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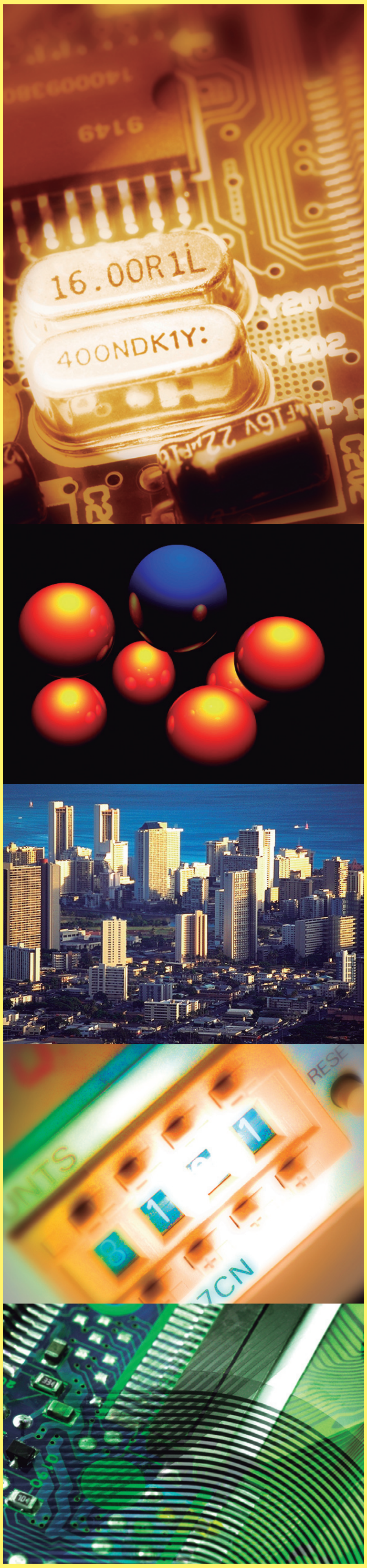


Foreword

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 periodically.

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

Life Sciences

1 Strategies for Reading and Writing Learning Difficulties (Dyslexia)

p.13

Developmental dyslexia (hereafter referred to as dyslexia) is a disorder that affects only the ability to learn to write and read words and numbers without mental retardation, sensory and motor problems, lack of concentration and motivation, or social and cultural hindrances. Dyslexia is caused by the selective developmental failure of the neuronal system associated with reading and writing on a certain genetic basis. There is no difference among races and nations, and reportedly, 6 to 10% of the entire population have a predisposition to some degree of dyslexia. Currently, there is no way of completely curing dyslexia. Up to now, people with dyslexia have had to make an enormous effort to acquire the necessary reading and writing skills, or they have had to live with difficulties throughout their lives. Reading and writing have been the basis of learning in traditional disciplines. For this reason, children with dyslexia who have normal or above-normal ability in other areas are at risk of losing the opportunity to develop their potential. There are examples of dyslexic people who have overcome this problem, and have taken advantage of their unique problem-solving ability, creative thinking ability, superior spatial perception, etc, to demonstrate outstanding achievements in the areas of mathematics, physics, fine arts, politics, economics, and others.

As far as the Japanese language is concerned, the relationship between kana (Japanese characters) and the sounds is consistent, and it is easy to guess the meaning of elementary kanji (characters of Chinese origin), even if you do not know how to pronounce them; therefore, it has been relatively difficult to identify dyslexia. However, when the number of kanji characters, especially those with abstract meanings, increases from around the 3rd grade of elementary school, pupils with dyslexia encounter more learning difficulties. After students enter junior high school and begin to learn English, which is characterized by phonological complexity and a less consistent relationship between orthography and pronunciation, learning difficulties tend to manifest themselves as obvious problems. Because teachers are currently preoccupied with children with behavioral/social disabilities, such as attention deficit disorder/attention deficit hyperactive disorder (ADHD) and high-functioning autism, and because dyslexia is poorly recognized by clinical doctors and therapists, children with dyslexia do not receive appropriate support. Because of unexpectedly poor learning performance, children with dyslexia tend to be misunderstood as being lazy and disobedient, and they lose self-confidence and suffer anxiety about the future, eventually dropping out from school and withdrawing from society.

Therefore, first of all, it is an urgent task to disseminate knowledge about dyslexia, establish a definition of dyslexia and standards for test methods that are suitable for the Japanese language and society, and conduct a survey on the current state of people with dyslexia in Japan. It is necessary that the Ministry of Health, Labour and Welfare, the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Justice (correctional education), local governmental bodies and educational institutions work together to establish a consistent, lifelong support system for people with dyslexia. More specifically, the support system aims (i) to identify children at risk of dyslexia at health checkups for school entry, (ii) to make the best use of the latest scientific findings to provide assistance to children for studying their weak subjects, and to further promote their strong subjects within normal classes, and (iii) to provide assistance to ensure that they do not miss higher education and employment opportunities, and that they can conduct a social life appropriate for their abilities and intentions.

