and supercomputers at universities and national research institutions are connected through high-speed networks.

More recently, encouraged by the launch of large-scale projects in the U.S. such as TeraGrid of the NSF and the Biomedical Informatics Research Network (BIRN) of the NIH (reported by Masao Watari in the sixth issue of this bulletin), grid research in the field of high-end HPC systems that use high-speed communications lines is making rapid progress.

In 2002, under the Bush administration, the U.S. government began integrating federal IT research and development initiatives such as HPCC, NII, NGI, and IT2 into the collective program called the "Networking and Information Technology Research and Development (NITRD)." This move could be considered as a symbol of a growing fusion between communications network technologies and information systems technologies, a fusion in which grid computing is expected to serve as a major pillar.

The U.S. is also actively promoting standardization and advocating the Globus Toolkit, middleware for distributed heterogeneous environments.

The wave of grid computing is even sweeping across the business sector, in addition to the academic sector.

IBM, which has been making earnest efforts for the application of grid technologies to B2B since around 2000, proposed the Open Grid Services Architecture (OGSA), which combines grid computing with Web services, as an extension of the Globus Toolkit.

The proposal was initially met with great excitement among experts, while it received cooler response from corporations, because even if the OGSA could be implemented relatively early within the corporate intranet framework, further extensions would require an additional network infrastructure, an obstruction that corporations thought would not be eliminated soon.

However, as broadband communications quickly became widely available and as the development of the content distribution business increased the need for solutions to the server-side bottleneck problem and to server load balancing, the demand for grid computing dramatically rose.

A new movement in the U.S. is that Oracle announced "Oracle Database 10g" ("g" represents "grid"), a new database based on grid computing, at OracleWorld 2003, which started on September 8 in San Francisco. At the event, Hewlett Packard (HP) Chief Executive Officer Carly Fiorina mentioned in her speech that HP would actively move toward grid servers in the next three to five years. These facts underscore that grid computing is rapidly being accepted not only in IBM but also across the entire IT industries of the U.S.

In Japan, the opening ceremony of the "Center for the Grid Research and Development (NAREGI)," an institution established by MEXT, was held on July 1, 2003. The Center was built as a new R&D base for NAREGI (National Research Grid Initiative), a five-year project that started in April 2003, based at the National Institute of Informatics (Director General: Yasuharu Suematsu). The NAREGI project aims at "the creation of an environment for next-generation computing systems, with the view of strengthening Japan's international competitiveness in the information and communications field." Through collaboration between industry, academia and government, NAREGI intends to develop a high-performance computing environment on the basis of grid computing in which multiple computer resources are effectively combined to substitute for a single supercomputer. A major objective of the project is the research and development on application software for use in the nanotechnology and biotechnology fields, which are expected to be critical fields of science in the next generation. The scientific fields the NAREGI project actually embraces are so extensive as to include even areas that are closely related to industrial applications, such as new communications principles, electronic devices, optical devices, molecules, and the development of new drugs.

The Ministry of Economy, Trade and Industry (METI) also launched its own initiative, "Business Grid Computing Project," on July 15, 2003. Chaired by vice president of Waseda University Yoichi Muraoka, the project seeks to support the development of middleware that can primarily be used for grid computing.

What made METI take this step was the awareness that grid computing technology will be the key to acquiring international competitiveness in the information systems sector. METI also recognizes that this sector is currently dominated by the U.S. from upstream to downstream network elements, under the influence of such industry leaders as Intel in the MPU (Micro Processing Unit) domain, Microsoft, with Windows, in operating systems, IBM and HP in data distribution servers, and Oracle in databases.

When grid computing becomes widely applicable for industrial purposes in addition to scientific computations, it will be the time when a transition starts in computer and network architectures. Having realized that this will present a good opportunity for Japan to assume the world leadership in the information systems sector, METI made the strategic decision of launching the project.

5 Directions of Japan's research and development

While deploying IBM, HP, or other American-made servers in combination with Akamai's content network services may be one solution, there are other options Japan could consider. As mentioned in the beginning of this article, Japan is armed with sophisticated 3D graphic technologies that could lead the global IT industry and unique video content such as animations and video game software, as it faces the forthcoming full-scale broadband network age. Japan is also the world leader in the development of digital home appliances and in optical communications technology. The grid is a highly potential solution that could help Japan take advantage of these technological strengths in the information, communications, and electronics sectors in an integrated manner.

There are two major methods to create a grid computing environment. In the first method, a grid is constructed by interconnecting the company's servers with a view to balancing load. This could be implemented on different scales, ranging from a grid created on a network or a cluster formed within a data center. The other method is to build a large-scale grid embracing user-side (client-side) computing resources.

In the latter case, in particular, processors embedded in digital home appliances and the device proposed as the "home server" may comprise a grid. By linking up these appliances and devices via high-speed fiber-optic cables, in an extreme case, even a massive-scale fast grid that covers all of Japan might become a reality.

Such a concept deserves serious attention from the viewpoint of delivering content, because it suggests the possibility that Japan as a whole could function as a huge server that offers to the world its exclusive high-resolution image processing technologies, animations and game software. This would be feasible if the nation could find an appropriate solution to interconnect processors in video game systems and digital home appliances, Japan's two areas of strength, instead of U.S.-dominated PC processors, and to build high-performance server systems by exploiting its world-class optical technologies, such as semiconductor lasers, and fiber-optic networks developed through the e-Japan program.

If this becomes a reality, Japan will come to play a much more important role as the hub of the high-speed networks linking the three continents, namely, North America, Europe and Asia.

A major problem in the delivery of high-resolution video content is delays that occur in long-distance data transmissions. For example, it is difficult to ensure Quality of Service (QoS) for high-resolution motion pictures transmitted to somewhere in Southeast Asia from the U.S. via Japan, because of signal delays.

Equally distant from North America, Europe and Asia (provided that an eastbound route from Europe is established), Japan is most conveniently located to play the key role in content distribution. Japan could largely benefit in economic terms from playing such a part, because it is obvious, even without citing examples in the U.S., that information critical to business activities, as well as spillover information, converges to the hubs of information and traffic. Acting as such a hub would have a significant impact on the domestic business community not because the illegitimate collection of personal or corporate information might be possible, but because even overall statistics concerning what type of information is being sent to which region would be valuable and useful for business.

6 Research and development on constituent technologies for grid computing

The MEXT-led NAREGI project, mentioned earlier, pursues the following themes as the constituent technologies of grid computing, or high performance computing as they mention it.

(1)Research and development of grid infrastructure software

- Research and development of resource management in the grid environment
- Research and development of grid programming modules in the grid environment
- Research and development of upper layer grid software/environment and grid application development tools
- Research and development of integration and operation technology for grid software
- Research and development on the adaptation of nano-simulation software to the grid environment

(2)Development of networking technology

- Research and development of network communication infrastructures

These themes are studied at the following institutions.

Industry: Fujitsu, Hitachi, NEC, etc.
Academy: National Institute of Informatics, Institute for Molecular Science, Tokyo Institute of Technology, Osaka University, Kyushu University, etc.
Government: National Institute of Advanced Industrial Science and Technology, ITBL Project, etc.

Among them, Fujitsu, Hitachi and NEC also participate in METI's Business Grid Computing Project. The project draws a fast-paced schedule and intends to build prototypes of grid computing software by the end of fiscal 2003, followed by field testing in 2004 and commercialization in 2005.

In addition to the software technologies being developed through these projects as elements directly comprising grid computing, namely, middleware and application software technologies, there are other areas where research and development efforts should be intensified. They are device technologies and hardware systems, in which areas Japan is already particularly competitive.

To develop grid computing environments even more efficiently, optical technologies need to be advanced. This involves not only the construction of additional backbone infrastructures, such as optical routing systems, to allow for large-volume long-distance communications, but another leap in fiber-to-the-home (FTTH) solutions to initiate a move from the current 100 Mbps range to the Gbps range.

Yet another critical element of grid computing is the promotion of the use of optical wiring for the processor's internal data transfers and the computer's internal connections between processors and memory, between chips, and between boards.

The U.S. took action ahead of Japan and its Defense Advanced Research Project Agency (DARPA) announced on September 11, 2003 that it would fund $30 million over four years to support the joint research project of IBM and Agilent Technologies (a spin-off from HP, providing testing and measuring instruments and semiconductor products), which pursues "terabit per second optical interconnect technology for multiprocessing servers." DARPA says the effort is part of the High Productivity Computing Systems (HPCS) initiative, which aims to develop interconnect technology that delivers 40-Tbps performance by 2010. Such technology, if used for connections much longer than chip-to-chip or board-to-board distances or for consumer products, will contribute to improving to a large extent the performance of cluster servers and grid servers.

Japan, as the pioneer and the world leader in fiber-optic communications technology and optical device technologies such as the lasers for long-distance communications systems and the vertical-cavity surface-emitting laser (VCSEL), should undertake greater research and development efforts than the U.S. is making, in order to maintain the current dominance in these optical fields.

Other constituent technologies that need to be developed include a home information appliance network based on, like IPv6 networks, Japan's original technologies, middleware to integrate information appliances and game systems, and operating systems suitable for these terminals. In other words, the key constituent technologies of grid computing will be achieved by pioneering the development of new architectures that combine software and hardware.

7 Conclusion

The above chapters discussed the importance of distributed processing and optical technology, with an emphasis on grid computing technologies as a tool to meet the growing demand for the distribution of rich content such as high-resolution motion pictures. The most remarkable point is that these technologies could trigger a major change in the 30-year-old concepts of the Internet and the network, both of which originate in ARPANET of the U.S.

The current Internet structure is by far dominated by the U.S., including TCP/IP and other protocols (procedures), fundamental technologies, the top-level route servers that manages IP addresses and domain names, server systems that deliver data, operating systems running on terminals, and the computer as the basic hardware component.

If the network architecture moves from the traditional server-client model to the grid model of shared computing resources, however, Japan will have a chance to pave the way for next-generation networks and computers that are of unconventional designs incorporating Japan's original technologies for IPv6 and digital home appliances. This could allow Japan to build a competitive advantage with its collective strength in the content and other industries. From a technical point of view, it is still a very challenging task to collect computing resources of an indefinite number of users (client computers) to construct a grid, while ensuring delivery control. This hurdle, however, could be overcome by first resolving technical difficulties in a small-scale cluster server system and then gradually expanding the range of the target.

Such an effort would benefit Japan not only technically, but in a sense that it might help transform the business structure of Japanese companies. The electronics industry, which is, along with the automobile industry, Japan's most internationally competitive sector, is suffering a serious decline in profitability in home appliances and audio-visual equipment, mainly because of the rise of China.

Furthermore, once-hopeful Internet businesses are in most cases having difficulty making a profit, as a result of the failure to earn wide acceptance from consumers about the concept of the B2C (Business-to-Consumer) business, especially that of the model where services are offered online for a fee. Their profitability has been also hurt by excessive investments to meet the growing demand for server capacity, as mentioned earlier.

By contrast, U.S. firms, such as IBM and HP, which have strength in information distribution functions upstream in networks, are enjoying high profitability.

What these facts suggest is that while Internet businesses are essentially fee-based business, customers in the B2C sector are reluctant to accept such a business model except for e-commerce in which purchased products are physically delivered to them.

A possible action for Japan to take under the circumstances is to actively move into B2B (Business-to-Business) commerce, which exists upstream in networks and has been dominated by the U.S. By combining B2B with the C (Consumer) sector, the basic business model for consumer electronics and other traditional industries, Japan could establish what one might call B2B2C, which would be a model unlike either the traditional Japanese style or U.S. style.

Here is a possible scenario to roll out B2B2C commerce. While Japanese consumer electronics manufacturers are currently proposing home servers to households, it is usually not very easy for consumers to understand the features of the equipment and benefits of spending a considerable amount of money to purchase it. To address this problem, the industry can launch a program in which the unused power of home servers may be loaned to those who are in need, and the owners of home servers can receive compensation for the loaned computing resources in the form of electronic money. Such an incentive to consumers will accelerate the proliferation of home servers.

MEXT's NAREGI project seeks for the development of middleware to construct grids and new application software for the nanotechnology and biotechnology fields, while METI's Business Grid Project aims at the development of middleware and application programs for the B2B sector. A possible addition to them will be a project that focuses on the C sector with emphasis on content distribution.

Similarly important as such comprehensive initiatives is the research and development of, not to mention software technologies to facilitate these network revolutions, detailed constituent technologies including optical technologies (communications, optical wiring, optical interconnection and optical routing), integrated computer architectures incorporating digital home appliances, and new business models.

(Original Japanese version: published in October 2003)

2

Toward the Improvement of Quality and Reliability in Information Systems Construction
– A Study of "Business Rules" and Requirements Engineering in the Upstream Process–

TOSHIAKI KUROKAWA *(Affiliated Fellow)*

1 Introduction

Information systems assume a critical role as the basis of effective activities at various organizations and as a social infrastructure. Establishing and proliferating technologies to build safe and reliable information systems promptly and inexpensively is an indispensable element of the safe and competitive society. Information systems are serving not only as the source of industrial strength in general but also as the foundation for overall research and development capabilities.

In other words, degradation in the ability to construct information systems may cause inconveniences in civic life as well as poor international competitiveness. Japan should therefore make relentless efforts to maintain and improve its level of system construction technology.

It is widely granted that the key to improving quality and reducing cost in system construction lies in the upstream phase of system construction, or more specifically, in the concept stage in which the requirements for the system are identified. That is to incorporate a mechanism to select key functions for the system and to enhance the system's quality in the upstream process. In Japan, however, rather little emphasis seems to have been placed on efforts for such upstream activities. No "technology" took root and only few people cares for that situation in this nation.

The 2003 White Paper on Information and Communications in Japan published by the Ministry of Public Management, Home Affairs, Posts and Telecommunications indicated that Japanese organizations often failed to discuss even the fundamental questions that should be answered prior to system construction, such as what are the possible effects of constructing the information system[1]. That is to say, organizations are not fully prepared before actually starting to build an information system, with respect to which aspects to be stressed in building the system and what potential returns to be expected.

This weakness of underestimating or neglecting the upstream part of system construction can be attributed to several and complex reasons, including institutional, traditional, technological, and social ones. For example, in terms of institution, software systems are often compared with architectural structures because of their common nature of serving as a social infrastructure as a whole while being privately owned. It has been pointed out that while there are mechanisms, such as construction authorization, instituted for architectural construction to conduct reviews during the design stage, there exists no equivalent scheme in the world of information systems construction. Furthermore, unlike architectural construction, design and installation are performed by the same company in systems construction. There has been a debate about whether these problems in the systems construction arena are something traditional or social. Some people declare that Japanese tradition does not ask any detailed specification before engagement. This article addresses these issues primarily from the viewpoints of human resources development and science and technology. More specifically, it discusses the significance of the upstream process, reviews technologies available for improving quality and reliability in systems construction, and proposes methods to foster human resources who have expertise in such technologies.

2 Definition of the upstream process in the system life cycle

There is no clear, universally agreed on definition of the upstream process. In an effort to define the upstream process, this article presents the system life cycle standard, which stipulates the overall construction and operation of systems. An international standard on system life cycle processes was established in 2002 as ISO/IEC 15288:2002, based on which the Japanese Standards Association is now working on the drafting of the JIS X0170 Japanese standard. According to ISO/IEC 15288, the system life cycle from creation to termination/disposal consists of the following six stages.

(a) Concept
(b) Development
(c) Production
(d) Utilization
(e) Support
(f) Retirement

These six stages can be divided into three phases as shown in Figure 1; upstream, midstream, and downstream.

ISO/IEC 15288 further defines 11 detailed technical processes (Table 1).

As Figure 1 indicates, the concept stage aims at laying the groundwork for systems construction. During this stage, the systems environment and the stakeholders must be identified. The concept stage includes the requirements definition process in which requirements of

Figure 1:Definition and elements of the upstream process

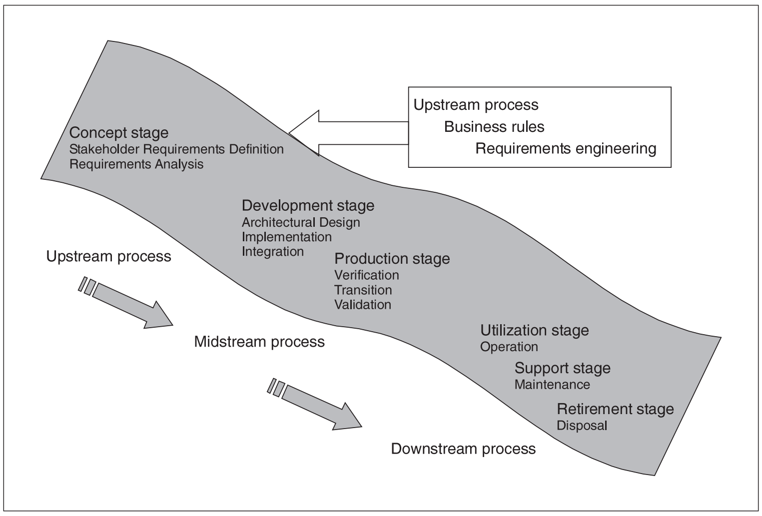


Table 1:Eleven technical processes

(a) Concept stage	(1) Stakeholder Requirements Definition process (2) Requirements Analysis process
(b) Development stage	(3) Architectural Design process (4) Implementation process (5) Integration process
(c) Production stage	(6) Verification process (7) Transition process (8) Validation process
(d) Utilization stage	(9) Operation process
(e) Support stage	(10) Maintenance process
(f) Retirement stage	(11) Disposal process

the stakeholders are elicited and defined, and the requirements analysis process in which relations/conflicts over these requirements are analyzed.

3 Problems in systems construction – The significance of the upstream process

There have been a few reports on specific problems caused by imperfections in the upstream process. A famous example among reported is a fault in the London ambulance dispatch system that occurred in October 1992 in the U.K. The project, which was ambitious for that time, intended to build a computer system, in place of traditional manual operations, that could automate emergency call taking and ambulance dispatch. In reality, however, the system failed to properly dispatch ambulances, causing chaos. The report about this case[19] shows that one of the major causes was that the system had been designed in the first place without asking or considering requests from ambulance crews who would use the terminals in the ambulances. Although the system required ambulance crews on board to report their vehicle's status and location to the dispatch center so as to be given their next destination, there had been no consideration during system development about whether the crews were capable of using such a system, an essential element of stakeholder requirements. Consequently, ambulance crews had difficulty in operating the terminals, disrupting overall ambulance dispatches.

With respect to the entire life cycle as shown in Figure 1, there is an interesting analysis[21] on how the cost to develop a system is allocated to individual processes. It shows that, in the U.S., the maintenance cost accounted for approximately 30% of the entire system development cost until the 1970s, while the figure increased to almost 80% by the 1990s.

It can be easily imagined that a tremendous amount of correction and modification work arises if a failure is found in a system after implementation, as was the case with the London ambulance dispatch system. However, one should also be aware that even an ordinary system cannot be operated properly without an enormous cost spent in the downstream process.

The fact that the downstream process cost accounts for a considerable part of the total expenses is, in general, well recognized even in the manufacturing industry. For instance, manufacturers are facing the need to incorporate recyclability into their upstream process such as design for minimizing overall cost, because now recycling after disposal has become an inevitable process for manufacturers.

The most effective approach to minimizing the maintenance cost is to make thorough efforts in the upstream process to ensure quality, in an attempt to eliminate any need for corrections in later processes. "Ensuring quality in the upstream process" is a well-know principle across industries including manufacturing. If a defect is ever discovered in the product after shipment, its financial impact can be so great that even the manufacturer's existence may be threatened.

Another fact to be noted is that the cost to maintain information systems is eventually borne by all the members of the society. Increased cost for the system is eventually passed on, for example, to bank customers in the case of a banking system in the forms of higher fees and lower interest rates.

However, little emphasis has been placed on the upstream process, which is also known as the "concept stage" in system life cycle processes, because it has been believed to be a preliminary step to the development stage in the midstream process and, therefore, reduced to be a mere process of collecting and organizing information before moving up to the development stage. Regrettably enough, there are still some cases where a system developed through considerable effort turns out to be unusable just because of the negligence of the upstream process.

A factor behind such poor practices is that only few organizations in Japan, whether a business enterprise or a national or local government office, have documentations that explicitly describe, in a format unified across the organization, individual job procedures and liaison with associated internal sections. This is a great disadvantage in systems construction, because such prerequisites are not readily available to initiating the identification of the people concerned and the collection and analysis of their requirements.

Some system developers skip the upstream process, despite their understanding of its necessity, based on the fear that the additional workload required for completing such documentation cannot be justified or can be too time consuming,. In addition, because of the lack of the formal documentation, system developers continue to receive additional modification requests from customers or users even after the specifications have been defined; a convincing reason for system developers to feel that any effort in the upstream process would be in vain.

One thing that makes the upstream process issue more complex is that failure to meet the prerequisite, such as the inexistence of formalized documentation of operations, does not always bring problems in the system. In fact, there are some successful examples of system development in which the explicit upstream operations were avoided by letting the staff who would use the system participate in construction of the system. This approach has proven effective, in particular, in the development of systems for manufacturers' production sites, a sector in which Japan boasts competitive strength. From another point of view, however, you can say these organizations did not have to conduct additional work particularly intended for the upstream process, because the equivalent operations are continually performed on a daily basis.

The thorough implementation of upstream activities is indispensable for improving the quality in system construction while minimizing the overall cost, including maintenance, even though whether the upstream activities may be started anew or not is a decision depending on the situation.

4 Technical elements of the upstream process

The upstream process should involve the establishment of "business rules" that, as described below, encompass the entire business operations in addition to the stakeholder requirements definition process and the requirements analysis process as technical processes,. Without business rules, requirements submitted by diverse stakeholders from different perspectives cannot be aligned consistently and will thus become dispersed.

The requirements definition and requirements analysis processes fall into the technological field known as requirements engineering. The significance of requirements engineering came to be acknowledged worldwide in the 1980s, as described later in details. Behind this is the perception that no matter how much productivity and quality are improved in the design and production, system developers eventually fail to satisfy user needs as long as an error or poor quality is inherited from the requirements processing. To make matters worse, developers are recently expected to assume that requirements are subject to change not only in the development and production stages but even in the utilization stage, thereby continuously facing the need to monitor and modify requirements as well as to verify the system against the ever-changing requirements. Requirements engineering provides techniques to process such "requirements" in almost all processes across the system life cycle.

In the 1990s, it became clear that collecting the existing user requirements alone was insufficient in building a completely new type of system or integrating existing systems into a new system. Also recognized was that, when constructing a large-scale system by combining multiple sub-systems developed in parallel, overall system efficiency could not be achieved if attention was paid only to individual sub-systems.

To cope with these issues, new initiatives have been launched with the view of defining "business rules" with which the structure of the system's operating environment is identified and the organization's policy and procedures to conduct operations are specified. These "business rules" are unlike protocols defined in schemes such as EDI for business-to-business commerce. Instead, they describe procedures through which individual jobs are conducted within the framework of a company or a group of companies.

5 Requirements engineering

Requirements engineering, as mentioned before, deals with technologies used for processing "requirements" for a system across almost all processes of the system life cycle. These technologies are intended for requirements acquisition, requirements analysis, requirements evolution, requirements management and so forth, as part of system/software engineering, an academic discipline that aims to increase productivity in the overall system.

The IEEE has been holding an international conference[9] and a symposium[10] regarding requirements engineering annually since 1993. In Europe, the REFSQ (International Workshop on Requirements Engineering Foundation for Software Quality) conference has been held annually in connection with the CAiSE conference on system engineering, while Australia has been hosting workshops and symposia since 1993 in this field. In addition, Europe has launched projects on requirements engineering through its schemes, such as with IST and ESPRIT, and the International Federation for Information Processing (IFIP) has established Working Group 2.9, which is dedicated to software requirements engineering. The significance of requirements engineering as a field of engineering is fully recognized, although requirements engineering has not become a term that is used as commonly as software engineering and system engineering and has yet to be unquestionably established as an academic discipline.

Professor Motoshi Saeki of the Tokyo Institute of Technology claims that today's international conferences on requirements engineering have their origins in Japan. When Japan hosted the International Conference on Software Engineering for the first time in 1982, Yutaka Ohno, then the professor of Kyoto University, organized an off-the-record workshop in Kyoto, an attempt that inspired participants to hold regular international conferences on requirements engineering.

This occurred at a time when there was an growing expectation for potential effectiveness of logical specification methods in software development, while Japan was undertaking research into logical methods through its Fifth Generation Computer Systems project and other initiatives. The formal specification methods at the time were applicable only to a limited range of problems, and could not provide effective solutions to practical problems.

Some universities in the U.S., Europe and Australia offer courses dedicated to requirements engineering. In Europe, research and development projects in the area of requirements engineering are ongoing as part of industry-academia collaborative programs such as with ESPRIT and IST. Recognizing the essential role of requirements engineering in national projects, particularly in areas such as space development and military and defense, both the U.S. and Europe are now even conducting field tests for requirements engineering techniques. Requirements engineering is also studied as part of software engineering and system engineering.

The following sub-sections describe findings of an analysis of presentations at IEEE international conferences and symposia since 1993, as well as the current status of requirements engineering including available tools.

5.1 IEEE conference presentations and presenters

The total number of presentations at IEEE conferences between 1993 and 2002 was counted and broken down by presenter types; namely, universities, national research institutes, and private companies and consultants. The total number for these 10 years counted 376, which consisted of 220 universities, 41 national research institutes, and 94 companies and consultants (figures broken down do not include presenters whose affiliation was unknown). Recently, there has been an increase in the number of presentations from companies, indicating a trend that businesses as well as national research institutes are more actively embarking on development and field trials.

On the whole, nearly two-thirds of the total presentations were derived from universities, underscoring the academic sector's dominant presence as the research body.

Only nine presentations were delivered by Japanese organizations in the 10 years. The presenters were the Tokyo Institute of Technology, Osaka University, Kyoto University, Hiroshima City University, and Ritsumeikan University from academia, and NTT, NEC, and Anritsu (note that NEC and Anritsu presentations were delivered by their U.S. subsidiaries) from industry.

5.2 Subjects of IEEE conference presentations

To identify trends in presentation contents, presentations were divided into 10 fields: models, specification methods, requirements acquisition/definition, requirements evaluation, requirements verification, requirements evolution (change), requirements reuse, engineers, techniques and tools, and others.

The mainstream presentation themes remained consistent: requirements acquisition and requirements definition. In other words, since 10 years ago the requirements engineering community has been tackling the same problem of how to elicit, compile, and define requirements, and no one has arrived at a satisfactory solution. This is an issue that is also associated with requirements evolution (change), the eternal challenge in systems construction.

Subjects that were addressed in parallel with requirements acquisition and definition were requirements evaluation and verification. Issues with them included system security analysis, risk prediction, and risk assessment. Some presentations addressed the question of what are the system requirements that are tolerant to human errors.

With respect to requirements acquisition, sociological techniques have been attracting attention since the early days and have been actually tested. Recently, requirements acquisition has become related to business administration issues such as knowledge management and knowledge sharing.

In requirements specification, models serve as tools as well as techniques. A variety of notation and logic schemes are used for specification. How to derive formal specifications from informal, natural language-based expressions is also discussed, which is a longtime issue in this area.

One of the major issues in software engineering is reuse. There has been progress in code reuse as well as in design reuse. Recognizing the persistent argument that reuse is most effective in requirements in the upstream process, reuse from this perspective recently became a topic discussed in these conferences on requirements engineering.

Some presentations focused on the issues of human resources development for requirements engineering and of the fundamental principles for requirements engineers.

Other noteworthy themes that were not selected for the above categorization include traceability, cost analysis, technology transfer, international/industrial standardization for requirements engineering, and requirements evaluation for commercial software. In particular, the traceability issue regarding how the requirements are reflected into design and incorporated into the system is likely to become an important factor, especially in relation to the future environments for systems development. One presentation on traceability proposed that even concerned parties be traced from the viewpoint of sociological organizational theory.

A total of nine presentations were delivered by Japanese organizations, of which two were on models, two on requirements acquisition, one on requirements analysis, one on requirements evolution, one on reuse, and two on techniques and tools. Of them, however, two presentations were based on joint research between U.S. subsidiaries of Japanese firms and universities in the U.S. and Europe.

5.3 Evaluation of the current status of requirements engineering

Requirements engineering is an academic discipline that has developed as a part of system engineering or software engineering. Some people still question, however, how much requirements engineering is matured as an establishedacademic discipline. And some argue how effective it has become in practical environments of the systems or software industry.

It is not an easy task in requirements engineering to yield results with good numbers. Since requirements engineering, among other fields in system or software engineering, is an exploratory and empirical field and where the human factors have so much significance. An honest evaluation from an external point of view would be that requirements engineering, aside from its principles, has yet to provide any techniques or tools that can instantly benefit field engineers.

The good news for the requirements engineering community is that background material for requirements acquisition is becoming machine processable because businesses and government organizations have deployed computer systems to process and accumulate their administrative data. In some cases, even corporate management policies and goals are presented in a machine processable way, as seen in the efforts toward "business rules" discussed in the next section.

Under technological circumstances where mechanization has become possible for the processes from modeling and design to implementation of a system, the next challenge for requirements engineering would be to allow machine-based management of requirements changes and provide traceability for a failure to be trace back to the requirements concerned.

Examples of requirements engineering tools are shown in Table 2.

6 "Business rules"

6.1 Background and brief history

From the viewpoint of system development engineers, the historical development of "business rules" can be outlined as follows (Table 3).

The concept of business rules was first introduced through a report titled "Defining Business Rules[20]," which was published in 1995 by the GUIDE Business Rules Project, an initiative that was organized in 1993 by GUIDE International Corporation, a U.S. association of IBM mainframe users founded in 1955 (an update to the report, containing models in Unified Modeling Language (UML) notation, was issued in July 2000). In 1997, the Business Rules Group[3] was formed and they introduced the Business Rule Motivation Model, which is described in 6-4.

The Object Management Group (OMG)[18], an international industry consortium that focuses on the standardization of object-oriented

Table 2:Examples of requirements engineering tools

Tool	Developer/Vendor	Brief description
REVEAL	Praxis Critical Systems[11]	A requirements engineering methodology. Enables the verification of requirements traceability in low-level systems by focusing on system integration and using Jackson's "World and the Machine" model. Uses Telelogic's DOORS as a tool.
Ask Pete Support Web[12]	NASA Glenn Research Center	A free tool for cost prediction and project planning. Can work with ARRT, listed below.
DDP/ARRT (Defect Detection Prevention[13] /Advanced Risk Reduction Tool[14])	JPL	DDP is a tool for risk prediction and prevention. It is available in the forms of RBP (Risk Balance Profile), a simplified version, and ARRT, a software-specific version of DDP. Available for free. The Java version is under development.
ISAT: Interactive Specification Acquisition Tools Project[15]	AT&T Lab. Research	A research project aiming at automated specification and validation, centering on reactive systems such as communications systems. Performances on several prototypes have been reported. The basic model is the state machine.
SCR (Software Cost Reduction) method[16]	U.S. Naval Research Laboratory	A method created by integrating principles and tools that have been developed since the 1970s at the Naval Research Laboratory to practice software engineering. The core is the Rational Design Process for software. It also uses techniques such as David Parnas's Four Variable Model (monitored, controlled, input, and output variables; NAT (assumption), REQ, IN, and OUT relations), the SCR requirements model (defining the system state), and the SCR table.
i-COST method[17]	Equity Research (Japan)	A method for cost evaluation and quotation for software systems. It can analyze operational cost, in addition to initial cost. For initial cost analysis, it uses the function point method for quantitative evaluation of system functions, and the COCOMO method, that is used in the U.S. and Europe.

technologies, embarked on a campaign in 2000 to promote the Model Driven Architecture (MDA) under the leadership of Chairman R. Soley. This is an approach that intends to automatically generate programs from formal models written mainly in UML, OMG's standard object-oriented modeling language. In the natural course of development, a debate took place over how to ensure the correctness of the initial system model, resulting in the formation of the Business Rules Working Group within the framework of OMG in 2002.

6.2 Definition and objectives of business rules

"Business rules" are intended to describe the business structure pertaining to the system to be constructed and to identify the expected functions of the system within the structure. The Business Rules Group[3], the Business Rules Community[2], and the OMG Business Rules Working Group are the leaders in this domain. The definition and objectives of business rules slightly vary from group to group. The variation probably reflects either chronological development in the form of business rules or subtle differences in interpretation on different occasions. The definitions are shown in Table 4.

These three definitions share the same basic concept of describing the business structure and consequently identifying the functions of the system within that structure, while slightly deferring in the focus of attention, depending on the assumed entity, objective, and situation.

6.3 Ongoing efforts into business rules

In the U.S. and Europe, a range of entities including universities, leading companies, venture businesses, and consultants are involved

Table 3:Historical development of "business rules"

1960s	Programming is everything	Before engineering
1970s	Structured programming, structured design, structured analysis	Testing became possible
1980s	Information engineering and object orientation	Rediscovery of data
1990s	Business rules	How should a system work?

Source:David C. Hay, "Managing Business by the Rules," 1999; Table compiled by the author.

in research and development on business rules, and even human resources development services are available in this field.

In general, a typical organization is said to contain a few tens of thousands to a few million business rules (an argument in the Business Rules Group). Japan lags behind Western countries in the business rules arena. The country has made little effort to launch such R&D schemes that involve researchers in human sociology, whose contributions are important in studies of business rules as the basis for systematizing business procedures. In addition, while the viewpoint of system users is more critical than that of system developers in addressing business rules, there have been few approaches taken from the system users' perspective in Japan.

6.4 Examples of tools and methodologies for "business rules"

One major example is the Business Rule Motivation Model[4]. This aims to identify the business through the model described below. The OMG Business Rules Working Group basically adopts the same model.

In the Business Rule Motivation Model, the functions of an Organization Unit are roughly

Table 4:Activities in groups on business rules

Group & year	Definition of a "business rule"	Explanation
Business Rules Group (1995)	A statement that defines or constrains some aspect of the business	Also intended for reverse engineering from existing systems.
Business Rules Group (1997)	To identify overall business activities through ends and means	Assumes that business rules aim to allow people in the business to describe, analyze, and explain to system engineers their business procedures in their own language (instead of IT language).
OMG (2003)	A directive intended to influence or guide business behavior, in support of business policy that has been formulated through analysis of strengths, weaknesses, opportunities, and threats (SWOT analysis)	OMG is working toward the establishment of a standard on these business rules and business models.

Table 5:Available tools and methodologies

Tool	Developer/Vendor	Brief description
MooD2003 Web Publisher[5]	The Morphix Company (U.K.)	Provides the Business Object Repository and uses the Business Context Models. Defines scenarios, processes, the process hierarchy, the process index, the object index, users, etc., and provides zoom-in capability to review, modify, or add elements to a greater detail in each model.
DEMO - Demo Engineering Methodology for Organizations[6]	Delft University of Technology (Netherlands)	Advocates organizational engineering (OE), as opposed to traditional organizational science (OS), which emphasizes teleonomic definitions on system functionality and behavior. Uses the communicative act, a model in cognitive science, as the fundamental theory.
MEGA Suite 6.0[7]	MEGA International Inc. (France)	Consists of MEGA Process, MEGA Architecture, MEGA Integration, MEGA Development, MEGA Database, and MEGA Repository. Enables cost prediction and risk management for processes. Also provides workflow functions through MEGA Integration, which involves EAI (Enterprise Application Integration).
Proteus, Rule Track[8]	Business Rule Solutions (U.S.)	Provides Proteus, a business rules development methodology, and Rule Track, a development tool.

identified in the framework of Means-Ends analysis. In addition to Means and Ends, which are internal elements of the Organization Unit, Influences and Assessments (SWOT assessment) are used to evaluate the environment. The evaluation results are measured in terms of Risk and Potential Reward.

In this model, the Vision, a statement about the Organization Unit's aspiration, is correlated with the Mission, which works as the Means. In a similar manner, the Strategy is defined for the Goal, which gives a concrete form to the Vision, and so are Tactics for the Objective, which quantifies the Goal.

Business rules act as Elements of Guidance in implementing the defined Strategies and Tactics (a Course of Action). A Business Rule forms a counterpart to a Business Policy. Business Policies are formulated in compliance with external Regulations, on the basis of an analysis of the Organization Unit's strengths, weaknesses, opportunities, and threats (SWOT analysis).

This is how business rules allow people in the business to describe, analyze, and explain to system engineers their business procedures in their own language (instead of IT language). As a result, system engineers are enabled to define the role of the system pursuant to the given business rules.

Other tools and methodologies currently available are listed in Table 5.

7 Conclusion

Japan, including its universities, national research institutes, and industries, lags behind in research and development on the upstream process. This can partly be attributed to poor awareness of the upstream process among the purchasers of systems, such as companies and government organizations.

In other words, Japanese customer organizations, as shown in the White Paper on Information and Communications in Japan, tend to neglect efforts to establish their "business rules" and define their requirements, which are the processes that should be completed before they contract out the development of any system. In an extreme case, an organization would oblige the potential contractor to prepare a quote free of charge. Worse yet, there exist a considerable number of organizations that embark on system construction projects with no attention paid to the upstream process and let the resulting systems grind to a halt before finally starting to discuss who is responsible.

Here are some proposals to solve these problems:

(1) Create environments that make "business rules" and requirements definitions to be identified during system development

More specifically, this refers to considering the enactment of legislation that enforces a process equivalent to construction authorization in housing construction, or making the third-party auditing of the customer's purchase specification mandatory at least for projects concerning public systems.

(2) Foster human resources who can develop "business rules" and requirements definitions

It is essential to foster human resources who can help the purchaser, or the user of the system, formulate correct requirements specifications. A possible solution is to make courses on "business rules" and requirements definition for information systems requisite for students who pursue a master's degree in business administration (MBA). Another important approach is that companies and government organizations provide education on business rules and requirements engineering for personnel not only in their systems departments but also in the departments that will purchase and use the systems.

A serious problem to Japan, when it comes to comparison with the U.S. and Europe, is its particular weakness in the area of university research and education. One of the reasons for this is Japanese universities' slow moves into the fields such as requirements engineering that require knowledge on both science and humanity.

(3) Encourage research and development in the upstream process

Major elements of research and development are listed below.

(a) Formal methods and mechanical verification

Given the advance in automation in the midstream process, important elements in the upstream process are technological development in the area of formal methods that use mathematical specifications and mechanical verification based on these methods. For example, efforts in this direction will allow system engineers to automatically detect contradictions between "business rules" and conflicts between requirements, thereby contributing to integrity checking or comparisons of requirements with the functions provided by commercially available packages. In addition, they will further facilitate the automation of the processes from design to coding, which follow requirements definition.

(b) Technologies for requirements acquisition from stakeholders

To achieve such technologies, not only superficial communication techniques but also techniques to understand what is not said are required. The key to this is the fusion of knowledge and technology between the science and non-science fields, that is to say, the cultural aspect, including humans, and the administrative aspect, as well as the scientific aspect, need to be taken into consideration in an integrated manner. This indeed requires not only systems and software, but also expertise in the concerned field and common sense.

(c) Quantitative evaluation

Because of insufficient quantitative evaluations conducted on technologies and methods for the upstream process, the benefits of upstream activities are underestimated. A possible first step in response to this is to collect data on system construction so that, for example, in the case of a public system, they can be offered for public use. If persistent efforts are made to perform quantitative evaluations using such a database, with a view to extensively analyzing correlations between upstream activities and downstream quality, cost and so forth, effective outcomes will result.

Acknowledgements

The author would like to express sincere thanks to Professor Kokichi Futatsugi of Japan Advanced Institute of Science and Technology, and Professor Motoshi Saeki of the Tokyo Institute of Technology, both of whom provided invaluable advice since the draft stage. The author also deeply appreciates the precious opinions from Visiting Researcher, Masao Watari and Senior Research Fellow, Kumi Okuwada, and other researchers of the Science and Technology Foresight Center.

References

[1] 2003 WHITE PAPER Information and Communications in Japan, in Chapter 1, Figure 2 "Essential elements for optimizing the effectiveness of IT investment" (extracted from successful U.S. and Japanese companies) of Section 2 "Strengthening Competitiveness of Companies and Developing Industry" (in Japanese). The following seven elements are listed as the areas where Japanese companies' results were lower than those of U.S. counterparts by more than 10%.

- "Selection of Core Competence" of business/operations (Identification of core operations, etc.).
- "Verification of cost-effectiveness" before systems construction.
- Reengineering of operations, organization, and systems to comply with IT system operations.
- "Selection and concentration" of investments in information systems.
- "Verification of cost-effectiveness" after the introduction of systems.
- Reutilization of business effects (e.g., Reallocation of reduced cost to new information systems).
- Review of investments in information systems and reinvestment.

[2] Business Rules Community: http://www.brcommunity.com

[3] Business Rules Group: http://www.BusinessRulesGroup.org

[4] "Organizing Business Plans - The Standard Model for Business Rule Motivation," The Business Rules Group, Published November 15, 2000 Rev. 1.0: http://www.businessrulesgroup.org/second_paper/BRG-BRMM.pdf

[5] The Morphix Company: http://www.morphix.com/

[6] Demo Engineering Methodology for Organizations: http://www.demo.nl/start.php

[7] MEGA International Inc.: http://www.mega.com/us/home/index.asp

[8] Business Rule Solutions LLC.: http://www.brsolutions.com/

[9] IEEE International Conference on Requirements Engineering

[10] IEEE International Symposium on Requirements Engineering

[11] Praxis Critical Systems: http://www.praxis-cs.co.uk/

[12] Ask Pete Support Web: http://osat-ext.grc.nasa.gov/rmo/pete/

[13] Defect Detection and Prevention (DDP): http://ddptool.jpl.nasa.gov/

[14] Advanced Risk Reduction Tool (ARRT): http://eis.jpl.nasa.gov/%7Emfeather/Requirements-etc.html

[15] ISAT: Interactive Specification Acquisition Tools Project: http://www.research.att.com/~hall/isat-project.html

[16] Constance Heitmeyer, "Software Cost Reduction," Encyclopedia of Software Engineering, Two Volumes, John J. Marciniak, editor, January 2002.

[17] Nikkei Computer, Aug. 12, 2002 issue, pp. 138-146: http://www.atmarkit.co.jp/fbiz/feature/0305itroi/01/01.html

[18] Object Management Group website: www.omg.org

[19] Finkelstein, A. & Dowell, J. "A Comedy of Errors: the London Ambulance Service case study" in Proc. 8th International Workshop on Software Specification & Design IWSSD-8, (IEEE CS Press), 1996, pp. 2-4. also from: http://www.cs.ucl.ac.uk/staff/A.Finkelstein/las.html

[20] "Defining Business Rules ~ What Are They Really?," Business Rules Project, GUIDE, 1995.

[21] Carma McClure, Japanese translation of "The Three R's of Software Automation: Re-engineering, Repository, Reusability," translated by Best CASE Research Group, Kyoritsu Shuppan, 1993.

(Original Japanese version: published in November 2003)

3

Technological Trends in Internet Routers
–Toward Construction of Next-Generation Communications Infrastructures–

AKIHIRO FUJII
Information and Communications Research Unit

1 Introduction
–A turning point in every ten years–

Trends in network technology are about to see the next turning point, which emerges about every 10 years. The mid-1980s was the time when computer networks were introduced to general society, and universities and enterprises began implementing local area networks (LANs). This brought a drastic change in telephone-based information communications and the ways of office document management. By the mid-1990s, optical fibers became a common type of transmission line, ushering in the advent of technologies such as asynchronous transfer mode (ATM) communications and gigabit Ethernet. These technological advances resulted in a significant reduction in communication cost per bit. It was also the time when personal computers came into widespread use, and Internet browsers running on them entirely changed how information was processed[1].

Now, in the 21st century, some argue that the technologies that constitute the Internet infrastructure have entered a period of next transition. Such an argument is convincing, with the following factors.

(1) An increase in user traffic

There has been a considerable increase in demand for data communications traffic because of the widespread use of ADSLs (Asymmetric Digital Subscriber Lines) and mobile phones. In the near future, multimedia or other applications that require heavy traffic are expected to emerge. Assuming that the rise in demand for data traffic continues at the current pace, existing infrastructures will be subject to drastic structural changes in a few years.