It is evident that dyslexia is a disorder with neurobiological origins, and ultimately, neuroscience is expected to completely clarify dyslexia and provide a scientific basis for educational support. The brain and cognitive sciences are not yet appropriately understood by the public. It would be beneficial if researchers in these areas explained to the public how these sciences contribute to life and society. In addition, pondering the problem of dyslexia provides an opportunity to direct people's attention to the fact that brain functions are diverse among individuals.

(Original Japanese version: published in December 2004)

Information and Communication Technologies

2 Information Systems Supporting Health-promotion Activities Focused on the Individual

p.32

Lifestyle-related diseases are becoming an increasingly prominent component of Japan's disease structure. In order to contain healthcare expenditure, prevention (health promotion) is more than ever required. Healthcare consumers must proactively participate in health-promotion activities, typically where lifestyle-related diseases are concerned. However, because it is not easy for individuals to improve their own habits and maintain them, appropriate outside support is strongly required. This must not be mere moral support, but rational, science-based support, too. Therefore, individual health risk must be assessed objectively, and then appropriate action taken. Information is key in this support.

In this situation, there are several information systems that enable people to handle personal health-care information by themselves. There are information systems that collect and aggregate health-screening data that are generally separated temporally and spatially by individuals' life stages. Systems that predict individual disease onset risk based on collected health-screening data are also being developed. Furthermore, systems that provide one-to-one support for personal health-promotion activities based on assessed health risk are now emerging.

Individual-focused health-promotion activities will increase in Japan as in United States. However, the cost effectiveness of health-promotion activities is not sufficiently clear, and the services are fragmented. At the same time, we should advance cost effectiveness studies based on the abundant data generated from certain services by implementing the test operation of advanced services first, then expanding the results obtained. Adopting information systems in this scheme will promote the efficient collection of individually generated health-related data, as well as tying in with data obtained through research.

Towards diverse services based on private sector creativity, the role of the government is to promote this trend, building an environment for collecting and aggregating health-screening data, finding a balance in the use of personal information between the protection of privacy and the promotion of research, and training "healthcare supporters" with high-touch, high-tech abilities. If the government were to take such an initiative, it would further the collection of information regarding health promotion. This would lead to the creation of a virtuous circle in which the effects of health promotion would be widely recognized, and further activities stimulated.

(Original Japanese version: published in October 2004)

3 Technology and Policy Trends in Frequency Sharing

p.41

The spread of mobile telephones is remarkable, and demand for wireless LAN is also explosive. The Japanese government is advocating "ubiquitous" connections as it advances IT policy.

Utilization of wireless technology requires the securing of spectrum. Utilization of a given frequency that is already in use causes interference. To avoid this, governments have developed spectrum policies that awards licenses to users. As a result, use of new frequencies with new technologies is pushed towards the high end of the spectrum.

However, in the case of television broadcasting for example, there are gaps between channels, so there is extra room within the frequency bands used by that service. Meanwhile, the bands available for use by wireless LAN are crowded and are already approaching their limits. In order to meet skyrocketing wireless demand, various countries are beginning major policy debates on whether to reduce television broadcasting bandwidth, expand frequency sharing for wireless LAN, and so on.

In the United States, a task force was formed within the FCC to carry out drastic review of spectrum policy. The task force recommended spectrum allocation through market principles, government command and control of spectrum designated as wireless for military purposes, and the creation of "spectrum commons." Spectrum commons are frequency bands that anyone can use. In Japan as well, the Information and Communications Council proposed the "Radio Policy Vision," which includes the expansion of spectrum commons.

Many wireless technologies are being developed in anticipation of an expanded spectrum commons. Technology that enables other users to utilize the same frequencies as licensees is being researched. Such technology is called "overlay," and is garnering much attention among those concerned.

Transmitting data below the noise levels of individual frequencies but on a broad frequency bandwidth is the idea behind spread spectrum. As an extension of that, ultra wideband wireless systems that use all of a wide frequency band are being researched. Their commercialization is only a matter of time.

Wireless technologies can only be applied to practical uses when frequencies are available. In this way, spectrum policy greatly influences wireless technology research and development. In order to apply wireless technologies to practical use, it is important that experimentation be easy to carry out. In Japan, outdoor experiments require individual licenses. The idea of utilizing outlying islands with a population of a few thousand as special wireless zones to carry out R&D just before the market stage may overcome this issue.