(2) A need for sophisticated and diverse network management capabilities

There is a growing need for sophisticated network services such as QoS (Quality of Service), which ensure communications performance in accordance with the mode of service, and network security protection. While the existing Internet has been designed on the basis of the “best-effort” concept, next-generation infrastructure designs will have to embrace a different point of view.

(3) New research and development trends in network communications equipment

A new breakthrough, such as the commercialization of optical switching, the development of a networsk processor, and the invention of a chip that enables sophisticated controls, is demanded from the perspective of enhancing hardware capability.

This article examines these aspects, while explaining technological trends in routers, a device that supports the communications infrastructure for data communications, followed by a discussion on challenges on technological policies that should be addressed during such a transitional period.

2 An overview of the Internet communications infrastructure

Before describing technological trends in communications infrastructures, represented by Internet routers, the author will sort out network technologies containing a variety of constituent technologies. The results will be used for discussing past efforts toward technological accumulation and future challenges in the communications infrastructure sector.

2.1 Classification of network technologies

Table 1 lists current hot issues in the network research community, based on the lecture material by Professor Maurizio Decina, Politecnico di Milano. The focus of attention is on the fields in which commercialization or proliferation of relevant technologies is intended in the next few years[7].

For the purpose of explanation, relations between these constituent technologies are shown in Figure 1 through categorization using two axes. The vertical axis corresponds to network communications protocol layers. The upper part represents technologies related to applications that utilize networks, while the lower part indicates technologies associated with facilities such as switching equipment. The horizontal axis represents whether the displayed field is pertinent to the communications service provider or the service recipient. Service provider refers to those who are usually known as ISPs (Internet Service Providers), offering infrastructures such as wide area networks that serve as the backbone, and network management capabilities. Service recipient consists of companies and households who use connectivity services. The infrastructure for them includes equipment that is used to consolidate locally distributed small-scale networks.

Constituent technologies positioned closest to the user side are those related to so-called "ubiquitous communication," which usually refers to the development of new applications that exploit home information appliances, mobile phones, and so forth. These are technological fields where significant growth is forecasted and where technologies of Japan are expected to develop in years to come. These fields are shown in the right half of the chart.

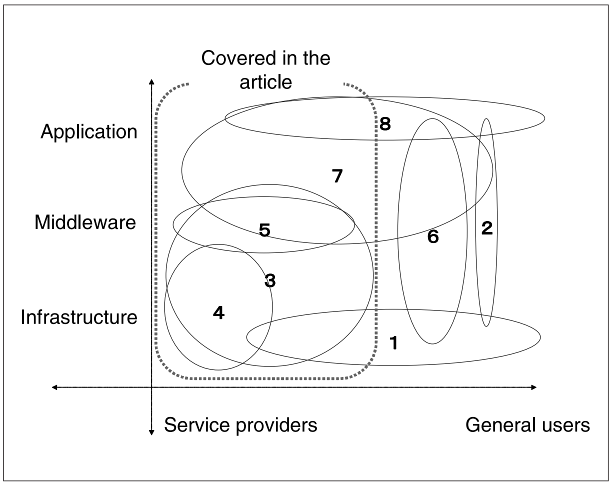
The discussions in this article are presented from the perspective that communications infrastructure technologies, in particular, contained in the left half of the chart is now in a period of technological transition. The following sections provide a description of "routers," a key element to the construction of infrastructures, by dividing them into two types: "core routers," which are indispensable for building network backbones; and "edge routers," which exist closer to the user end.

Table 1:Important R&D fields in the future

1. Broadband access	• Cable • Wireless
2. Home/personal networks	• Wireless • Wearable information devices
3. Switching/routing	• Soft switches • Qos, MPLS, DS • IPv6 • Activity network • Peer-to-peer networks
4. Backbone networks	• IP/ATM/SDH/WDM, GMPLS
5. Service platforms	• Open service architecture • Messaging, Positioning
6. Mobile communications	• Third-generation IP cellular phone • Ad-hoc networks • Sensor networks
7. Content distribution	• Storage networks
8. Security	• Network security • User security

Source: Author's compilation based on the lecture material by Professor Maurizio Decina of Politecnico di Milano

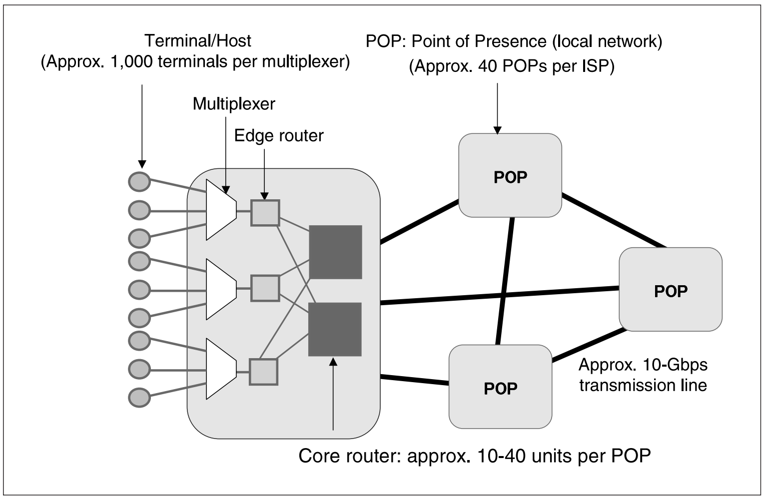
Figure 1:Classification of important technological R&D fields



2.2 Edge routers and core routers

This section provides an overview of the Internet infrastructure and one of its components, the router. There are two types of routers: "edge routers," which handle complex processing such as routing and traffic control as described below, and "core routers," which

Figure 2:Edge routers and core routers



Source: Author's compilation based on the lecture materialby Professor Nick McKeown of Stanford University

perform high-speed processing of large volumes of traffic flowing into the trunk network, using relatively simple methods. The distinction between the two is not definite, because router functions vary depending on the network scale, traffic type, the size of capital investment, and so forth.

The original design concept of the Internet was to interconnect networks that had been constructed by different organizations for their own use. Communications infrastructures evolved in line with this concept, and thus Internet connectivity in the 1980s and earlier was based on a simple architecture. However, as networks expanded in scale, its systems became hierarchical. In today's hierarchical systems, where each layer requires constituent technologies covering a broader scope, greater emphasis is placed on techniques to manage such technologies in an integrated manner.

Figure 2 shows a block diagram of network communications devices that support current communications infrastructures. General connectivity to the Internet is provided through these devices operated by service providers[8].

A core router assumes a role of collecting traffic flows in the backbone networks. Incorporating 16 LSI boards, each providing 10-Gbps-per-port switching capacity (one port accommodates a pair of physical communications lines), a core router delivers an aggregate switching capacity of approximately 160 Gbps. A core router costs about ¥100 to 200 million. An edge router, located in a network layer lower than core routers, is responsible for processing traffic flows in a smaller range. With 16 2.5-Gbps-level integrated boards, an edge router's switching capacity ranges from 20 to 30 Gbps. An edge router is priced at about several tens of million yen.

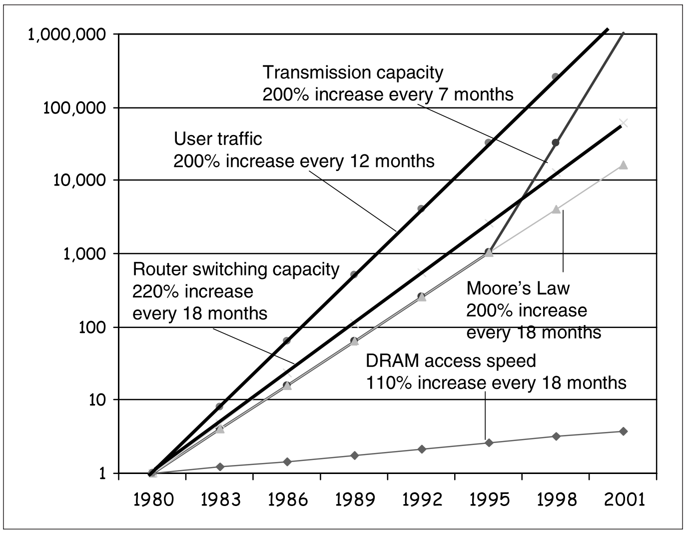
2.3 Router market size and its future growth

Let us now look at the scale of the communications infrastructure equipment industries. Global Information, Inc. (GII), a U.S. survey company, reported that the 2002 worldwide sales of all network devices, including routers and end-user network equipment for small networks, reached approximately ¥2,770 billion. GII forecasts that the figure will continue to grow hitting ¥3,300 billion by 2004, ¥4,910 billion by 2006, and ¥7,470 billion by 2008[6].

Routers account for over 50% of the entire communications infrastructure equipment market, forming an industrial sector whose sales reached well beyond ¥1 trillion in 2002. The ratio is expected to remain almost flat for years to come, indicating that the market size of the router as a basic element of communications infrastructures will increase to the ¥4 trillion level worldwide in three to four years.

Cisco Systems claims the overwhelming share in the router market. Cisco held the lion's share of 69% in terms of sales of overall network equipment for 2001, followed by 3Com Corporation in second place (7%) and Nortel

Figure 3:Traffic growth and change in related technologies



Source: Author's compilation based on the lecture material by Professor Nick McKeown of Stanford University

Networks in third place (3%). Among Japanese companies, none has a market share greater than 1%.

2.4 Network traffic on the rise

Then, how challenging are the requirements for R&D on these router products as an indispensable component of communications infrastructures? As widely known, the integrity and the computing power of a semiconductor chip have been increasing exponentially to maintain the Moore's Law trend. Meanwhile, the volume of traffic flowing into networks swelled to the point where access line speeds exceed a few Mbps, driven primarily by ADSL connections, which have recently become widely available to ordinary households in Japan. In addition, the user population of mobile phones and the demand for data traffic between mobile phones are on a sharp rise.

Figure 3 compares past growth rates in different sectors, including the processing speed of electronic devices, demand for traffic, and router switching capacity, based on observed trends. Provided that traffic maintains its upward trend and that routers' traffic processing capacity rises at the current pace, in a few years processing capacity will need to expand to a few times the size of what is demanded. Although this is nothing but a prediction, if the demand for communications applications remains brisk into the future and user traffic continues to grow at the same rate, new innovations will be needed in the arena of developing communications infrastructure equipment[2].

Future growth in traffic will widely vary in terms of volume and quality, depending on the content of communications applications that will be introduced. One likely scenario is that so-called multimedia traffic will increase, resulting in higher demand for realtime transmission of digital video data. Potential progress in use of home information appliances is also expected to generate frequent flows of small amounts of data, thereby increasing the overall traffic.

3 Technological trends

The foundation of current routing devices is a technology known as "IP switching." At the boundaries between individual networks constituting the Internet, "IP packets," which act as the containers of information to be delivered, are given forwarding information. Unlike telephone line switching, the forwarding process in IP switching is required on a packet-by-packet basis and, therefore, takes time. An IP switching technology that appeared in the 1990s presented a solution to this problem by adopting an approach called "cut-through routing." In cut-through routing, packets that are recognized to belong to the same logical connection and be addressed to the same destination are labeled as a single stream at a communication level near the hardware, in order to bypass the routing process and reduce the time to forward. The method has improved switching capacity.

Nevertheless, switching capacity remains a bottleneck in communications capabilities, which can be divided into transmission capacity and switching capacity, with the former surpassing the latter. This is attributed to that while optical communications technology has been implemented for the transmission path, the mainstream technology for switching is still electronics.

Next-generation routers are required to provide sophisticated routing ability in terms of both volume and quality. This means that at the core of the communications infrastructure, even higher transmission and switching capacities will be demanded, while at the edge, complex functions will need to be performed at high speed. In response to these requirements, there has been progress in functional differentiation between the two categories as well as advancements in each side. Technological challenges in both core and edge arenas are described below.

3.1 Increasing core router speeds

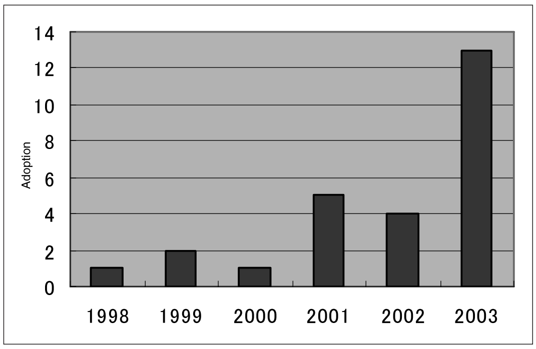
At a time when optical switching technology is moving toward commercialization, the development of next-generation network devices is also in progress in the area of core router technology. The transmission path that is principally fiber-optic allows for Tbps-class transmissions, whereas the switching process for forwarding still consists of electronic technologies. However, it is expected that recent achievements in R&D on photoelectronics will contribute to the implementation of optical switching technology into routing devices.

3.2 Enhancing edge router functionality

Under the circumstances discussed above, functional requirements for edge routers will most likely increase further toward the future. And it is no doubt that technologies to be accumulated in this area will form the core to construct the next-generation Internet.

Figure 4 shows the recent trend in the number of technical specifications, called "Requests for

Figure 4:Growth in MPLS technologies



Source: Author's compilation based on Reference[5]

Comments" (RFCs), adopted by the Internet Engineering Task Force (IETF), a standardization organization on Internet protocols. MPLS (Multi-protocol Label Switch), a technology to process a variety of packets at high speed by using the above-mentioned cut-through routing, is a basic architecture that shapes the current routers. The chart indicates that proposals related to MPLS technology have been increasing in recent years[4, 5].

The proliferation of technical proposals on MPLS suggests active innovations, especially those concerning edge routers, have been under way. A factor behind this is a need for edge routers that provide more powerful network management capabilities, as discussed in the next section.

3.3 R&D challenges

The Internet has been designed as a "best-effort" system. The concept originated in the 1960s to the early 1970s, a time when the computer network was in its infancy. In those days, individual organizations built their own networks, and these networks were interconnected to create an "inter-" "net (work)" or what is now known as the Internet. The routers, the key element of the Internet infrastructure, have been developed as a means to embody best-effort technologies. A concept opposed to this has been adopted whenever the nation provides public infrastructures such as telephone switching networks, electricity and water-all users equally receive uniform quality of service.

Described below are areas where R&D is moving into a new phase. In other words, they are the areas in which new ideas beyond the traditional architectural concept of the Internet are needed for augmenting network management capability.

(1) Traffic quality control

A key issue in R&D on best-effort networks is the difficulty of guaranteeing the communications bandwidth in accordance with the type of communications service. There has been extensive debate over the importance of bandwidth guarantee as a technological challenge since the 1990s. The lack of bandwidth guarantee did not cause a serious problem in the past, because multimedia applications that accompanied broadband digital video transmissions failed to come into widespread use. However, now that an increased number of ordinary households are given access to circuit speeds of about 100 Mbps, it is necessary, in order to allow communications applications to take advantage of such high-speed circuits, that technology for bandwidth guarantee be embodied as a major factor that determines the direction of the technological change. This technology should be able to guarantee QoS in communications between individual connections, a requirement that could be satisfied by managing and controlling traffic volume across all network devices. Such a project, hardly feasible if conducted by a limited number of communications carriers, needs to involve multiple organizations that operate communications infrastructures, with the view of implementing sophisticated information switching and their control.

(2) Network management and control

The best-effort concepts naturally lead in the direction of "distributed" network management and control. Such architectural concepts contributed to the quick development and expansion of the Internet as a communications infrastructure. Distributed monitoring and control, however, are vulnerable from a security point of view, an aspect that is particularly emphasized these days.

For example, when illegitimate traffic is generated by a virus or the like to conduct a denial-of-service (DoS) attack, the origin of the attack needs to be tracked down across the boundary of an "area," which is a distributed element of networks. Capabilities like this are recognized as essential to next-generation edge routers, which should be able to provide controls that can affect multiple network operators, at any security protection stage ranging from attack prevention to attack response to subsequent tracking.

As this example indicates, applying only the "best-effort" concept, which has been the basis of the Internet's development, is insufficient to facilitate the future evolution of communications infrastructures. From a different perspective, this can be considered a good opportunity for Japan to utilize its technologies to make contributions in the area of fundamental Internet technology, which has become part of data communications infrastructures. The following section discusses technological policies from this standpoint.

4 The initiative in technological evolution

4.1 The age of the telephone switching network

In the age when telephone switching networks were built as a communications infrastructure, the laboratory of Nippon Telegraph and Telephone Public Corporation and other central research laboratories of NTT Public Corp. related companies served as the engine that drove Japan's technological growth in the communications infrastructure sector. Technological accumulation was facilitated through large-scale telecommunications carriers' capital investments expended as scheduled in their annual plans. Through the process of planning and developing "de jure" standards for a few years forward, technological accumulation took place in a well-planned manner. This approach was adopted not only in Japan but also elsewhere in the world with respect to communications infrastructures. In terms of human resources supplied from higher education institutions, graduates from technical colleges and the communication engineering course at universities favored NTT Public Corp. and its related companies as the places to start their careers. This fact can be seen as an indication of how such a traditional model functioned well.

4.2 The age of the Internet

In the subsequent age when the Internet was invented, a change occurred in the traditional model of technological growth. Those who drove the technological advances in this age were companies that aimed to set up “de facto standards” by introducing products with new capabilities onto the market ahead of others. Take the strategy of Cisco Systems of the U.S. as a typical example. Cisco’s technological accumulation has been mainly enabled by acquiring venture firms that own cutting-edge technologies. The reasons that such a technique was feasible and proven highly effective had something to do with the “best-effort” architecture of the Internet. In this architecture, networks have been operated by individual companies and universities, who could promptly adopt as part of their communications infrastructure any new products containing functions useful to them. Consequently, the driving force of R&D in this sector has shifted from large telecommunications carriers, who operate in line with national policy, to Cisco and other venture firms in Silicon Valley[3].

4.3 The course of next-generation R&D

NTT Corp. (formerly NTT Public Corp.) still assumes the major role in R&D among communications equipment manufacturers. It remains unchanged that the firm holds superior talent and is making enormous investments in R&D. However, now privatized, it can no longer explicitly take the national strategy-oriented initiative in the industry in responding to environmental changes as mentioned in the previous section. In addition, among other Japanese communications equipment manufactures, there has been a general tendency to scale down their central research laboratories. Yet another concern is that new entrants to the data communications business seem to pay little attention, concerning investing in R&D, to the aspect of long-term development of communications infrastructures.

As has been discussed, communications infrastructures are, from a technical point of view, in a period of transition, a time when technologies should be developed outside the traditional boundaries of the “best-effort” architectural concept. Under such circumstances, an initiative that is different from the traditional one should be taken in technological progress, for the purpose of facilitating further development of the Internet.

5 Challenges and proposals on technological policies

In the age of telephone switching networks, state-run corporations were given important and clear responsibilities. Now, at a time when the communications business is in the private sector, what the nation is expected to do are to define specific guidelines to set the course of the R&D on next-generation communications infrastructures and to promote basic research in this field. In the meantime, communications carriers will roll out their operations pursuant to their business principles and, consequently, conduct R&D activities as required. Then, it should be the academic sector that plays the role of continuously conducting basic research from a long-term perspective. The national government, with its strategy, needs to guide universities in what kind of leadership they should have and what kind of partnership they should forge with businesses in the related industries. More specifically, the following concrete measures should be considered.

5.1 Contribution to standardization

The adoption of RFCs, which serve as de facto standards as mentioned in section 3.2, is more reliant on past personal contributions to the standardization process and personal influence on the IETF than the presence of organized approaches. There exist some academic researchers in Japan who can attract certain attention in discussions on such issues. Given the scale of the Japanese industry, however, the number of people who can be qualified for such a role is limited. Japan should start with allowing its universities to conduct studies that will potentially contribute to international standards and establishing a system to actively support and evaluate such activities in the academic sector.

5.2 Formulation of an original vision

The current process of defining Internet standards, although claimed to be open, is said to be strongly influenced by a small group of people who share the same vision and made significant contributions to the invention of the existing Internet. Therefore, the future of technology will see no fundamental changes in the current picture in which the accumulated Internet technologies form the foundation of data communications technology. However, Japan needs to formulate its own vision on how to develop the national communications infrastructure in the future.

5.3 The future direction of research activities

The development of network processors, which would be essential to next-generation network management, requires not only practical knowledge on router design techniques but basic research efforts in areas such as parallel processing. To achieve research results of superior practical value in these fields, universities should embrace young researchers who have practical experience. Nowadays, a number of overseas universities have many competent researchers who once worked in private-sector research institutes such as those owned by vendors and communications carriers. This trend is particularly remarkable in Asian universities, whose number and quality of presentations at international conferences have reportedly been improving dramatically. Japanese universities should follow suit and actively recruit qualified talent.

R&D results on network management technology should be embodied, for example, as an ASIC (Application-Specific Integrated Circuit), a chip that incorporates control logic. Japan should allow academic research results to be commercialized in such a way and the resulting products to achieve competitiveness in the communications equipment component market. Universities play a significant role in the effort to produce such practical results, which require research in basic fields such as traffic theory.

References

[1] Janet Abbate, “Inventing the Internet,” MIT Press, 1999.

[2] David C. Mowery, “Is the Internet a US Invention? – an Economic and Technological History of Computer Networking,” Research Policy, 31 (2002), 1369–1387, 2002.

[3] Shuji Honjo and Hiroshi Menjo, “Business Management by Imaging Growth – Cisco Systems: The Secrets of Its Explosive Growth–”, Diamond, Inc., 1999 (in Japanese).

[4] Akihiro Fujii and Kiminori Gemba, “Network De Facto Standard,” Miyagi University prospectus, 2001 (in Japanese).