(Original Japanese version: published in November 2004)

4 Trends in Optical Fiber Communication Technology and Industry, and Proposals for Future Directions

—Towards the Fusion of Seeds and Needs—

p.50

The world market for optical communication device industry has a scale of about ¥10 trillion. Because it enables ultrahigh-speed, high-capacity communication, it is vital basic social infrastructure. If optical fiber is connected not only to backbone systems but also to fiber to the home (FTTH) and non-PC data terminals, market scale may expand even more. However, the optical communication industry is now in a recession, led by the North America. One cause is concentrated simultaneous investment in the innovative technology wavelength division multiplexing, which in a few years saturated a market that should have taken 10 years to mature. In other words, the problem was that the supply of communication services outstripped demand before it could grow sufficiently.

Ironically, since that bubble burst, Internet traffic volume has been rapidly increasing. It is believed to be because Japan has been working day and night to become an “IT nation” and IT is advancing in work and business, and that traffic is accumulating to create the Internet’s peculiar synergistic effects. Therefore continued public investment in the optical communication field that is part of the basic infrastructure of data networks is necessary. In particular, investment in corporations, whose ability to invest in R&D has been weakened, is needed.

Investment should not be made in the traditional way of simply prioritizing seed research themes in commodities supply. Instead, R&D to create demand should be set up through test beds such as the Japan Gigabit Network (JGN II), a high-speed 10-20 Gbps optical fiber network, to create new communication services, and that should be the vehicle driving research.

In access systems in Japan’s optical communication network, Japan currently leads the world in FTTH subscribers with 1.75 million. This gives Japan the opportunity to create service superior to that of the video, audio, and data provided by cable television in Europe and North America. In cooperation with South Korea, Taiwan, China, and countries in Southeast Asia, who share similar conditions, Japan can also take the lead in setting international standards in FTTH and fiber to the building (FTTB). For that reason as well, a prompt resolution to the copyright issues that are keeping Internet content distribution services from moving forward is needed.

In backbone systems, generalized multi-protocol label switching (GMPLS, which carries out processing by using optical signal wavelength as a label to decide routing, preparing a specially controlled IP channel to route data as an optical signal) is the next-generation optical communication protocol for exchange nodes, which are expected to become traffic bottlenecks in the future. The technology of Japan’s world-leading parts and equipment, which have been boosted by Japan's technical prowess, will be a formidable argument for Japan to take a stronger lead in the field.

(Original Japanese version: published in December 2004)

Environmental Sciences

5 State of Japanese Research on the Ozone Layer

p.66

The concentration of chlorine (originating from chlorofluorocarbons, etc.) in the stratosphere, which increased dramatically in the latter half of the 20th century, began to decrease gradually this century, with a series of regulations coming into play. It is expected to decrease further to 1980 levels by the middle of the 21st century. Accordingly, the stratospheric ozone layer is recovering from damage, a process that is likely to progress further.

There are factors other than regulating chlorofluorocarbons that could deplete stratospheric ozone. In general, greenhouse effects, accompanied by a decrease in stratospheric temperature, an increase in stratospheric water-vapor, an increase in N_2O levels and an increase in stratospheric aerosols, have potential to reduce ozone concentration, although the amount of reduction depends on altitude, or may work in opposite ways. While climate change has complicated effects, the chances are high that increasingly extreme weather events will affect the stratosphere, resulting in the emergence of areas with unusually high or low ozone concentrations in the Arctic, Antarctic and other regions.

The total ozone amount (the total amount of ozone from ground level to the top of the atmosphere) decreased by 3% from pre-1980 levels in the last two decades of the 20th century; it shows no signs of increasing. According to the latest model-based prediction, the ozone layer is expected to recover in accordance with its scenario, even if the effects of climate change are taken into account. The current numerical models, however, do not give due consideration to "other factors," and hence there is room for improvement.

Ever since the discovery of the ozone hole, studies of the ozone layer have made great progress, while Japan has achieved satisfactory results through satellite observations, ground-based observations and international joint research efforts. Yet Japan has a lot to learn from the U.S. and Europe, which took immediate action upon the discovery - particularly effective were open forums attended by researchers and the preparation of budgets that can be used flexibly, without the constraints of academic and bureaucratic fiefdoms. The atmospheric chemistry sensors on board the satellites of the U.S. and Europe are gathering observational data in the stratosphere and the troposphere, which are compared with long-term data accumulated through ground-based observations, etc. However, the recent worldwide trend has been to scale down ozone layer research (except that using satellites) and budgets for observation activities. It is therefore essential that the Earth Observation Summit pave the way for the creation of a system that ensures long-term observations of the ozone layer. In line with this, the following are suggested:

(1) Evaluate the possible effects of "other factors" (substances other than chlorofluorocarbons that are not regulated by the Montreal Protocol) on the ozone layer, and incorporate the evaluation results into forecast models for more accurate prediction.

(2) Prepare a budget and create a system to support long-term observations of the ozone layer (including advanced observations that should be supported by researchers); this is a means to monitor whether the ozone layer is really recovering according to the forecast based on a scenario of reducing chlorofluorocarbons, etc.