[5] http://www.rfc-editor.org/rfc.html

[6] http://www.gii.co.jp/

[7] http://web.cefriel.it/~decina/

[8] http://www.stanford.edu/~nickm/

(Original Japanese version: published in December 2003)

4

Water and Sewer Treatment Technology in the World and Trends in the Privatization of Public Water Utilities

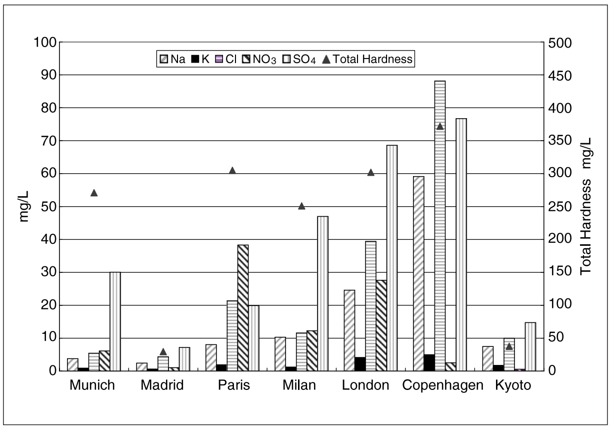
KUNIKO URASHIMA
Environment and Energy Research Unit

1 Introduction

As a matter of course, water is indispensable to all forms of life; it is a decisive element in sustaining life. There has been a growing interest in water around the world. For instance, the industrialized countries face a pressing need to upgrade and replace aging water/sewer lines. Water pollution is looming large in China, in which air pollution has been considered a major environmental threat - a national project is underway in Lake Taihu (located on the outskirts of Shanghai), where there is a massive outbreak of blue-green algae due to the continuous inflow of domestic and industrial wastewater[1]. The developing countries, meanwhile, are saddled with serious problems such as extreme water shortages and the lack of water infrastructures due to fund shortages - in addition to public funds, development projects funded by industrialized countries are indispensable to solving these problems.

The privatization of public water utilities has been underway in Europe, into which big companies are making inroads. These companies are also extending their reach into other areas such as energy and telecommunications, pushing ahead with their diversifying strategies. Underlying this trend is a growing attention to the promising infrastructure market, which has been monopolized by municipalities. Furthermore, they are now poised to branch out into other countries, taking advantage of expertise (in services, etc.) obtained on their home grounds. Based on the recognition of these trends, this report addresses the present status of water utilities and water treatment technology in each of the countries concerned.

Figure 1:Concentrations of inorganic ions in tap water in major cities



Source: Author's compilation based on data quoted from http://www.jousui.com

2 The status of water treatment technology

Only a few countries including Japan seem to have the habit of drinking tap water as it is, while the majority of countries and regions in the world boil it before drinking. Naturally, water treatment technology varies from place to place since water quality is unique to each country and region. Figure 1 shows the concentrations of inorganic ions in tap water in major cities of the world[2].

2.1 Recent trends in water and wastewater treatment

The safety of water is becoming a big concern in urban and industrial areas where water pollution from hazardous substances and bacteria is becoming increasingly serious. In these areas, water sources are closely monitored for possible

Table 1:Water treatment technology

	Treatment Technology	Objective
Clean/Tap Water	Chemical treatment, membrane filtering, ultraviolet treatment, ozone treatment, chlorination, activated carbon treatment	Removal of floating/soluble materials, disinfection, sterilization, removal of carcinogens
Sewer/Wastewater	Activated sludge treatment, membrane filtering, ultraviolet treatment, ozone treatment, chlorination, activated carbon treatment	Removal of floating/soluble materials, disinfection, sterilization, removal of carcinogens
River/Lake Water	Biofilm treatment, filtering, membrane filtering	Removal of floating/soluble materials, nitrification of ammonia nitrogen

contamination. With this situation as a backdrop, municipalities managing water are showing more interest in advanced water purification systems that are safer and more efficient than conventional ones.

Japan was originally blessed with water of good quality and abundant water sources. Not many people were buying bottled mineral water or teas about 20 years ago. However, it is now becoming a common practice to boil tap water before drinking, and an increasing number of households are installing water purifiers. In addition, those who prefer bottled mineral water to tap water are on the rise.

Ensuring the supply of tasty water inevitably involves conservation of water sources, but the realities are that a number of problems are emerging: eutrophication in water sources (lakes, reservoirs, rivers, etc.) resulting in a bad odor in tap water, ground water pollution from organic chlorine compounds, and generation of trihalomethanes during the water purification process. Worse yet, more chlorine is added to water to prevent contamination from E. coli O157[*1] and other pollutants - which ruins the taste of tap water. These problems cannot be solved overnight; what is needed is a concerted effort among all the parties concerned, that is, the government, municipalities, private companies and local residents.

2.2 The status of water treatment technology

With water quality varying from place to place, a variety of methods are in use to treat water (see Table 1).

Coagulation, sedimentation, filtering and disinfection are the basic processes of treating water and sewer. These processes are designed to remove impurities, but cannot remove musty odors. New treatment methods replacing chlorination, meanwhile, are being developed in Japan in the wake of an accident in which tap water was contaminated with cryptosporidium[*2], a protozoan organism that can survive chlorination.

Because of the need to reduce musty odors from tap water, municipalities in the Kansai region have long been addressing advanced water purification technology. The then Ministry of Health and Welfare mapped out “Guidelines for the Introduction of Advanced Water Purification Facilities” in March 1988, launching a government subsidy system in an effort to support public water utilities in setting up advanced facilities. The guidelines define “advanced water purification facilities” as “activated carbon, ozone, and biological treatment facilities that treat impurities such as odorants, trihalomethane precursors, pigments, ammonia nitrogen and anionic surfactants, all of which cannot be treated by conventional processes.” The objective: solve existing problems by adding one or more advanced water purification facilities to operating facilities[3].

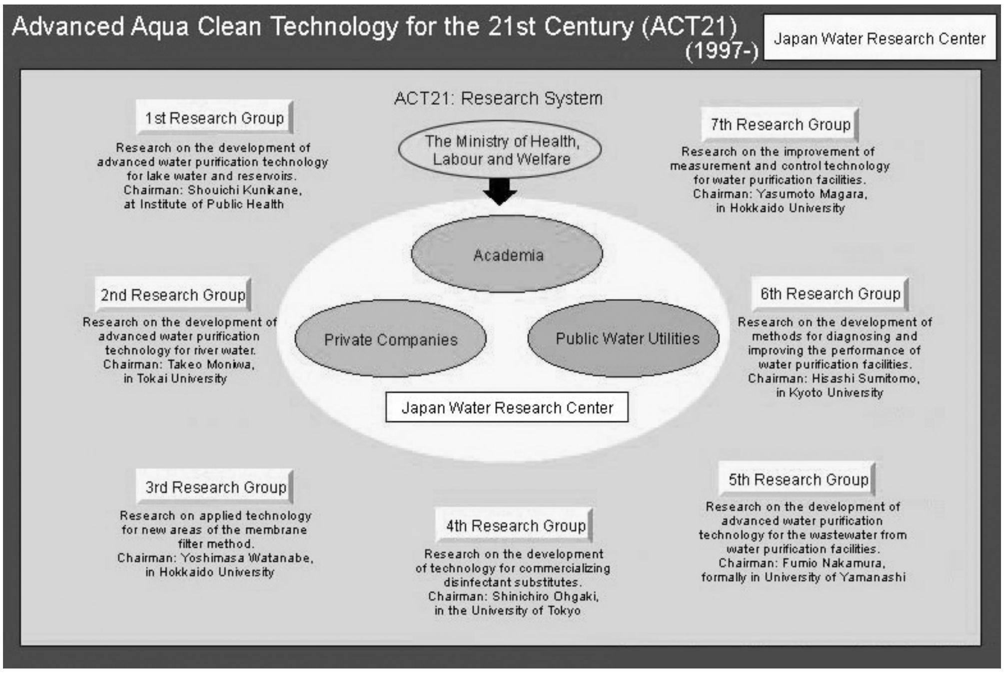
As part of this project, R&D efforts have been underway, funded partly by a health-science research budget. For instance, a five-year program with a budget of some 1.3 billion yen was launched in 1997: Advanced Aqua Clean Technology for the 21st Century (ACT21). Under the initiative of the Japan Water Research Center (JWRC), universities along with a total of 45 private companies took part in the program (see Figure 2[4]).

Advanced water purification systems remove organic matters in water, using less chlorine. These systems incorporate “biological treatment,” “ozone treatment” and “activated carbon treatment" into conventional water purification processes to further improve the quality of treated water - organic matters are removed to the maximum extent possible, along with nitrogen, phosphate and endocrine disrupting substances, each of which cannot be fully removed by conventional processes. Figure 3 shows an example of advanced water treatment (some processes such as injections of pH adjusters are omitted from the process flow[5]).

Biological treatment is a water purification process in which microorganisms decompose or coagulate impurities in water. This treatment uses less chlorine for disinfection purposes since it can remove ammonia nitrogen and odors quite effectively. The biological treatment of advanced water purification systems includes the submerged filtration method (using honeycomb media), the rotary disk method and the biological contact filter method. In addition, a method combining biological treatment and activated carbon treatment is already in practical use. Because of its porous structure, activated carbon has a high specific surface area, offering an ideal habitat for microorganisms that in turn provide activated carbon with biological treatment capabilities. Activated carbon equipped with these capabilities is called "biological activated carbon," and the treatment using this type of activated carbon is referred to as "biological activated carbon treatment." This advanced treatment is receiving attention as a new process that can be applied to processes in which activated carbon treatment precedes chlorination[3].

Ozone treatment is designed for disinfection, deodorization and decoloration purposes. Activated carbon treatment, though, is needed after ozone treatment to remove by-products produced from ozone oxidation. Ozonizers that can generate high concentrations of ozone need to be developed to reduce the high costs of ozone

Figure 2:Advanced Aqua Clean Technology for the 21st Century (ACT21)[3]



Source: Japan Water Research Center (JWRC)

Figure 3:Example of advanced water purification system

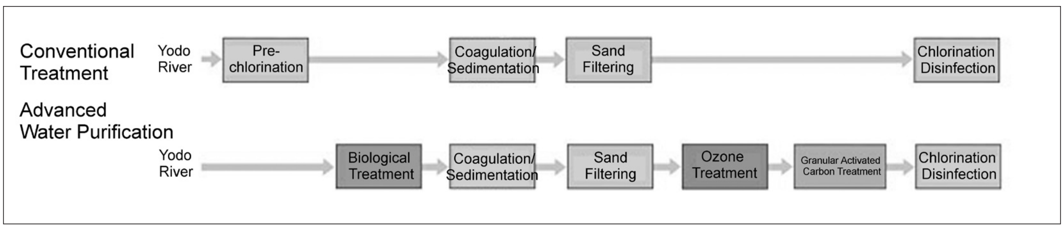


Table 2:International conferences on ISO/TC224

Date	International Conference	Subject
Apr. 2001	Proposed by France	International standardization of water/sewer services
Sept. 2002	The 1st ISO/TC224 Conference in Paris	Presentation of suggestions, scheduling
Jan. 2003	The WG4 Conference in Vienna	Discussions about water/sewer systems, presentation of Japan's plan
Mar. 2003	The Paris Conference (WGs)	Counterproposals to the secretariat's plan, presentation of Japan's plan
May 2003	The WG4 Conference in Lisbon	Discussions about water/sewer systems, presentation of Japan's plan
Jul. 2003	The WG3 Conference in Banff, Canada	Discussions about water/sewer systems, presentation of Japan's plan (service guidelines)
Sept. 2003	The 2nd ISO/TC224 General Conference in Ottawa	International standards (draft), determination of a general framework
Sept. 2004	The 3rd ISO/TC224 General Conference in Marrakech	Presentation of international standards to member countries, approval procedures
Jul. 2006	ISO/TC224 International Standards	Slated to come into effect

treatment[6, 7].

Activated carbon, because of its absorptive properties, is effective in removing odorants, trihalomethanes, total organic halogen compounds and trace hazardous chemicals such as agrochemicals. Activated carbon recycling plants (facilities that recycle used activated carbon through the heating method) have already been commercialized - an economical option for water purification facilities using a large amount of activated carbon.

More than 70% of trihalomethane precursors can be removed by these biological, ozone and activated carbon treatment methods, which together contribute substantially to reducing chlorine dosage. Likewise, more than 90% of surfactants, which cannot be treated by conventional treatment, can be removed.

3 Progress in international standardization efforts

France recently proposed the "standardization of service activities relating to drinking water supply and sewerage" to ISO. The objectives: address possible water shortages in the future and set out guidelines for water and sewer services that offer quality services at reasonable rates. If the standards stipulated in the proposal are adopted "as is" as international standards, however, Japan may have to revise its own standards. In addition, companies in a country whose domestic standards are similar to ISO standards may gain a competitive edge in branching out into other countries. These factors are expected to have a substantial impact on the operation and maintenance of Japan's water and sewer system, the total cost of which stands at some 3 trillion yen a year. A domestic task force, therefore, decided to actively participate in the preparation of international standards and has made a number of suggestions through international conferences (see Table 2 for details).

On the domestic front, moreover, there is a move afoot to set out domestic service guidelines to streamline domestic public water utilities and to ensure the transparency of their services - an effort in response to ISO/TC224 (Standardization of Service Activities Relating to Drinking Water Supply and Sewerage). International service guidelines of this kind would help each public water utility analyze its management status both at present and in the past, and quantify the quality and efficiency of its services - which would lead to improving the public water utilities themselves.

Another reason why ISO/TC224 is attracting the attention of those engaged in water and sewer services is its relation to WTO. ISO standards are voluntary standards in the first place, and hence the adoption of these standards is left to the discretion of each company/utility concerned. Possible agreements on environmental services through the ongoing inter-governmental negotiations on WTO services, however, would create a new framework - i.e., according to the WTO-TBT Agreement (an agreement that precedes any relevant domestic laws, where international standards are available), both the government and municipalities must comply with applicable international standards when handing out contracts (totaling more than 21 million yen for the government or 33 million yen for municipalities)[8].

What would then be the situations in other countries? The following chapter addresses other countries' water and sewer systems and their management statuses.

4 Water and sewer services and technology in other countries

4.1 Germany

Ozone treatment, using ozonizers developed by Siemens, has long been in use for disinfection purposes in Germany. Among natural substances, ozone is the most powerful oxidizer next to fluorine; it decomposes naturally into oxygen with no residual toxicity. Because of these properties, ozone is widely used for deodorizing and decolorizing water and air, as well as for disinfection/sterilization purposes by enhancing biodegradability against persistent organic matters. It is also used for disinfecting swimming pool water - a total of 1,057 swimming pools were disinfected with ozone in 1983. Ozone is generally used in combination with activated carbon. Figure 4 shows the interior of a typical ozonizer. The German government is currently making efforts in conserving water sources. Incidentally, tap water is not chlorinated in the country.

As for privatization movements, RWE (a leading electricity and gas supplier in Germany) bought out Thames Water (a leading water supplier in the UK), and is poised to extend its reach into the world infrastructure (water and sewer) market. In September 2001, moreover, the company bought out American Water Works (the biggest water-service company in the U.S.) for 912 billion yen. The North American market is estimated at 10 trillion yen a year, and projects worth 60-120 trillion yen are expected for the improvement and replacement of aging water and sewer lines.

Figure 4:Interior of a typical ozonizer

4.2 France

While advanced water purification and membrane treatment are widely practiced in France, this section addresses other technological trends, presenting specific examples.

Biological treatment is receiving widespread attention in France as an ecological option. This particular treatment, which involves a wastewater purification system using biotechnology developed in Germany in the 1960s, has been in operation for about 10 years; it takes advantage of the purification capacity of bacteria, purifying wastewater by means of plants without using any electricity or chemical treatment. Biological treatment is also becoming widespread in other countries such as the U.S., the UK, the Netherlands, Denmark and Austria. The number of projects involving biological treatment has increased from 20 to some 100 over the past five years in France. Although this technology is designed to treat domestic wastewater from small households, R&D efforts are underway for applications to industrial wastewater.

In France, a major part of water business is run by small municipalities - about 75% of which is outsourced to private companies. Specifically, a system called "concession·affermage" is in place; it leaves basic management authority to municipalities or public corporations (i.e., they manage assets and assume management responsibilities), while outsourcing operations to private companies. Currently, the top three companies - Vivendi, Suez and Saur - together account for some 90% of the domestic market. Those who have accumulated expertise and capital, both of which are indispensable for water business, gain a competitive edge in the market. The rates of privatization stand at 78% for water systems and 74% for sewer systems in France. Vivendi, meanwhile, fully took over PVK (a water/sewer service company based in Prague), which indicates that the company is gaining a stronger foothold in the European market[9]. The French government, however, has begun to discuss policies for water services to address regional disparities in the quality and rates of water - a growing trend due to the privatization. In response to EU's decision on the framework of water services, the Minister for Ecology and Sustainable Development, who takes charge of the policy-making, has held a series of meetings to discuss in detail policies for water services in France, inviting representatives from all sectors of society (government, industry, academia, citizens, etc.) and gathering opinions both on a national and regional basis by means of dialogues and questionnaires through the Internet[10].

4.3 The United Kingdom

In the UK, UV-radiation has long been a common treatment for disinfecting swimming pool water. Being particularly effective in killing viruses, UV-radiation treatment has become widespread across the country to prevent polio infection. UV rays, which have no residual toxicity, are effective in killing E. coli, bacteria, fungi, yeasts and viruses; they produce no hazardous substances such as trihalomethanes, and, hence, have a negligible impact on the quality of water. Specifically, UV-radiation treatment is a method in which UV rays disinfect (in a matter of seconds) the water passing through devices. The chlorination method was later developed to make up for the shortcoming of this treatment - i.e., UV rays cannot penetrate turbid water. In the 1960s, however, ozone treatment began to take over the method combining UV-radiation and chlorination since the latter produces trihalomethanes as byproducts[11].

Scotland previously experienced an outbreak of cryptosporidiosis - an accident attributable to tap water - that raised havoc not only with local residents but also with a water supplier because of the lack of an appropriate communication system. While the UK water business had been run by 10 public water utilities until 1989, the operations of water services were subsequently outsourced to private companies due to a shortage of public funds for capital investment. And Thames Water (UK), which originally held a dominant share of the privatized market, was later bought out by RWE (Germany) in January 2000. The privatization rates are now close to 100% in the UK[12].

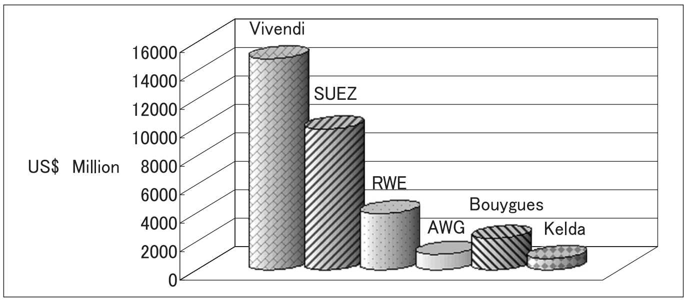
4.4 The Netherlands

KIWA Water Research is a Dutch institute primarily engaged in research on water, the environment and energy. Its specific activities include: surveys and control of the quality of drinking and industrial water, environmental research, surveys of human resources for water services, services related to pipeline construction, and information services[13]. In particular, a national initiative is underway to improve the quality of water. Nuon, a Dutch company providing electricity, gas and water services, bought out a leading US water-service company in early 2001. Overall trends in the Netherlands are similar to those in France.

4.5 The United States

Lagging far behind its European counterparts, the U.S. set out guidelines for ozone treatment in 1986. Although funds and demand for water/sewer systems were on the rise in the country due to stricter water quality regulations and aging water treatment facilities (which together fueled demand for improved water/sewer systems), the need arose in 1990 to capitalize on private funds since federal subsidies were abolished. In 1992, the Federal Government stepped up a tax preferential system for public facilities, extending its period from 5 to 20 years. In April 1999, Vivendi (France) bought out US Filter (the No. 1 water service company in the U.S.) for 972 billion yen. In June 1999, Suez (France) took over Nalco (the No. 1 manufacturer of water treatment chemicals in the U.S.) and United Water (the second largest water service company in the U.S.) for a total of 612 billion yen. These buyouts symbolize the growing presence of European companies in the US market, which situation suggests that they have strengthened their control over the world water market. In fact, Vivendi, Suez, and RWE (Germany) combined account for more than 80% of the world's

Figure 5:Sales of water treatment companies



Source: Materials provided by Mr. Kazunari Yoshimura

privatized market for water and sewer services, which covers some 360 million people in 130 countries - the market is increasingly dominated by these three companies. Figure 5 shows the sales of each major company's water treatment business.

Because of the deregulation policy to introduce private funds into public utilities, the privatization rates in the U.S. currently stand at 35% for water services and 28% of sewer services. On the other hand, there has been a particular case where a contract for the privatization of water/sewer services was canceled. The incident took place in Atlanta: in 1997, the municipal government signed a contract worth 22 million dollars with United Water for its services to be provided for 20 years. With the services privatized, the operational costs were reduced from 50 million to 22 million dollars. However, it turned out later that the deterioration of water/sewer lines was worse than originally expected, with inaccurate statistical figures surfacing one after another. For instance, the municipal government originally reported that a total of 1,200 water meters needed to be repaired or replaced; the actual number reached 11,200. Likewise, damaged parts of water/sewer mains increased from 100 to 280, and malfunctioning hydrants, from 730 to 1,630. In addition, other costs related to labor unions and default payments stood at as much as five million dollars for municipal facilities alone. Due to this series of false descriptions, United Water eventually cancelled the contract in January 2002. The municipal government, therefore, ended up paying 48 million dollars to place the services back under its management - a serious blow to both the municipal government and United Water.

A bill for investing a total of 25 billion dollars in water/sewer services in five years has recently been presented to the House of Representatives. The objectives: evaluate and analyze the vulnerabilities of water/sewer lines, discuss innovative methods to alleviate a shortage of funds for the infrastructure, conserve water sources, regulate emissions of new pollutants and improve the infrastructure as needed. As for chlorine used for advanced water treatment technology, regulations for the byproducts of germicides and disinfectants are also presented as a priority issue.

G. Tracy Mehan, III (Assistant Administrator of the Office of Water, EPA) announced recently that a national program is under study at EPA to promote water-efficient products. As water shortages, if not drought, are expected in more than 36 states in the decade ahead, they are becoming the focus of increasing attention in the U.S. The program is designed to improve the efficiency of water usage by disseminating information about water-saving products, encouraging manufacturers to produce more water-saving products, and supporting wholesalers and retailers in promoting sales of those products[14].

5 Conclusion

Being blessed with water of good quality and abundant water sources, Japan is believed to have properly managed water sources and water/sewer treatment. The current situation, however, is such that treatment/management processes need to be reviewed for both water and sewer services to address a variety of problems - e.g., E. coli O 157, cryptosporidium, contamination of well water with organic chlorine compounds and arsenic, generation of trihalomethanes, contamination with foreign materials due to aging water lines, and generation of by-products associated with chlorination. Other problems inherent to water/sewer services include: aging facilities; tightening water quality standards that require improvements in technology; the need to improve management efficiencies; disclosure of information that is required; expanding service areas due to the consolidation of smaller municipalities; and sluggish revenues from water sales due to the ongoing recession. In addition, it has long been pointed out that soil pollution is contributing to groundwater pollution. A nationwide survey of the contribution rates of sewer to the water environment shows that the national average stood at 27.6% as of the end of 2002; Shiga prefecture marked the highest rate (71.8%), while Gunma prefecture registered the lowest (1.3%). The contribution rates vary substantially from prefecture to prefecture[15]. As "water" in this particular case refers to water sources, tap water, sewer, wastewater, industrial water, well water, seawater, lake water, river water, etc., with each involving its unique environment, debates over "problem-solving" are increasingly complex.

Water treatment technology has been making headway, involving technological innovation - which is symbolized by improved water quality due to the introduction of advanced water purification techniques. In response to a suggestion made by France about ISO standards, there have been active discussions in Japan on the possible adoption of international standards - the spotlight centers on water utility services. The introduction of ISO standards could further improve Japan's water quality control, which in itself is beneficial from the viewpoint of ensuring the supply of safe water.

An increasing number of public water utilities in European countries are being privatized, each of which is striving to improve services and reduce costs - the time will come soon when Japan needs to address this vital issue. When opting for privatization, however, there is a need to have a clear picture of the circumstances surrounding the domestic public water utilities, as the example of the U.S. shows.

On the other hand, growing demand for mineral water in Japan indicates that public requirements for drinking water are becoming more stringent, from "potable water" to "safe and tasty water."

In view of all these factors, what is required for water treatment technology in the future is not only to produce potable water and treat wastewater but also to improve water quality and establish technology best suited for Japan's unique nature and culture. Technological innovation should also be promoted to improve services as a whole. In solving the problems mentioned above, therefore, there is a need to monitor water sources and introduce overseas expertise in addition to adopting advanced water treatment systems. In this context, it is desirable that due attention be given to both domestic and international trends and appropriate approaches be adopted, taking into account a water cycle as necessary.

Acknowledgements

This report, based primarily on the lecture of Mr. Kazunari Yoshimura (UN Technical Advisor) at the Science and Technology Foresight Center, was prepared by collecting relevant information and materials. I would like to express my gratitude to Mr. Kazunari Yoshimura for delivering a foresighted lecture, providing informative materials and participating in a number of discussions.

Glossary

*1 O157

E. coli strains are ubiquitous in the intestines of livestock and humans, most of which are harmless. Some E. coli, however, are called "enteropathogenic E. coli," which may cause digestive problems such as diarrhea and complications. Among these enteropathogenic E. coli, there are strains producing toxins that cause hemorrhagic enteritis and hemolytic uremic syndrome (HUS); they are referred to as "enterohemorrhagic E. coli." These enterohemorrhagic E. coli strains can be classified according to their components (surface antigens or flagellar antigens), one of which is "E. coli O157." As E. coli O157 produces toxins that cause hemorrhagic enteritis, it is officially referred to as "enterohemorrhagic E. coli O157."

*2 Cryptosporidium

Cryptosporidium is a protozoan organism that causes a parasitic infection called "cryptosporidiosis," which results in diarrhea, stomachache, fever and nausea. As it can survive chlorination, mass infection through tap water and swimming pool water occurs every year primarily in industrialized countries. Japan, too, experienced an outbreak in 1996 that was caused by tap water.

References

[1] Nikkei Ecology, May 2003: 38-41. (in Japanese)

[2] http://www.jousui.com/info/good-b2.html

[3] http://www.005.upp.so-net.ne.jp/wanatra/Nw3/26koudoshori.htm

[4] Materials issued by the Japan Water Research Center (JWRC) (in Japanese)

[5] The Okinawa Enterprise Bureau. Chatan Water Purification Plant and Advanced Water Purification Facilities (in Japanese)

[6] http://www.kubota.co.jp/

[7] Itoh, Tairo, The Mysteries of Ozone: All About its Advance andDisadvance, Blue Backs: Koudansha (in Japanese)

[8] Journal of Japan Water Works Association, vol. 72, No. 8: 88 (in Japanese)

[9] Station d'epuration A LITS (Curiennes)

[10] http://www.environment.gouv.fr/actua/com2003/juin/26-debat-eau.htm

[11] http://www.senlights.co.jp/gijyutu/poolseries2.htm

[12] http://www.envix.co.jp

[13] "KIWA WATER RESEARCH," http://www.kiwa.nl/en/home.asp

[14] http://www.senlights.co.jp/gijyutu/pool3.htm

[15] http://www.mlit.go.jp/kisha/kisha03/04/040922-.html

(Original Japanese version: published in October 2003)

5

Trends in Earth Monitoring and Observation Satellites
– Advances in Monitoring and Observation with Satellites in File-formation Flight –

Hirokazu Kobayashi *(Affiliated Fellow)* and Kuniko Urashima
Environment and Energy Research Unit

1 Introduction

Earth monitoring and observation utilizing satellites is characterized by the ability to grasp broad global conditions quickly and without interference from weather or national borders.

The diverse purposes of work performed by Japanese satellites include space-related development of various satellite technologies, such as communications satellites that upgrade social infrastructure, weather satellites that serve the people, resource satellites that investigate resources, information and monitoring/observation satellites that ensure national security, and satellites for space exploration and other scientific research.

Among those working with satellites, there is awareness that the satellites that protect Japan must not only observe Japan and, obviously, issues such as global warming, water resources and food issues, but also monitor the East Asia region, including geopolitical issues, and indeed the entire world. Under these circumstances, earth monitoring and observation satellites not only have scientific goals, they are increasingly important in protecting the nation and obtaining information needed to set policy.

2 Satellite file-formation flights

To carry out earth monitoring and observation with satellites, conventionally a large satellite bus*1 is loaded with numerous observation sensors. For example, Japan's ADEOS-II (launched December 14, 2002) weighs 3.7 tons and carries 5 kinds of sensors, and the European Space Agency's (ESA) ENVISAT environmental observation satellite (launched February 28, 2002) weighs in at 8.2 tons with 10 types of sensors.

As an alternative to these massive satellites with numerous sensors, NASA and others propose lining up small satellites with relatively few sensors (1 or a few) and flying them in formation. Unlike aircraft that fly in parallel formations, the nature of satellite orbits requires that satellite formations consist of multiple satellites flying consecutively in the same orbit, orbiting the earth much the way a train travels over the ground. From the perspective of the ground under that orbit, satellites pass overhead in succession at intervals of tens of seconds to over ten minutes.

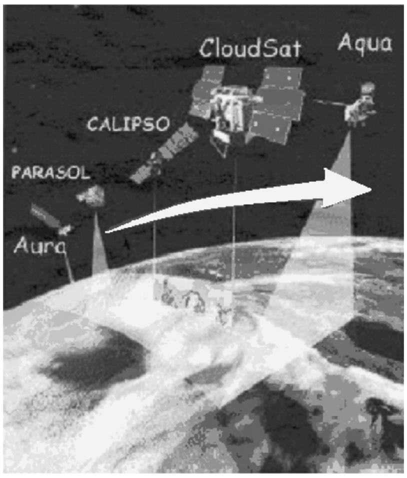
In the past, positioning control over such formation flights was by no means easy. The loading of GPS receivers on satellites, however, has enabled the necessary degree of precise control over position and timing required for formation flying. These file-formation flights are expected to lead to new developments in satellite observation.

For example, NASA has a project[1] called "Taking the A-Train"*2 in which a formation of satellites is led by Aqua and ended by Aura (see Figure 1). Before the A-Train, satellites have already been launched in the same orbit as existing satellites, resulting in formation flying. For example, Landsat-7 is now followed in the same orbit by EO-1, SAC-C, and Terra*3 at about 30-minute intervals. (The time varies with orbital corrections.)

Table 1:Overview of the A-Train

Satellite name	Launch date (scheduled launch date)	Developing organization, purpose, etc.	Sensors
Aqua	May 4, 2002	Earth Observing System (EOS) series satellite, collects data on global water cycle	Advanced Infra-Red Sounder (AIRS), Advanced Microwave Sounding Unit (AMSU-A), Humidity Sounder for Brazil (HSB), Advanced Microwave Scanning Radiometer for EOS (AMSR-E), Moderate-resolution Imaging Spectroradiometer (MODIS), Clouds and the Earth's Radiant Energy System (CERES)
CloudSat	Autumn 2004	NASA satellite	CPR (Cloud Profiling Radar)
CALIPSO	2004	NASA satellite, observation of atmospheric clouds and aerosols	Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), Imaging Infrared Radiometer (IIR)
Parasol	Following the others	An approximately 100-kg microsatellite to be launched by CNES	Polarization and Directionality of the Earth's Reflectance (POLDER)
Aura	January 2004	NASA, EOS series observation satellite, to collect data on ozone and changes in air quality	High Resolution Dynamics Limb Sounder (HIRDLS), Microwave Limb Sounder (MLS), Ozone Monitoring Instrument (OMI), Tropospheric Emission Spectrometer (TES)

Figure 1:The CloudSat Mission and the A-Train



Source: CloudSat satellite team document describing the sensors

3 The relationship of monitoring and observation sensors and satellite buses

3.1 The advantages and disadvantages of large satellite buses and multiple satellite buses

The proverb "Don't put all your eggs in one basket" is sometimes brought out, with sensors as the eggs, when discussing the risks of loading multiple sensors onto large satellites. That is because the risk of launch failure for satellites is still extremely high. For example, even the Space Shuttle, a manned system with a high design safety factor, is designed to have a success rate of 99.5 percent. (With 2 accidents in 109 launches, its actual success rate is 98 percent).

That is why even today any enterprises utilizing satellites for earth monitoring or observation must consider risk. However, sensors do the bulk of the work in satellite monitoring and observation, with satellite buses as nothing more than the necessary platforms that support them. That raises the question of how sensors should be loaded on satellites. For example, the first question whose pros and cons must be examined is whether to place multiple sensors on a single satellite or to launch them separately. Suppose that three sensors are to be launched, and the success rate is k = 0.9. If the three sensors are loaded on a single satellite bus, the probability that none will make it to orbit is 0.1. If, on the other hand, the sensors are loaded on three separate satellite buses, the probability that none of them will make it to orbit is only 0.001. Utilizing multiple buses greatly raises the probability that some sensors will be successfully launched. If, however, we look at the probability that all three sensors will exist in orbit simultaneously, the probability for a single satellite bus is 0.9, while for three satellite buses it is only 0.729. In that case, the single satellite bus has the advantage.

In addition, the operation of each of the three sensors in space can be assigned a result (value) of p and the expected value can be considered (This does not consider the cost of the rocket used for launch). In the case of both a single satellite bus and three satellite buses, the expected value is 3kp. In other words, from the perspective of launch risk alone, there is no essential difference in the expected value of sensor operation between a single bus and multiple buses. From the perspective of the expected value of the sensors' results, there is no advantage in lowering the risk with multiple satellite buses.

When the value of each sensor is increased through their working together to collect data, however, a higher value is achieved by launching them on a single satellite. Continuing with the same example, if the three sensors must all be present to obtain useful data, then launching a single satellite is clearly advantageous.

3.2 Policy advantages of multiple satellite buses

On the other hand, in the event that technological advances decrease the costs of launch rockets and satellite buses so that the overall costs of multiple satellite launches to single-bus systems and multiple launches become more realistic, multiple launches offer several advantages from a satellite-related policy perspective. The following are some examples.

(1) Avoidance of interruptions of observation

In general, continuous long-term earth monitoring and observation utilizing satellites brings additional value to the data obtained because changes in the earth's surface and so on can be detected. Therefore when, for example, a launch fails or a satellite malfunctions and no observation sensor exists-in other words, when there is an interruption in earth monitoring and observation-it has a negative impact on the execution of policy. A multiple bus system can avoid such interruptions.

(2) Spreading costs over time

Combining a large satellite with multiple sensors requires the concentrated investment of funds during a limited period. The nature of earth monitoring and observation, however, requires that they be continued over long periods. Preparing multiple small satellites could spread budgets over longer periods, making it easier for policies to be implemented.

(3) Enabling easier participation in satellite observation ventures

For example, if an institution (e.g., private sector or academic) develops a unique sensor and that sensor requires the supplemental use of data from other sensors, the institution can participate in a formation of satellites that provides all the necessary sensors without having to prepare them all on its own satellite. The result is that its observations can be made at a lower cost.

(4) Standardization through the manufacture of multiple satellite buses

Manufacturing multiple, small satellite buses and their rockets will lead to standardization of manufacturing processes and products. That can be expected to lead to various kinds of profits for manufacturers as well as reduced procurement costs. Furthermore, increasing the reliability of rockets manufactured in large numbers for the launch of small satellite buses is probably more possible than increasing the reliability of only a few rockets manufactured to launch large ones.

4 Characteristics of satellites flying in file formation

4.1 Classification of satellite formations

Formations are classified by purpose as follows.

(1) Formations that strictly maintain relative positions in orbit

Primarily these use multiple satellites to function as interferometers studying deep space. However, examples of those that engage in earth monitoring and observation include the U.S. military's TechSat 21 project (high-resolution military radar) and the ESA's Cluster II (four satellites performing high-precision observation of earth's electromagnetic field)[2]. Both are examples of projects planned from the beginning as formation flights for specific purposes.

(2) Formations that more loosely control relative positions in orbit

In contrast, formations that offer more flexible earth monitoring and observation and the possibility of lower costs are likely to be important in earth monitoring and observation from now on. The formations headed by Landsat-7 and Aqua mentioned above are two such observation projects.

Formations that maintain or measure strict positioning comprise satellites that have all been designed and planned for specific purposes. Such plans do not change for the life of the project. In the sense that their operation is fixed, they do not differ essentially from conventional large satellites.

Formations that more loosely control their positions in orbit, however, comprise satellites that join in the same orbit despite having completely different purposes. This opens the possibility that new scientific or policy value may be created, or that the reason for the satellites' existence may be transformed as more of them join even though that was not part of their original purposes. This would lead to satellite observation that is without precedent.

Because multiple satellites must simultaneously operate in such formations, complex satellite operation and precise orbital insertion are required. Their greatest advantage, however, is that comprehensively processing the data from each sensor enables high-quality data to be obtained.

As mentioned above, the mutual distance maintained in formation flights normally would vary from tens of seconds to over ten minutes. Earth conditions will not change greatly during such intervals. Therefore even if a group of sensors are not loaded on the same satellite bus, the same point on earth or the same region can be monitored or observed with different sensors or with identical sensors utilizing different methods. In other words, measuring earth conditions from a variety of aspects enables valuable data to be collected.

4.2 The advantages of formation flying from a sensor perspective

From the perspective of earth monitoring and observation, multiple sensors on multiple satellites flying in formation result in the creation of a virtual giant satellite that can be simultaneously operated. A number of advantages of formation flying over single large satellites can be noted.

(1) Operation of sensor clusters

For example, earth observation satellites have become large in response to various scientific requirements. As mentioned above, the ESA's Envisat large earth observation satellite launched in March 2002 carries 10 different kinds of sensors. In such cases, operation of multiple sensors is extremely complex. For example, because all the sensors share the same power source and data transmission system and are controlled on the same satellite body, resources related to operation must constantly be adjusted among the sensors. Because satellites flying in formation are independent, very large numbers of sensors can be operated together in a way that is not possible with conventional earth observation satellites.

(2) Avoidance of inter-sensor interference

For example, when active sensors for cloud radar and measurement of electric wave dispersion are loaded on the same satellite, it must be carefully designed so that the electric waves put out do not cause interference with other sensors. Furthermore, sensors with mechanical vibrations or moving parts often influence other sensors, so the same careful design of the sensors and the satellite bus is required. Because the individual satellites in a formation flight can be freely equipped, the problem of inter-sensor interference is greatly abated.

(3) Forming sensors to detect phenomena that change over short periods

Although we stated above that earth conditions do not change greatly over short periods, satellites in file formation can detect phenomena that do change over very short periods. They can detect the speed of changes in rapidly changing phenomena on the earth's surface. For example, they can detect flood conditions and changes in natural formations caused by natural disasters. From the current formation of Landsat-7, EO-1, SAC-C, and Terra, Tanaka, et al.[3], use image data from Landsat-7 and SAC-C (passing over the same surface points about 28 minutes apart) to estimate the speed and distribution of currents in the Strait of Magellan and from Landsat-7 and EO-1 (images obtained 54.5 seconds apart) to estimate the course of ships in Yokohama Harbor.

5 The influence of satellites in formation on earth monitoring and observation activities

When satellites build formations, points differing from the planning, operation, and data of conventional earth monitoring and observation satellites will appear. This will likely have great influence on overall policy related to earth monitoring and observation. The following are some areas where this may be expected to occur.

(1) Increased flexibility in planning for sensor development and operation

Sensors that observe topical earth sciences phenomena must be able to undertake measurement in a timely way. Basic sensor types are expected to obtain observed values necessary for weather forecasting models, and at the same time function as sensors to obtain basic data that illuminate topical phenomena. Because satellites in file formation make possible the combination of standardized satellite buses and unique sensors, individual sensors can be developed and planned in a flexible manner. For example, basic sensors can be designed for maximum stability of operation, while sensors for topical uses can be developed quickly. Because the development and operation of large satellites with many sensors generally required planning and operational adjustment among the sensors, long term planning and development and high overhead costs were often required.

(2) Gradual increase in monitoring and observation data from satellites in formation

In many cases, data obtained from an individual sensor can be combined with data from others sensors to increase the value of that data. Furthermore, combining data from different types of sensors opens the possibility of new scientific and policy knowledge. Current single earth monitoring and observation satellites cannot change their sensors for the life of the satellite, so new technologies and ideas cannot be implemented until the next satellite is ready.

In contrast, after a formation of satellites has temporarily formed, the data from those satellites' sensors can be utilized in planning for the development and operation of a new sensor to be added to the formation. The result is that new technologies and ideas can be implemented faster than with single satellites. When the number of sensors in a satellite formation is increased in this way, the value of the monitoring and observation that utilizes them is increased along with the number of sensors participating in the formation.

(3) Concentration of the operation of satellites in formation and data collection and distribution

Even though control of the individual satellites comprising a group of satellites in formation is relatively easy, and even though they may be owned or have been launched by different institutions, from a cost perspective it is desirable that they be operated by a specialized institution such as JAXA. Because of convenience to users and cost considerations, the operation of the accompanying sensors, in other words, the receipt and distribution of earth monitoring and observation data, will likely be handled by the same institution that operates the group of satellites.

6 Conclusion

Japan has outstanding earth observation sensors such as the Global Imager (GLI), the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), and the Precipitation Radar (PR), and its sensor development capacity is not inferior to that of countries such as the United States. For example, GLI obtains images of ocean and land surfaces on a very broad range of wavelengths, leading to new scientific developments relating to those areas. The AMSR-E measures faint microwaves radiating from the earth's surface and the atmosphere to estimate water vapor volumes and soil moisture. Its antenna aperture is in the largest class of any scanning radiometer. The sensor is loaded on the ADEOS-II and on the United States' Aqua satellite. PR is the world's first satellite=loaded precipitation radar. It is the first satellite sensor to capture a broad range of three-dimensional data on the mechanisms of precipitation, and provides information important to research on the global water cycle. PR is the main sensor on the satellite bus of the United States' TRMM, and a new version is now being planned.

These sensors are loaded on several satellites along with other sensors, and are playing an important role. This demonstrates that Japanese sensors are key instruments that obtain data that increase the value of other sensors. Japan has led the world in sensor development. It must be noted, however, that Japanese efforts to form a monitoring and observation system that continually prepares and develops those sensors, involves domestic and overseas users, and responds to diverse user needs have been insufficient.

As we mentioned above, to realize groups of satellites in formation, more than the technical development of satellites and sensors is required. Cooperation with other countries and advances in the management of earth monitoring and observation that seek to add overall value are also needed. With its outstanding key sensors, Japan's planning and operation of its own groups of satellites in formation would respond to social needs, particularly those for safety and peace of mind. From the perspective of space policy development as well, it should be engaged in for the sake of the development of space transport systems and satellites.

Glossary

*1 Satellite bus

The basic system of a satellite, which does not include the various sensors loaded on the satellite.

*2 Taking the A-Train

A play on Billy Strayhorn's composition "Take the 'A' Train," best known as Duke Ellington's signature song.

*3 Landsat-7, Terra, EO-1, SAC-C

Landsat-7 was launched on April 15, 1999, Terra on December 18, 1999, and EO-1 and SAC-C were launched together on November 21, 2000.

Reference

[1] "Changes in Polar Ice Concentrations," April 22, 2002.: http://www.gsfc.nasa.gov/topstory/20020418aqua4.html

[2] "Survey examination of guidance control technology for formation flight satellites", National Space Development Agency of Japan (NASDA).: http://giken.tksc.nasda.go.jp/seika/gaiyou/H11/34files/

[3] Sotaro Tanaka, Kenji Takasaki, and Jose Kuba. "Remote sensing by tandem operation," RESTEC, 51, June 2003. (in Japanese)

(Original Japanese version: published in November 2003)

6

New Measurement Technology: Multi-probe System – Toward Direct Measurement of Functions of Nanomaterials and Biomaterials –

TSUYOSHI HASEGAWA *(Affiliated Fellow)* AND KUNIYUKI TADA
Materials and Manufacturing Technology Research Unit

1 Introduction

Progress of many scientific technologies often proceeds together with the development of new measurement technologies. It would not be an exaggeration to say that new apparatus is indispensable for discovering new phenomena and to elucidate them, and this fact has been proven by many researchers who have received the honor of the Nobel Prize. Among the recent Japanese Nobel laureates, the case of Dr. Masatoshi Koshiba (in physics, 2002)[1], honorable professor of Tokyo University, who has realized the detection of neutrino from a supernova by developing "Super-Kamiokande," is exactly an example of this fact. Furthermore, development of new measurement technology itself is also being appraised. The case of Mr. Koichi Tanaka (in chemistry, 2002)[2], fellow of Shimadzu Corp. who has developed the "Desorption Ionization Method" enabling the mass spectrometric analysis of biopolymer, is a direct example. These examples show how important the development of new measurement technologies is for carrying out research work with high originality.

In this report, we would like to introduce the outline and the present status of the development of devices for the "Multi-probe System," which is expected to contribute to the development of new research areas in the fields of nanotechnology and biotechnology. These fields are considered to be very important for Japan who advocates a technology nation.

In the fields of nanotechnology and biotechnology, development of completely new technologies and products are being sought by utilizing characteristic functions of newly developed bio-materials and nano-materials. In the research and development with such targets, the first thing to be done is to know the functions of these new materials. The Multi-probe System makes it possible to measure the functions of these new materials, which has been impossible with conventional apparatus, and it is expected that the Multi-probe System will create new methods of research and, consequently, to create new research fields.

2 Outline of the Multi-probe System

The Multi-probe System is a device that uses a plural number of micro probes that directly touch bio-materials or nano-materials to measure functions such as electrical characteristics including signal transmission, and chemical and mechanical characteristics. And the basic technology of the Multi-probe System lies in the scanning probe microscope (SPM)[3] that uses a single scanning probe.

The SPM is the first device that made it possible to directly observe individual atoms on the surface of a sample, and the use of SPM has rapidly grown after its invention in a wide range of research and development areas. The inventor of SPM was, as in the cases of similar inventions, awarded the Nobel Prize (in physics, 1986)[4]. Although the Multi-probe System is based on SPM technology, it is a device that enables the direct measurement of functions of nanomaterials and biomaterials, which has never been facilitated by the use of a single probe. As shown schematically in Figure 1, while a single probe provides only information relating to the area directly under the probe, the use of a plural number of probes enables the obtaining of the total information of the sample including the situations of transmission of signals that are input. In addition, since the System is based on the technology of SPM with a resolution on the atomic level, it is possible to carry out with a spatial resolution on the nano-scale. For this reason, the Multi-probe System is expected to provide new research techniques in the fields of nanotechnology and biotechnology.

The following is an outline of the Multi-probe System and SPM, which is the basic technology of the Multi-probe System.

2.1 Scanning Probe Microscope (SPM)

The SPM, which is the basic technology of the Multi-probe System, is a device that obtains information on the sample surface by scanning the sample surface using a single probe. There are several types of SPMs including Scanning Tunneling Microscope (STM) that uses the tunneling current between the probe and sample for the control of the position of the probe, and Atomic Force Microscope (AFM) that uses the atomic force between the probe and sample for the control of the position of the probe.

The type of SPM that was first developed by researchers of IBM in 1982 was STM[5]. When the probe is brought close to a sample within a distance of about 1 nanometer, a tunnel current flows between the probe and sample. The amount of the tunnel current depends on the distance between the probe and sample. For example, if the distance of 1 nanometer between the probe and sample is made shorter by only 0.1 nanometers, the amount of current is increased by a factor of 10. Therefore, it becomes possible to keep the distance between the probe and sample constant by controlling the position of the probe (height) so that the tunnel current is kept constant. If the fluctuation of the tunnel current is kept within a range of several percent, for example, the distance between the probe and sample can be kept constant with an accuracy of 0.001 nanometers (one hundredth of the atom size). When the probe is scanned along the sample surface with such accurate control of distance, the probe would move as if it were exactly tracing the surface of the sample. Thus, the surface topography can be observed by imaging the movement of the probe (see Figure 2). Because the tunneling current is sensitive

Figure 1:Difference in measurement information according to the number of probes

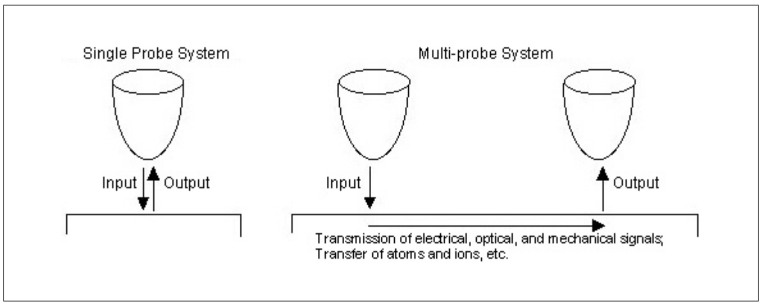
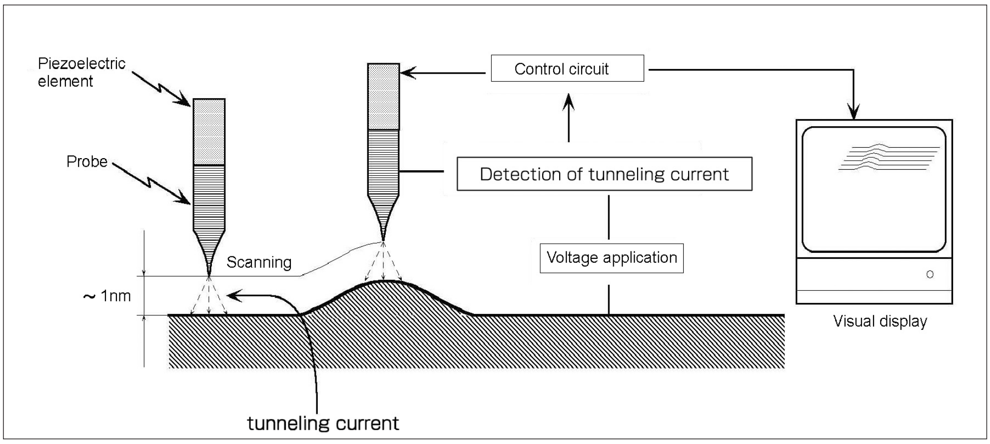


Figure 2:Principle of scanning tunneling microscope



to the change of distance between the probe and sample, individual atoms can be directly observed.

In addition, the STM provides diversified physical information including the energy diagram of electrons derived from current and voltage characteristics between the probe and sample. It can be used not only as a mere instrument for observation but also as a method for fine processing by manipulating atoms, for example, making use of the interaction between the probe and sample[3]. For this reason, the STM became a device that has been used in a wide range of applications in a very short period of time. It is not an exaggeration to say that the propagation of the STM paved the road to the present day nanotechnology, and the inventor of the STM was awarded the Nobel Prize for this contribution.

Other types of STM include the AFM and the Scanning Near-field Optical Microscope. The AFM is used to control the position of the probe by detecting the weak force acting between the probe and sample (atomic force) using a miniature detector of a cantilever type. And the Scanning Near-field Optical Microscope (SNOM) is a device to control the position of the probe, by detecting the special light that exists only in the near field of the sample using a probe of optical fiber provided with a sharp tip. These microscopes can be used for insulator samples that do not pass the tunneling current, and also for the measurement of various physical values with a nano-scale spatial resolution that cannot be measured with the STM, such as hardness and luminescence properties.

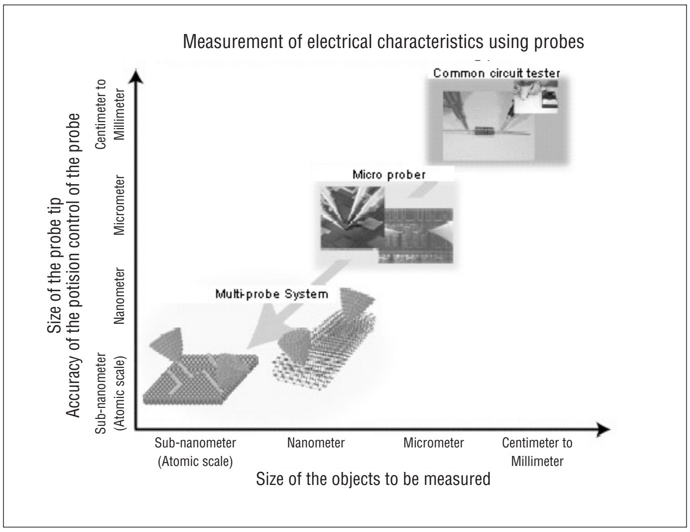
2.2 Background of the development of the Multi-probe System

In the development of devices that have functions, it is always necessary to confirm these functions. In the development of semiconductor devices of present day, for example, a device called a prober is used to measure the performance characteristics of transistors. This measurement is performed using a plural number of probes provided with tips on the micron-scale, which are brought to contact to the measuring electrodes of the sub-millimeter order. Therefore, this measurement can be carried out only on elements for the confirmation of performance characteristics called TEG (Test Element Group). To measure the performance characteristics of individual transistors that are actually used for operation, it is required to bring a plural number of miniature probes to an area of 0.1 μm ×0.1 μm or smaller, and this cannot be done by conventional measuring instruments.

In the development of nano-devices for the future, the size of area to be approached becomes still smaller. In addition, even the technologies for wiring have not been developed for many cases of the development of nano-devices that use new materials such as carbon nanotubes and DNAs, and there is no other means than the direct contact of the probe with the sample to be measured. In order to solve this problem, a Multi-probe System that uses several SPM probes that can approach areas on the nano-scale is being studied and some researchers are already carrying out basic experiments. Since direct contact between the probe and sample is required for the measurement of electrical characteristics, the development of nano-contact technology that applies the probe control technique using the SPM with an accuracy on the nano-scale is also being carried out. The Multi-probe System is also able to elucidate various phenomena such as antibody antigen response and ion transmission with a high spatial resolution, and it is expected to play an important role in medical applications.

From a mechanical point of view, the Multi-probe System is a device equipped with a plural number of SPMs. However, it requires the development of new techniques that have never been used for conventional equipment, such as the control of relative positions of a plural number of probes, exchange of signals among the probes, and the linkage between the probe control and measuring system. Since the development of these techniques requires a vast amount of accumulated know-how and a very long period of time, it is difficult for a single measuring instrument manufacturer to develop them independently. The reality of the present situation is that the development of measuring instruments relies on the efforts of

Figure 3:Multi-probe System that enables the direct measurement of nano-structures



Source: Authors' compilation based on the chart provided by Dr. Tomonobu Nakayama, associate director of the National Institute for Materials Science

some researchers. In the following section of this report, we will introduce some application examples of the Multi-probe System and elucidate the role of the Multi-probe System in the fields of nanotechnology and biotechnology.

3 Application examples of the Multi-probe System

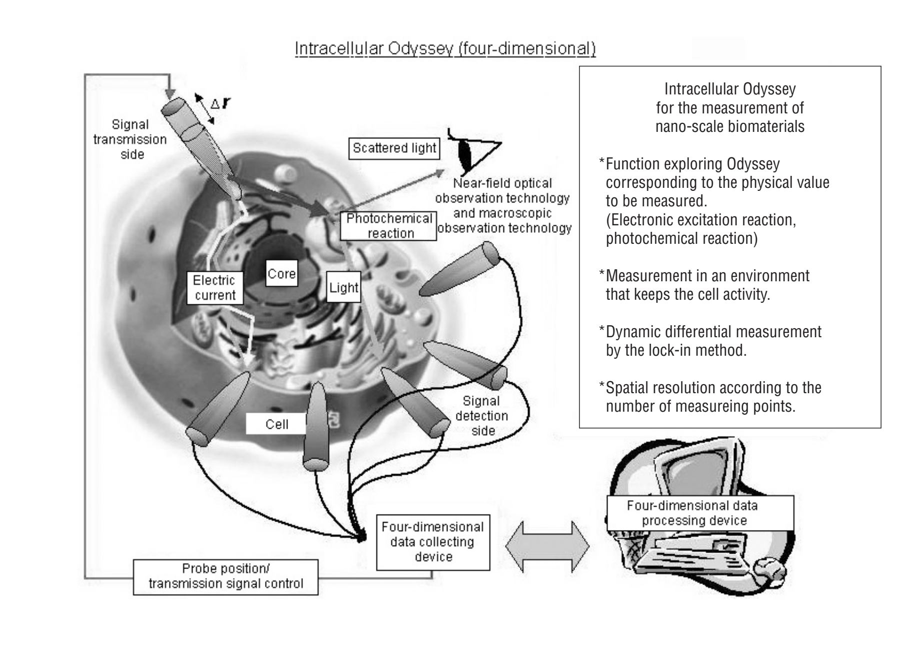
3.1 Direct measurement of electrical conductivity of nanomaterials

As a result of the recent progress in nanotechnology, research and development of nano-devices using nano-materials such as carbon nanotubes and DNAs has become a boom. In these studies, the measurement of the functions of nano-materials used is one of the most important issues. There are various kinds of carbon nanotubes, for example, and it has been reported that they show properties of metals, semiconductors, or insulators depending on their types. Therefore, it is very important to know the characteristics of the carbon nanotubes being used for a device. However, there is no established method to determine the characteristics. In an extreme case of the electrical conductivity of DNAs, there are various contradicting theories and it is not an exaggeration to say that nothing has been clarified.

To directly measure the electrical conductivity of these nano-materials, measuring systems suitable for the size of materials are required (see Figure 3). The resistance of a resistor of a size of about 1 cm used for a general electrical appliance can be measured by a common circuit tester. To measure the characteristics of semiconductor devices, an instrument called a "prober" provided with probes having fine tips on the micron-scale is required. Furthermore, to measure the characteristics of nano-scale structures, the Multi-probe System provided with probes having fine tips on the nano-scale is required, which is now being developed by researchers.

The first measurement of the characteristics of nano-materials was carried out by a group from the National Institute for Materials Science, which was a measurement of electrical conductivity of a piece of fine $ErSi_2$ wire having a width of only 3 nm[6]. $ErSi_2$, which was the material of the fine wire they used as the sample for measurement, exhibits the electrical conductivity characteristic of metals when it has large dimensions in a bulk state. Although the results of the measurement of the electrical conductivity of the fine wire showed a characteristic of metals, the values actually obtained were on an order of magnitude larger than those expected from the values in a bulk state. This is proof of the fact that electrical conductivity shows special characteristics in the nano-scale range. As shown in this example of electrical conductivity, characteristics of nano-materials are not on the extension of conventional materials, and the measurement of

Figure 4:Schematic diagram for the measurement of the functions of biomaterials using the Multi-probe System



Source: Prepared by Dr. Tomonobu Nakayama, associate director of the National Institute for Materials Science

characteristics is indispensable when using these materials. At present, the Multi-probe System is considered to be the only means that enables such measurement.

3.2 Direct measurement of the functions of biomaterials

The Multi-probe System is expected to contribute not only to the development of nano-devices that use biomaterials but also to the development of medical technologies. For example, it is expected that the Multi-probe System will enable the elucidation of the functions of biomaterials expressed in the antibody antigen response and the mechanism of the ingenious signal transmission and material transportation in biomaterials.

While the fine probes are brought to contact with the surface of materials in the above-mentioned measurement of electrical conductivity of nanomaterials, it becomes necessary in the measurement of the functions of biomaterials to obtain information of the inside of the material. In order to realize this, thin-long probes made of carbon nanotubes and metallic nano-rods are being investigated, as well as the means to extract the information obtained from the probe tips (inside of living organisms) by covering the portion other than the probe tips with insulating material. Also being studied is the manner to detect specific antibody antigen responses from the change in mass caused by the response of attaching a particular biomaterial such as antibody to the probe tips. The use of a probe that detects light will enable the detection of chemical reactions by catching luminescence. By arranging such probes in a three-dimensional space, and measuring with the elapse of time, it will become possible to measure functions of biomaterials in four dimensions.

Figure 4 illustrates a schematic diagram of a Multi-probe System used for measuring functions of biomaterials. In this project called the “Intracellular Odyssey,” signals are input into cells using a Multi-probe System and space-time distribution data (four-dimensional information) such as current are measured in order to catch the changes in cells corresponding to the input signals. It is expected that functions of biomaterials can be accurately measured by realizing the measurement in an environment that keeps the activity of cells.

3.3 Application to the development of existing semiconductor devices

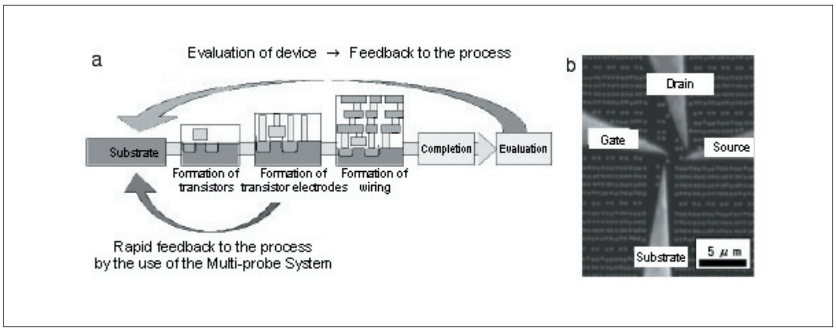
In addition to the creation of new research fields in the nanotechnology and biotechnology areas, the Multi-probe System is expected to contribute significantly to the development of existing semiconductor devices.

In the process of present semiconductor development, the loops of "design-manufacturing-assessment-change of design and manufacturing process" (the loop shown in the upper part of Figure 5) are repeated. In the past, the performance of a device had been evaluated by the finished product after the completion of the manufacturing process. This process from the start of production to the completion of assessment requires about 50 days. To reduce this long period required for the development of a device, Hitachi, Ltd. and Renesas Technology Corporation are trying to utilize the Multi-probe System for the assessment of performance during the manufacturing process before a product is completed[7, 8]. The use of the Multi-probe System enables the confirmation of the performance of a device when manufacturing of the main structures including transistors have been completed, making it fast to generate feedback for the changes in the design and manufacturing process (the loop shown in the lower part of Figure 5). By adopting this process, the assessment can be made within about 20 days after the start of manufacturing, so that the period required for the loop of a device's development is reduced to half or less. This means that when the period required for development is half a year at present, it can be reduced to three months. Since the speed of product development and the improvement of yield (ratio of accepted products) are directly linked to profits, effects of the reduction of the period required for product development realized by the introduction of the Multi-probe System are significant.

4 Status of development in Japan and overseas

Table 1 shows major organizations that are carrying out the development of the Multi-probe

Figure 5:Reduction of the period required for the development cycle by use of the Multi-probe System



Source: Authors' compilation based on the chart provided by Hitachi, Ltd., Renesas Technology Corporation, and Hitachi High-Technologies.
a: Conceptual diagram for the reduction of the development cycle
b: Probes brought to contact with a transistor electrode

Table 1:Major organizations that are carrying out the development of the Multi-probe System

	Research institute	Measuring instrument manufacturer
Domestic	National Institute for Materials Science* The University of Tokyo* Hitachi, Ltd.* Fuji Xerox Co., Ltd.* Osaka University* National Institute of Advanced Industrial Science and Technology Toyota Technological Institute Tokyo Institute of Technology	JEOL Ltd. Hitachi High-Technologies Unisoku Co., Ltd.
Foreign	University of North Carolina (U.S.A.) Harvard University (U.S.A.) University of Wisconsin (U.S.A.) Denmark Institute of Technology Seoul National University (Korea)	Omicron (Germany)

* Organizations that have disclosed actual data

System. Both in Japan and foreign countries, most of them are research institutes (including private research institutes). This fact indicates that researchers themselves are developing equipment in order to carry out the most-advanced research and development work. The Multi-probe System is often thought to be a simple device constructed only by adding a plural number of probes to the SPM. However, the difficulty of development is much greater because the subject of measurement has been changed from structures to functions. For this reason, some research institutes have given up on continuing research due to this difficulty. However, the number of institutes that challenge the difficulty, stimulated by the report mentioned in the preceding section, is definitely increasing.

Table 1 shows that the development is being carried out by many Japanese organizations. This comes from the fact that the first successful prototype was completed by a Japanese research institute. In particular, actual data have been disclosed only by Japanese organizations. That is, Japan is now leading the world in the development of equipment at the research level.

As for the status of development carried out by domestic and foreign manufacturers, however, domestic manufacturers are dominant in number, but Omicron (Germany), which is the only foreign manufacturer that is carrying out the development, has already completed a prototype and started sales. Although Japanese manufacturers are promoting the development cooperating with research institutes, they have not yet reached the level of commercialization.

In the Multi-probe System, it is important how to control a plural number of probes in the measuring procedure as well as the accumulation of tremendous know-how that can be obtained only by actual application of the device in research work. This means that both the ability to carry out research work and that to develop equipment are required. If a measuring instrument manufacturer constructs a device by simply mounting a plural number of probes, the device will not function as a Multi-probe System. In the development of a most-advanced device, manufacturers often provide the market (researchers) with prototypes and obtain feedback from the market in order to complete the products with higher quality. This is certainly the case with the development of the Multi-probe System. The reason why no data have been reported from research institutes that have just purchased instruments available on the market is that the performance of instruments is not yet satisfactory. Table 1 does not include those research institutes that use purchased instruments available on the market.

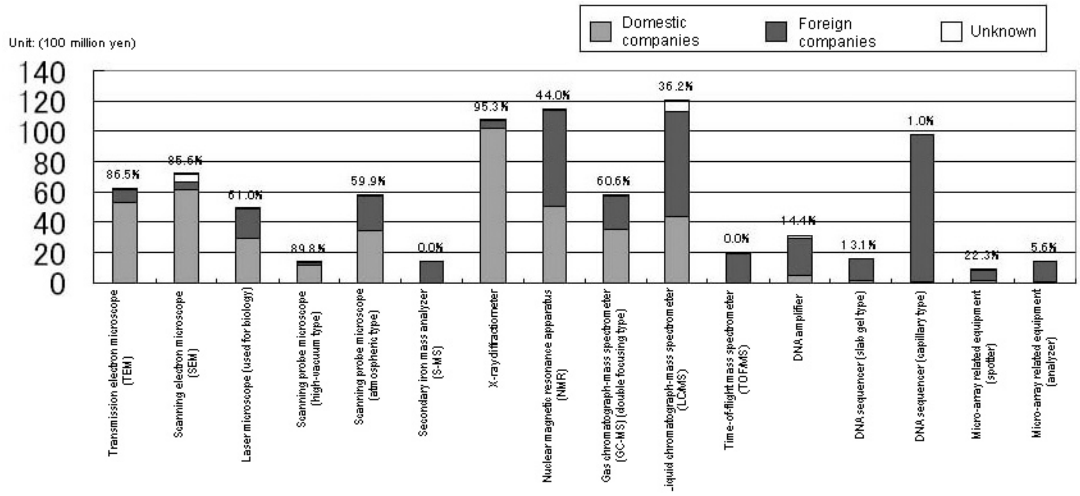
The know-how indispensable for the development of the Multi-probe System has been sufficiently accumulated in Japan because research institutes are leading the world in the development, and, as such, Japan has a good chance to catch up and lead in the competition of commercialization. To realize this, it is necessary to promote the development with close cooperation between researchers and equipment developers.

5 Importance of the development of new measuring and analytical instruments

Most-advanced measuring and analytical instruments are indispensable for leading foreign countries in research and development and early commercialization of new technologies. In many cases, creative research results are supported by the most-advanced instruments that have been developed independently. The fact that many of the researches that have been awarded the Noble Prize have been integrated into the development of new measuring methods also indicates this. An immediate example is carbon nanotubes that were discovered in Japan and are considered to play a very important role in nanotechnology. This discovery was very much dependent on the electron microscope technology, which is one of Japan's specialties.

Unfortunately, however, many of the measuring and analytical instruments being used in the present workplaces for research in Japan are those that have been developed and commercialized in foreign countries. This is particularly true for the most-advanced equipment. Figure 6 shows the share of domestic and foreign companies for major most-advanced

Figure 6:Share of domestic and foreign manufacturers in major most-advanced measuring and analytical instruments (FY 2001)



Source: Prepared by the Research Environment and Industrial Relations Division, Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology based on the "Science and Technology Year Book" (published by R & D Corp., 2002)

instruments that are used in Japan. The chart shows that the most-advanced instruments used in biomaterials, which belong to one of the most important fields of research and development, are almost monopolized by foreign companies. Even with the instruments, the market share of which is occupied by domestic manufacturers, many of the high-performance instruments are provided by foreign manufacturers, and the scanning probe microscope, which is the basic technology of the Multi-probe System we are talking about, is an example of such cases.

It should be noted that procurement of most-advanced measuring and analytical equipment of foreign make leads not only to the outflow of budget but also to defeat in the fields of research and development. From this point of view, measures to promote the development of most-advanced measuring and analytical equipment are being investigated by the "Commission investigating the development of advanced analytical technology and instruments" (Ministry of Education, Culture, Sports, Science and Technology) and other organizations, and it is strongly desired that these measures are taken without fail as quickly as possible. We would like to point out that emphasis must be placed, under such development, on new devices and instruments that may contribute to the exploitation of new research and development fields with originality as well as on those that provide the research and development fields with new methods by improving conventional devices and instruments.

Particularly in the efforts to improve conventional devices and instruments, it is important to judge whether the development can contribute towards opening a road to new research and development fields. In the history of the development of the electron microscope, for example, the improvement of resolution power from 1 nm to 0.1 nm gave much stronger impact to the fields of research and development than that from 10 nm to 1 nm, although both improvements are expressed by the same factor of 10. The former made it possible to observe atoms for the first time and opened the road to the technology that is called nanotechnology today. The above-mentioned STM had a prototype instrument called a "topografiner"[9]. Although its constitution was almost the same as that of the STM, its resolving power was at the sub-micron level and it could not give such impact to the research fields that the STM did. The STM is now widely used because resolving power at the atomic level has been realized.

6 Conclusion

In order to lead foreign countries in the fields of research and development, it is indispensable to develop new, unique measuring and analytical equipment with originality. In the fields of nanotechnology and biotechnology, for example, completely new technologies and products different from conventional ones are being developed by making use of the unique functions of new materials such as biomaterials and nanomaterials. To achieve such objectives, the first and foremost thing to be done is to obtain knowledge of the functions that those new materials have, and the measurement of the functions cannot be done with conventional apparatus. In this report, we have introduced the Multi-probe System that is expected to pave the road toward creating new methods of research and, consequently, to create new research fields.

The Multi-probe System is a device in which the number of probes of the Scanning Probe Microscope (SPM) is increased. By the integrated control of a plural number of probes, direct measurement at the nano-scale level is enabled, which even the SPM could not achieve. Fortunately, Japan is leading the world in the development of this apparatus that has just started. The key to the success of the Multi-probe System lies in the development of the integrated control method of a plural number of probes including the development of measuring methods. In the development of the Multi-probe System, therefore, it is required for researchers, the users, and the device makers to closely cooperate more than in any other conventional devices and instruments. For Japan to overwhelm other nations in the fields of nanotechnology and biotechnology taking the advantage of the present lead, it is strongly desired to take national measures that promote the research and development in these fields.

Acknowledgements

We would like to express our gratitude to Dr. Tomonobu Nakayama of the National Institute for Materials Science and Dr. Yasuhiro Mitsui of Hitachi High-Technologies for the relevant advice and precious materials that they have provided.

References

[1] http://www.sk.icrr.u-tokyo.ac.jp/index_j.html
[2] http://www.shimadzu.co.jp/aboutus/nobel/
[3] Seizo Morita, “Scanning probe microscope,” Maruzen. (in Japanese)
[4] http://www.1.ibm.co/ibm/history/catalog/itemdetail_802000213.html
[5] G. Binnig, H. Rohrer, Ch. Gerber and E. Weibel, “7×7 reconstruction on Si (111) resolved in real space,” Phys. Rev. Lett. 50, 120 (1982).
[6] Masakazu Aono et al., “Nano-wire Electrical Conductivity,” Japanese Scientific Monthly, 54, 989 (2001). (in Japanese)
[7] Y. Mitsui et al., “Physical and Chemical Analytical Instruments for Failure Analyses in G-bit Devices,” International Electron Devices Meeting 1998, Technical Digest, IEEE, 1998, pp. 329-32.
[8] Takahiro Onai et al., “Outlook for Advanced Semiconductor Process and Manufacturing,” The Hitachi Hyoron, p. 5, April 2003. (in Japanese)
[9] R. D. Young, J. Ward and F. Scire, “The topografiner: An instrument for measuring surface micro-topography,” Rev. Sci. Instrum. 43, 999 (1972).

(Original Japanese version: published in December 2003)

7

The Expanding Percentage of Women among Corporate Science and Technology Human Resources
– EU Policies and Japanese Issues–

YUKO ITO
Life Science and Medical Research Unit

1 Introduction

Sponsored by Germany's Federal Ministry of Education and Research and the European Commission, the Women in Industrial Research (WIR) conference was held on October 10 and 11, 2003, in Berlin's Dresdner Bank. The conference discussed topics such as the significance of support for female researchers (engineers)*1 in industry, results and analysis of statistical surveys carried out in the EU, and policies to increase the number of female researchers (engineers). The conference was an international one, with 300 registered participants drawn not only from the EU but from all over the world. The high level of interest in the subject was made clear.

Women in Industrial Research (WIR) is a research program within Women and Science, a part of Science and Society in Europe (€80-million budget) in the EU's Framework Program 6 (FP6, 2002-2006). The WIR specialist group gathers and analyzes statistics on female researchers (engineers). In 2003 it published two reports, "A wake up call for European Industry[1]" and "Analysis of statistical data and good practices of companies[2]."

In addition to WIR, the other Women and Science programs are Mainstreaming Gender and Collecting Statistics in FP6, the Helsinki Group on Women and Science, Women and Science Networks, Sex-disaggregated Statistics and Indicators on Women Scientists, and Promoting Gender Equality in Science in a Wider Europe (see Table 1). In this way, Europe is advancing policies on "Women and Science" not just at the national level but also at the EU and European levels.

In Japan, a policy research program under the science and technology policy advice program for fiscal 2001-2002 science and technology new adjustment funds was implemented in the form of survey research focusing on female researchers in science and technology. The program issued

Table 1:FP6 Science and Society programs*

Program	Content or included programs
Young people and Science	• EU Young Scientists Contest (ages 15 to 20) • Young Women Scientists Contest
Women and Science	• Mainstreaming Gender and Collecting Statistics in FP6 • The Helsinki Group on Women and Science • Women and Science Networks • Sex-disaggregated Statistics and Indicators on Women Scientists • Women in Industrial Research (WIR) • Promoting Gender Equality in Science in a Wider Europe
The Science and Society Action Plan	Thirty-eight actions, including: • Promoting scientific education and culture in Europe • A science policy closer to the citizens • Responsible science at the heart of policy making

*In addition to the above, Science and Society also includes programs on Science and Governance, Ethics, and Scientific Awareness.
Source: Author's compilation based on "EU Sixth Framework Program" (http://www.cordis.lu/fp6/society.htm)

a science and technology policy advisory report, "Developing the ability of female researchers in science and technology fields," in March 2003. The survey research focused on female researchers and engineers at universities and research institutes. The implementation of such policy research programs is highly significant, and it is to be hoped that such large-scale research will continue with its focus expanded to include female researchers and engineers in private industry as well.

This article will discuss the EU's experiments with the fostering and promotion of female researchers and how Japan could adapt that experience into a comprehensive science and technology human resources policy.

2 Why does the EU focus on female researchers?

Underlying the attention that the EU pays to female scientists is the advent of an era of global competition in science and technology. The status of advances in science and technology has come to impact societies and economies.

The following two reasons create the necessity for and form the background underlying the EU increasing the number and percentage of female researchers.

(1) Strengthening the competitiveness of the EU

At the 2000 Lisbon Summit, it was declared that the EU would become the world's leading intellectual-base economic body, and at the 2002 Barcelona Summit it was determined to raise research and development spending in the EU from 1.9 percent of GDP to 3 percent by 2010. The EU is therefore studying how to raise the number of researchers in the EU as a whole by 500,000[*2].

(2) Economic activation

Women pay attention to women as a market of consumers and develop products that meet women's needs and attract their interest. This is expected to result in increased domestic consumption and the development of new industry.

The EU considers policies towards science and technology human resources important in achieving such "strengthened competitiveness" and "economic activation." It emphasizes the need to increase the percentage of female researchers on these grounds also:

- Ensuring outstanding human resources
- Introducing diversity into human resources

There is an increasing need for human resources who welcome this era of global competition, have multiple skills, are highly creative, can respond innovatively across disciplines, can create new ideas and businesses, and will become a driving force for diversity.

The EU has the following ideas regarding concrete steps to improve the insufficient development of outstanding science and technology human resources and to increase the percentage of female researchers.

(a) Improved work environments

The lifestyles of young people (both men and women) are changing, and when choosing a place to work they are tending to look for fluidity (adaptability) of balance between work and life, and for fully-realized systems. In order to secure the outstanding science and technology personnel of the next generations, current deficiencies in systems must be improved.

Progress on workplace environments (childcare and family leave, for example) varies among the countries of Europe, and in comparison with the United States this becomes an obstacle in the flow of outstanding personnel into Europe and their retention there.

(b) Finding new points of difficulty by analyzing successful cases

The percentage of women grows smaller at each step up the career ladder. Polices to increase the percentage of women at the top can be found in companies that have succeeded in bringing women into the tops of their hierarchies.

3 International comparison of the percentage of female researchers

In order to better understand the status of female researchers, I compared the percentage of female researchers among all researchers in various countries.

3.1 Percentage of female researchers

Figure 1 shows the percentage of female researchers among researchers in all fields. While the percentage of researchers who are female in Japan is about 10 percent, in Europe it ranges from 25 to 40 percent.

Because the percentage of female researchers is likely to be connected to the percentage of women among graduates from university science and technology departments and recipients of PhDs, Figure 2 shows the percentages of such women in Japan and the EU.

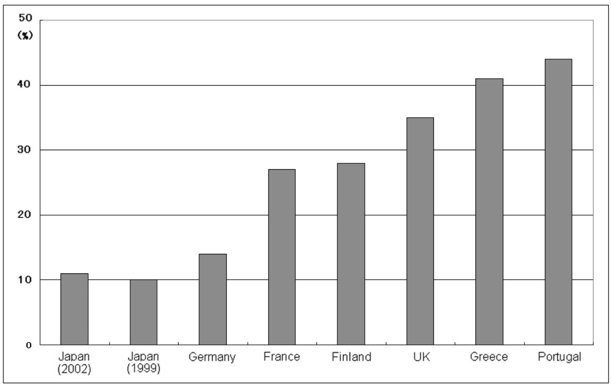
The percentage of women among graduates of university science and technology departments in Japan is approximately the same as in Germany, while it is about 10 percentage points below that of France, the UK, and the EU 15.

As described in section 5 below, Germany has worked out a policy emphasizing "researcher development" to increase the percentage.

3.2 Percentage of female researchers in industry

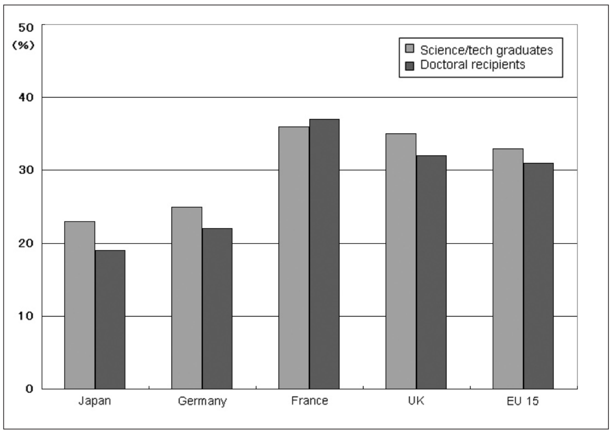
What is the percentage of females among researchers attached to corporations? Figure 3 shows the percentages of researchers who are

Figure 1:International comparison of percentage of female researchers (1999)



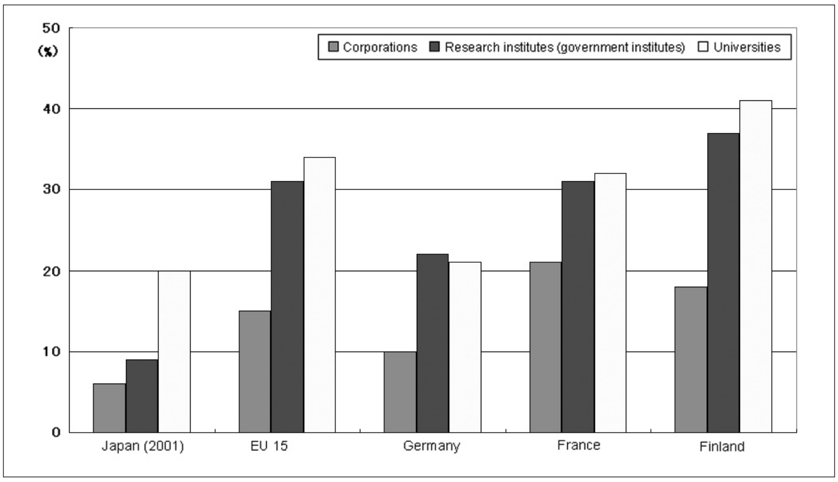
Sources: Author's compilation based on "She Figures 2002", Science and Society, European Commission and "Survey of Research and Development", Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications.

Figure 2:Percentage of women among graduates of science and technology departments and recipients of doctoral degrees



Sources: Author's compilation based on Reference[2] and FY 2002 Basic Survey on Schools.

Figure 3:International comparison of female researchers by sector (2000)



Source: Author's compilation based on "She Figures 2002," Science and Society,European Commission.

female by sector in Japan, three EU countries and EU15.

The percentage of researchers who are female in all three sectors-universities, research institutes (government institutes), and corporations-is much lower in Japan than in the EU. Within the EU, Germany has the lowest percentage of female researchers in all three sectors, while Finland has the highest in each.

Comparing the percentage of females by sector, universities have the highest percentage. The average for the EU 15 is 34 percent, and 44 to 46 percent of researchers at universities in Ireland, Portugal, and Greece, which are not included in the chart, are female.

The percentage of researchers who are female is lowest in the corporate sector in each country. The average in the EU 15 is 15 percent, while in Japan it is only 6 percent.

4 EU experiments to increase the percentage of female researchers

Although, as described in section 3 above, the percentage of EU researchers who are female is significantly higher than in Japan, there is a sense of crisis concerning the situation in the EU, and, as mentioned in section 2 above, the EU is undertaking a number of experiments to improve it.

The following policies can be considered in order to increase the number of female researchers in corporations: 1) Fostering of female researchers by corporations and 2) improving the corporate environment. Furthermore, In order to understand current conditions and any progress that is made, 3) statistical research can also be considered important.

Below I will describe some examples of programs.

4.1 Fostering of female researchers by corporations

(1) Cases in Germany

As can be seen in both Figure 2 and Figure 3, Germany has a lower percentage of women proceeding with science and technology study compared to the EU 15 as a whole, and the percentage of researchers who are female in corporations is also low. A number of national programs related to increasing the number of women majoring in information technology fields and working in corporations are therefore underway (see Table 2).

Expectations for Girls Day, which has been held since 2001 with support from Germany's Federal Government and elsewhere, as a policy to foster future human resources in science and technology fields are particularly high. Last Girls Day, May 8, 2003, 100,000 girls at 10 and older

Table 2:Current major German programs to foster female researchers

Program name	Purpose	Targets	Website
Women in the Information Society and in Technology	To increase the number of women majoring in science, technology, and computer science	Young women	www.kompetenzz.de
Be.ing – in Future together with Women	To increase the percentage of women in information technology (IT) fields	Young women	www.be-ing.de
be.it	To increase the percentage of women in IT fields	Young women	www.werde-informatikerin.de
Do.ings	To support higher education for women who choose science and technology courses	Female children and students	www.do-ing.rwth-aachen.de
Initiative D21	To increase the percentage of women in IT fields	Young women	www.initiatived21.de
Girls@D21	To increase understanding of the jobs of IT specialists	Female children and students	www.girls-d21.de
Girls Day	To increase opportunities to find out about corporate jobs through corporate visits	Female children and students	www.girlsday.de
Chemistry in Context	To increase the number of female university students who study chemistry	Female children and students	www.chik.de

Source: Author's compilation based on Reference[4] visited 3,905 research centers, corporations, and offices.

(2) Cases in the UK and the USA

Similar to the German program are the Take Our Daughters to Work programs in the UK and the USA. The US program began 10 years ago, while that of the UK began on April 3, 2003. The purpose of the programs is to show girls who may only be thinking of traditionally female jobs a variety of workplaces and jobs. They are intended to broaden girls' options when they choose jobs in the future.

The US program was revised on April 24, 2003, becoming Take Our Daughters and Sons to Work. According to the sponsors, that is because the goals for girls in the US have been achieved.

4.2 Improvement of workplace environments in corporations

Corporations that provide workplace environments comfortable for all workers can be considered as providing the same for researchers as well. To promote the improvement of workplace environments, the European Commission holds the Great Places to Work contest. On March 27, 2003, it announced the latest list of the 100 most outstanding companies (www.eu100best.org). Many of the 100 companies carry out research as their primary business. The list is the result of a survey of over 210,000 people (about 124,000 valid responses) who work for more than 1,000 organizations within the 15 EU countries. Eleven nominated companies are chosen from the results of the survey, and the best are finally chosen after further judging. In the 2003 contest, the legal firm Hannes Snellman (Finland) was chosen as best in the Lifelong Learning category, IT company Intel (Ireland) in the Diversity category, and pharmaceutical corporation Schering (Germany) in the Gender Equality category.

The magazine The Scientist also surveyed its readers (most of whom are researchers) regarding the quality of their workplace environments, and the results were announced in June 2003[9].

The abovementioned WIR also carried out survey research (including individual interviews) regarding workplace environments, and the results were made public[3]. The survey asked: 1) If company managers are carrying out "gender equality," "human resources diversification," and "maintenance of dignity in the workplace." 2) If the company carries out supervision, evaluation analysis, statistical surveys, and advice regarding gender equality. 3) If the company welcomes innovation and provides fulfilling career opportunities. 4) If hiring, promotion, and evaluation practices are fair and open. 5) If work schedules are flexible. 6) If childcare and family leave and facilities related to them are available. 7) If there are programs (internships and fellowships) to help young women enter scientific fields. 8) If there are women's networks. Table 3 shows data regarding women researchers made public after a WIR survey. Data are from one or two companies that cooperated with the survey in each sector.

Along with providing incentives for workplace improvement, the results are likely to be considered by young people (both men and women) seeking employment. Corporations are therefore likely to become more aware of the issue of workplace improvement.

It is to be hoped that in the future Japanese corporations will also make public the status of their utilization of women researchers.

5 The corporate need for researchers and current conditions in Japan

This section will discuss current conditions for researchers in Japanese corporations and consider the possibilities for the utilization of women as science and technology human resources.

5.1 A perception of too few researchers in corporations

In September 2003, the results of a survey of approximately 2,000 corporations that carry out research and development activities and are estimated to be capitalized at ¥1 billion or more were reported in the "The Survey on Research Activity of Private Business (FY2002)" (Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology). The survey results included data regarding science and technology human resources such as researchers.

The report indicated a shortage of science and technology human resources (see Figure 4). Of 1,061 companies responding, 40 percent answered "Insufficient" regarding their "Researcher" human resources.

Research sectors in which close to 30 percent of companies reported a shortage of researchers are Information and Communications, Manufacturing Technology, and Nanotechnology and Materials (see Figure 5).

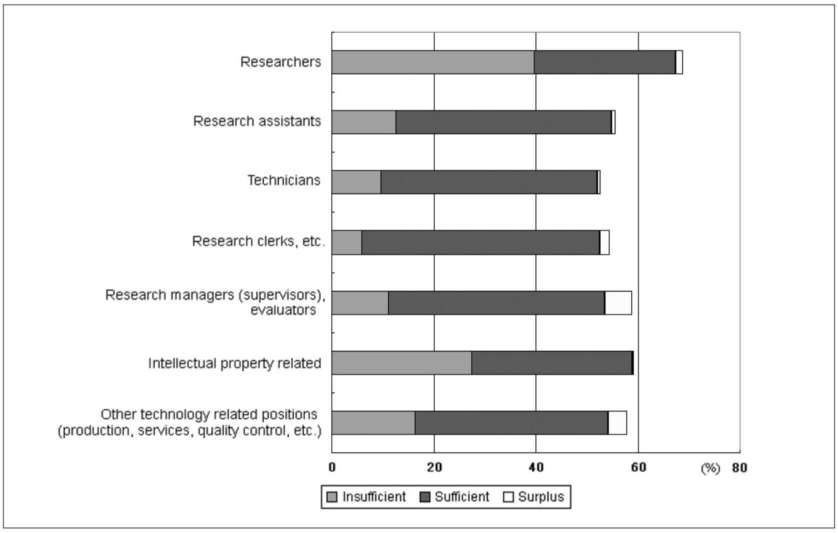
Of corporations reporting a shortage, 45 percent chose "The total number of researchers is small due to employment conditions and other factors" or "Because of the diversification of specialties, there are not enough researchers, including new graduates, to handle them" as the reason.

Table 3:Utilization of women in major corporations

Company (headquarters country)	Sector	Number of researchers	Number of female researcher (percentage)	Number of female research managers (percentage)	Percentage of patent applicants who are female
AstraZeneca (UK)	Pharmaceuticals	10,000	5,000 (50%)	29% (of research supervisors)	17%
Schering AG (Germany)	Pharmaceuticals	480	140 (29%)	27 (17%)	
DSM (Netherlands)	Life sciences	2,000	400 (20%)	1 (0.5%) R&D director, 20 (20%) resource managers, 50 (10%) project managers	
Ford European Research Center (Germany)	Automobile manufacturing	272	16 (6%)	3 (5%)	1 of 43 patent applications
Schlumberger, worldwide (USA, France, Netherlands)	Petroleum	3,308 (including engineers)	614 (19%) (including engineers)	47 (9%)	
Siemens AG, worldwide (Germany)	Energy	53,100	7,400 (14%) (including engineers)	8.6%	

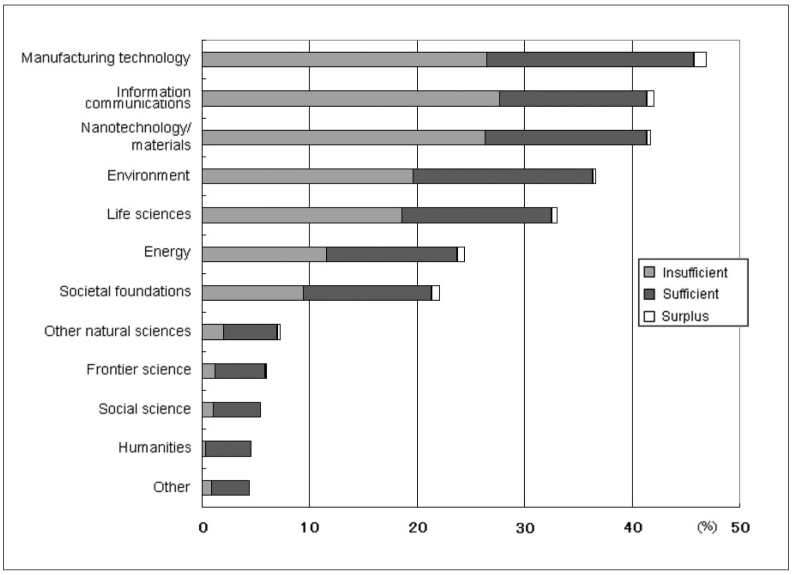
Source: Author's compilation based on Reference[3]

Figure 4:The shortage of science and technology personnel in Japan (percentage of 1,061 corporations responding)



Source: Survey on Research Activity of Private Business (FY2002)
(Science and Technology Policy Bureau, Ministry of Education,Culture, Sports, Science and Technology)

Figure 5:The shortage of researchers in Japan (percentage of 1,061 corporations responding)



Source: "Survey on Research Activity of Private Business (FY2002)"
(Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology)

5.2 Changes visible in the utilization of female researchers by corporations

Can the deficiency of researchers shown in Figure 5 be made up for by female researchers?

Figure 6 shows trends in the number of women researchers and can help answer that question. Most Japanese women researchers in corporations are in the chemicals, electrics and communications, and pharmaceutical sectors. Looking at trends over the 20 years since 1981, the increase in women researchers in electrics and communications is remarkable. The number of female researchers has increased markedly in the past 5 years as well. This trend continued in fiscal 2001 and 2002, with a reported increase of about 1,000 female researchers in 1 year. Furthermore, in electrics and communications, the percentage of researchers who are female increased from 2 percent in 1996 to 4 percent by 2002.

In the Information and Communications sector (in the survey, including information, communications systems, electrical, electronics, computers, etc.), shown in Figure 5 to perceive a shortage of researchers, and in the identical electronics and communications sector, a strong upward trend in the number of female researchers can be seen. It is likely that corporations are actively employing female researchers in sections experiencing shortages.

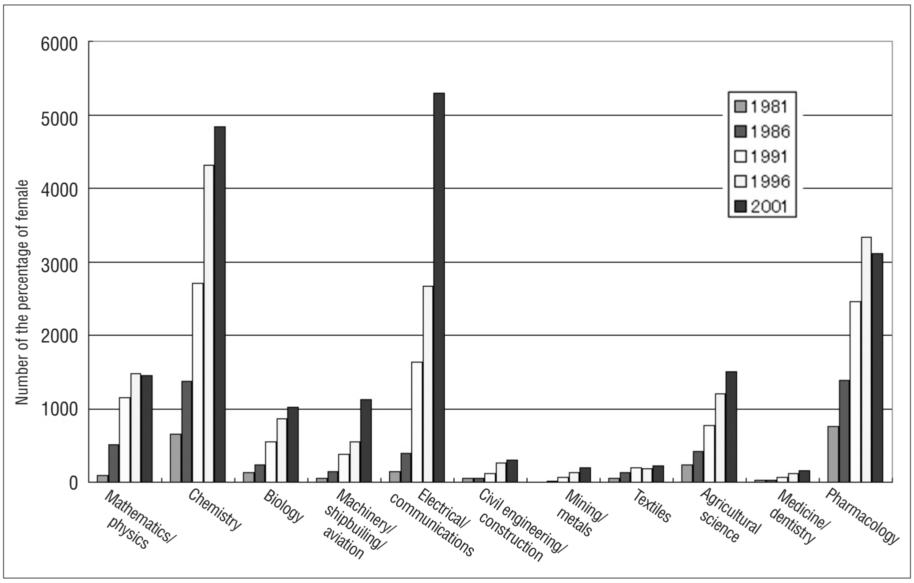
In universities, the most common fields for female researchers are medicine and dentistry, while in laboratories and other research institutes agriculture is the most common field for women researchers. Both universities and research institutes have seen increases in the 20 years since 1981. In this way, the fields in which women researchers have increased have differed among corporations, universities and research institutes.

Because corporations must respond quickly to advances in science and technology, it appears that they are tending over the past few years to employ human resources who meet their needs without regard for gender.

5.3 Gender gap visible in work performed by researchers

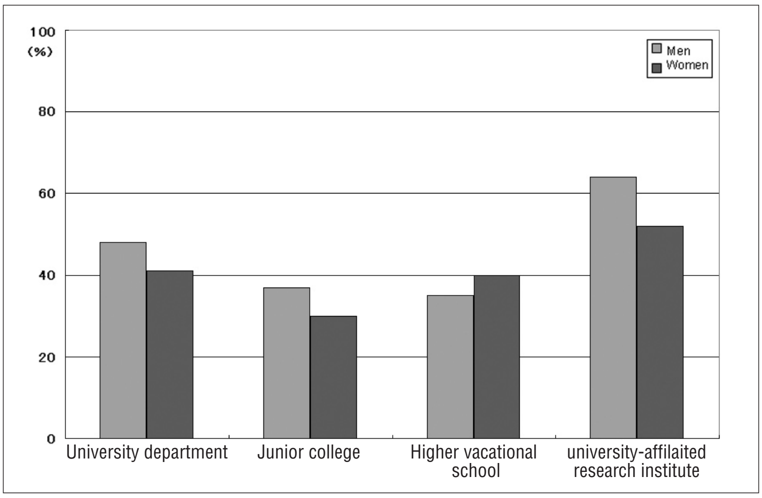
The amount and percentage of time spent on research will vary among researchers. The work of some researchers will primarily be research, others will have some additional duties, while still others will hold an additional post other than research. The non-research activities of university researchers include education (teaching, advising students, and so on) and societal activities (consulting, transferring technologies resulting from research, and so on). The non-research work of corporate researchers may include management duties and patent-related tasks. To understand the status of researchers' activities,

Figure 6:Trends in female researchers by sector (corporations)



Source: Author's compilation based on "Survey of Research and Development," Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications

Figure 7:Comparison of percentage of all work time spent on research by gender and type of institution



Source: Author's compilation based on "Report on the survey of FTE Data on Researchers in the Higher Education Sector," Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology)

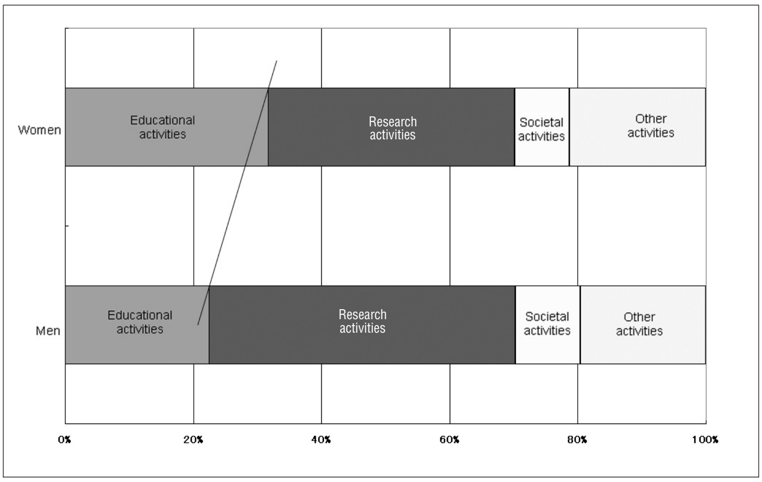
factors such as their work duties and time spent on research must be surveyed.

The Report on the survey of FTE Data on Researchers in the Higher Education Sector (Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology) was published in November 2003. Educators (professors, assistant professors, lecturers, and assistants) at randomly selected colleges (including junior colleges, higher vocational schools, and university-affiliated research institutes) were surveyed regarding the content of their work, such as "Research activities" and "Educational activities," and the amount of time put into it. Respondents numbered 6,090 men and 1,088 women, and the results showed a difference in time spent on research by men and women.

As shown in Figure 7, when the research hours of men and women are compared by university department, junior college, or university-affiliated research institute, women spend a smaller percentage of their time on research than men do.

To compare the time spent by men and women on non-research activities, Figure 8 shows a breakdown of the annual work hour usage, which demonstrates a gender difference. Women spend less of their time (39 percent) than men (48

Figure 8: Breakdown of annual work hours (percentage) by gender



Source: Author's compilation based on "Report on the survey of FTE Data on Researchers in the Higher Education Sector," Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology)

percent) on research activities, and more than men on educational activities (32 percent and 22 percent, respectively).

The causal factors of this difference are unclear, as is the question of whether it disadvantages the promotion and advancement of women. Detailed analysis of those points is needed. First, however, research to determine how many female researchers are employed by corporations and whether their actual duties differ from those of men in the same jobs is required.

6 Conclusion and proposals

The development and use of science and technology human resources that are the driving force behind breakthroughs and scientific and technological advances constitutes an important policy for advanced countries.

In Europe, it is believed that "A society of clones will only produce cloned ideas." With "Escape from a clone society" and "Moving towards a diverse society" as keywords, polices to create diversity by increasing the percentage of women among science and technology human resources are being implemented. The United States, which holds to the ideal of a "diverse society" that incorporates women and various races and is one of the first in the world to become such, leads the world in science and technology.

In Japan as well, "diversity" is now seen as important in science and technology and society, and the activities of women in various sectors of society are noteworthy. The number of female researchers has indeed increased over the past 10 years. However, women as a percentage of all researchers have remained at about 10 percent for several years, and there is no sign that this will change. Moreover, in corporations, only 6 percent of researchers are female.

The percentage of researchers in the EU is double or triple that of Japan. Despite that fact, the EU believes it is necessary to increase the percentage of female researchers to 30 percent in corporations to build "diversity," and it is undertaking various initiatives to do so.

It is difficult to estimate the optimal percentage of female researchers for Japanese corporations. One idea is that raising the percentage in Japan to the EU's current level should be Japan's goal for the time being. It should be possible for Japan to consider national policies in reference to those of the EU.

Below I discuss issues for Japan and some possible measures.

Issues

(1) The percentage of women in science and technology fields among university graduates and PhD recipients is low.

(2) The percentage of corporate researchers who are women is low.

(3) There is no national body like Women and

Science of the EU's Framework Program 6 to implement comprehensive programs for statistical surveys related to women and science, academic research, or research-support grants.

Policies regarding issue (1)

- Foster female human resources in science and technology from school age

Plan a Japanese version of Girls Day and Take Our Daughters to Work, increase opportunities for girls to dialog with researchers and engineers and to visit science and technology facilities, awaken girls' interest in science and technology, and secure and foster future science and technology human resources.

Policies regarding issue (2)

- Carry out survey research regarding women who do research in corporations

In the EU, the career path of women is referred to as a "leaky pipe." At each stage up the career path, from university graduation to the very top, the percentage of women declines until finally very few of them come out of the pipe at the other end. This phenomenon is found not only in women's academic career paths, but in corporate ones as well. Various research is now being carried out to uncover its major causes.

As in the EU, in Japan it is necessary to analyze obstacles to the career paths of female researchers, through statistical surveys of employment forms and work duties and conditions, by tracing the career paths of women who hold university and graduate school degrees in scientific and technical fields, and by carrying out interviews with female researchers in corporations.

Policies regarding issue (3)

- Clarify the agency responsible for "women and science"

A government agency should be designated to function to plan and carry out survey research and research grant support and research programs including statistical surveys related to the development and support of women as science and technology human resources.

In the European Commission, since 1998 the Women and Science Unit of Directorate C of the Research Directorate-General has been carrying out such policies[10].

- Focus on women as science and technology human resources in the Third Basic Plan

In the Third Basic Plan to open in 2006, establish the category "Developing, utilizing, and supporting women as science and technology human resources" and clarify its place in science and technology policy.

Notes

*1 The definition of "researcher" in this report

In the Report on the Survey of Research and Development (Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications), "researcher" is defined as "a person who has graduated from a college other than a juniror college (or who has at least the equivalent amount of specialist knowledge) and who carries out research on a specific research theme." "Research" is defined as "creative efforts and pursuits to obtain new knowledge about things, functions, phenomena, etc., or to open the way to new applications of existing knowledge." That definition is identical to the one used in the Frascati Manual, an international statistical guideline. The definition of "researcher" is also therefore also broad, and for the purpose of this article "researchers" includes "engineers." However, technicians and others who perform support or routine work are not included among "researchers."

*2 Number of researchers

940,000 in the 15 EU countries, 1.22 million in the United States, and 660,000 in Japan (1999 statistics).

References

[1] Women in Industrial Research, A wake up call for European Industry, Science and Society, EC (2003).

[2] Women in Industrial Research, Analysis of statistical data and good practices of companies, Science and Society, EC (2003).

[3] Women in Industrial Research, Good

practices in companies across Europe, Science and Society, EC, (2003).

[4] Future Opportunities, generated by diversity in higher education and training, Gender mainstreaming as an impetus and driving force behind the course reform in computer science, engineering and natural sciences, International conference (Munich), February 2002, Bundesministerium für Bildung und Forschung.

[5] National Policies on Women and Science in Europe, The Helsinki Group on Women and Science, Science and Society, EC (March 2002).

[6] She Figures 2003, Statistics and Indicators, Women and Science, Science and Society, EC (2003).

[7] Frascati Manual, OECD (2002).

[8] Sally Goodman, "Europe is pushing to get more women scientists into industry and academia, but can the commission legislate for gender equality?" Nature 426, 210-211 (2003).

[9] The Scientist Readers' survey : www.the-scientist.com/industry/topten.html.

[10] Organization of the European Commission Research Directorate-General: http://www.europa.eu.int/comm/dgs/research/index_en.html.

[11] Survey of Research and Development (Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications)

[12] FY 2002 Survey on Research Activities of Private Companies (Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology) (in Japanese)

[13] Report on Fiscal 2002 School Basic Survey (Ministry of Education, Culture, Sports, Science and Technology)

[14] Report on survey of full-time equivalency data in universities (Science and Technology Policy Bureau, Ministry of Education, Culture, Sports, Science and Technology) November 2003. (in Japanese)

(Original Japanese version: published in December 2003)

About SCIENCE AND TECHNOLOGY FORESIGHT CENTER

It is essential to enhance survey functions that underpin policy formulation in order for the science and technology administrative organizations, with MEXT and other ministries under the general supervision of the Council for Science and Technology Policy, Cabinet Office (CSTP), to develop strategic science and technology policy.

NISTEP has established the Science and Technology Foresight Center (STFC) with the aim to strengthen survey functions about trends of important science and technology field. The mission is to provide timely and detailed information about the latest science and technology trends both in Japan and overseas, comprehensive analysis of these trends, and reliable predictions of future science and technology directions to policy makers.

Beneath the Director are five units, each of which conducts surveys of trends in their respective science and technology fields. STFC conducts surveys and analyses from a broad range of perspectives, including the future outlook for society.

The research results will form a basic reference database for MEXT, CSTP, and other ministries. STFC makes them widely available to private companies, organizations outside the administrative departments, mass media, etc. on NISTEP website.

The following are major activities:

1. Collection and analysis of information on science and technology trends through expert network

— STFC builds an information network linking about 3000 experts of various science and technology fields in the industrial, academic and government sectors. They are in the front line or have advanced knowledge in their fields.

— Through the network, STFC collects information in various science and technology fields via the Internet, analyzes trends both in Japan and overseas, identifies important R&D activities, and prospects the future directions. STFC also collects information on its own terms from vast resources.

— Collected information is regularly reported to MEXT and CSTP. Furthermore, STFC compiles the chief points of this information as topics for "Science and Technology Trends" (monthly report).

2. Research into trends in major science and technology fields

— Targeting the vital subjects for science and technology progress, STFC analyzes its trends deeply, and helps administrative departments to set priority in policy formulating.

— STFC publishes the research results as feature articles for "Science Technology Trends" (monthly report).

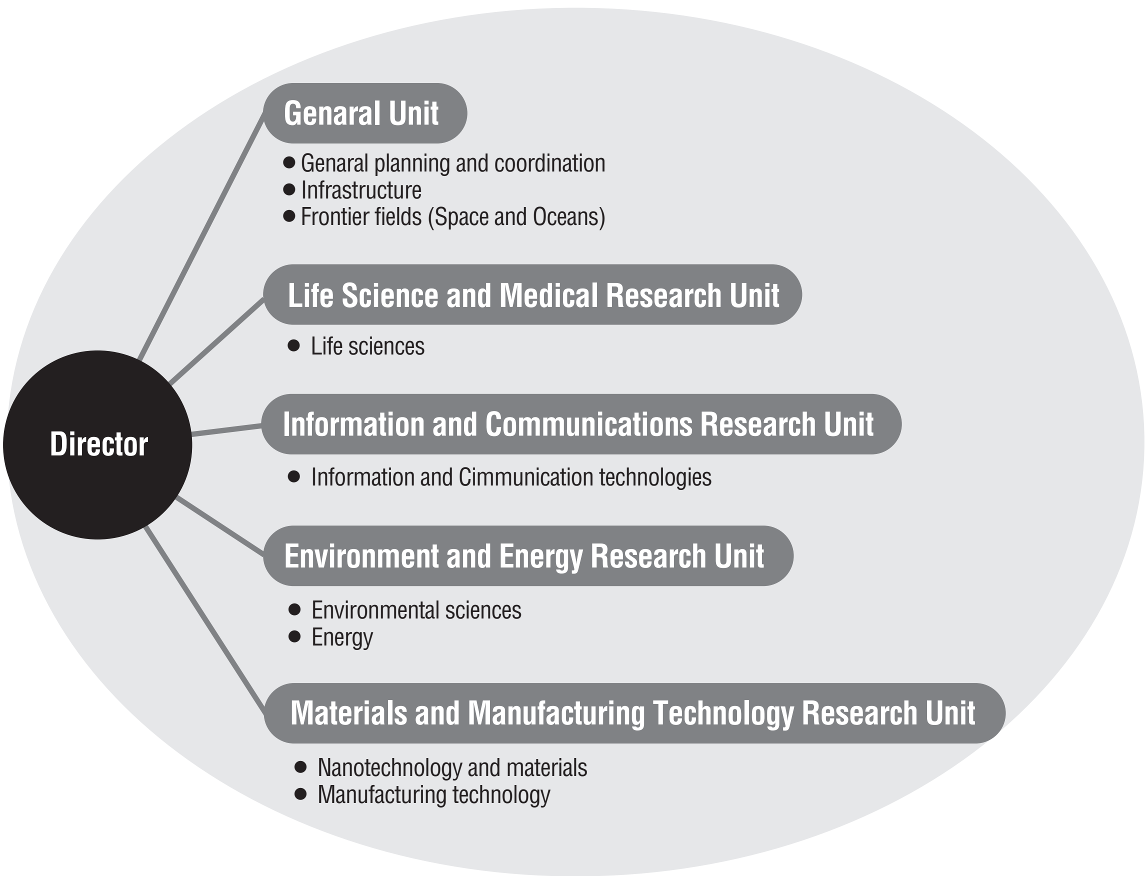
3. Technology foresight and S&T benchmarking survey

— STFC conducts technology foresight survey every five years to grasp the direction of technological development in coming 30 years with the cooperation of experts in various fields.

— STFC benchmarks Japan's current and future position in key technologies of various fields with those of the U.S and major European nations.

— The research results are published as NISTEP report.

Organization of the Science and Technology Foresight Center



＊Units comprise permanent staff and visiting reseachers (non-permanent staff)
＊The Center's organization and responsible are reviewed as required

- Life Sciences
- Information & Communication Technologies
- Environmental Sciences
- Nanotechnology & Materials
- Energy
- Manufacturing Technology
- Infrastructure
- Frontier
- Science & Technology Policy

Science and Technology Trends —Quarterly Review

No.11 April 2004

Science & Technology Foresight Center

National Institute of Science and Technology Policy (NISTEP)

Ministry of Education, Culture, Sports, Science and Technology, JAPAN