(3) Create a system (a data center), with a budget earmarked for it, to store

long-term observational data, analyze variations or long-term changes in the subjects observed, accumulate models and their implementation results, and facilitate data utilization.

(4) Develop atmospheric chemistry sensors on board satellites (a sensor that can monitor the concentrations of atmospheric constituents and meteorological parameters of the stratosphere and the troposphere, simultaneously and separately, is a promising means of keeping track of the stratospheric ozone layer and regional air pollution along with its impact on tropospheric air quality, and to gather information on interactions between the troposphere and the stratosphere).

A system should be in place to create an open forum attended by researchers and supported by flexible budgetary arrangements so that immediate action can be taken to address emerging environmental problems such as the Antarctic ozone hole.

(Original Japanese version: published in October 2004)

6 The US Strategy for Research on the Health Effects of Airborne Fine and Nano Particles
— A Comparison with Japan

p.80

The "2003 Survey Report on Rapidly Developing Research Areas" specified 51 areas, one of which concerns the "Health Effects of Airborne Fine and Nano Particles." It may seem strange, however, that this particular subject was specified. A scientific basis has nearly been established for the health effects of conventional air pollutants (including particulates) and, for that matter, the subject is considered unrelated to "rapid development," at least in Japan.

The recent rapid development in this research area can be attributed to US environmental standards on airborne particulates, which were revised in 1997 to regulate finer particulates. In line with this, a substantial amount of resources have been funneled into research on airborne fine particulates, with the National Science Board organizing an ad hoc committee to select priority subjects, map out a research strategy (including the allocation of research funds) and keep track of the progress in research activities. As a result, a total of 10 subjects were selected based on three criteria: scientific value, decisionmaking value, and feasibility and timing. Specific research areas include: "the quantitative relationship between the amount of exposure and its health effects," which is essential in setting environmental standards; air pollutant emissions and their dynamics in the atmosphere; human exposure to air pollutants; air pollutant inhalation; and the development of biological effects. Research resources have also been put into other areas that technically support the research subjects. Between 1998 and 2003, a total of US$370 million (about ¥40 billion) was invested in EPA's research institutions and other external research bodies including universities in the form of both competitive and noncompetitive funds. It is considered that this research strategy not only contributed to reducing uncertainty in the scientific basis for setting environmental standards for airborne particulates but also influenced the direction of basic research on atmospheric science and measurement technology.

Epidemiological findings on domestic air pollution and the health effects of exposure to air pollutants are essential in setting Japan's own environmental standards. The reality, however, is that both the financial and human resources needed to conduct research on air pollution and epidemiology related to environmental pollution are far from sufficient. To gather scientific findings unique to Japan, therefore, it is imperative that short-term research funds be made available and long-term support programs be administered to develop human resources.

In the meantime, the validity of making large-scale investments in Japan, following the example of the US initiative, should be reviewed carefully, taking into account the amount of risk involved, their cost-effectiveness and health risks associated with other kinds of environmental pollution. According to a study conducted in the U.S., airborne particulates cause substantial health risks, and the cost-effectiveness of countermeasures is estimated to be as much as US$100 billion.

As for the health effects of airborne particulates associated with conventional environmental pollution, the focus has shifted to smaller-diameter particulates. At the same time, there has been growing concern over the toxicity of a variety of nanomaterials that are increasing along with progress in nanotechnology. With measurement technology as a common technique and health risk assessment as a common objective, these two areas are being linked together. It is therefore recommended that the authorities and research institutions concerned make concerted efforts to take the initiative in research on the toxicity of nanoparticles, incorporating this subject into Japan's R&D strategy for nanotechnology.

(Original Japanese version: published in October 2004)

Energy

7 Latest Trends in and Prospects for Coal Utilization and Clean Coal Technologies

p.91

About 20% of Japan's primary energy source is dependent on coal, a percentage that should be maintained in view of energy source diversification. The key, however, lies in offsetting coal's disadvantages (high environmental load) and making the most of its advantages (abundant reserves and geographically dispersed distribution). At the same time, it is increasingly important to develop eco-friendly clean coal technology (hereinafter referred to as "CCT") and to ensure the supply of this fossil fuel.

With respect to CCT development, the development and commercialization of low-cost coal gasification technology are recommended. CCT can reduce the environmental load caused by coal combustion. An adequate budget should thus be provided for the following initiatives, in which the government is expected to play a leading role:

1. Develop a cost-effective power generation system by 2010, based on coal gasification technology, while improving its reliability and power generation efficiency. Promote coal ash utilization technology.
2. Further improve the power generation efficiency by 2015 through combined cycle power generation technology comprised of coal gasification power generation and fuel cells.
3. Reduce greenhouse gas emissions by 2020 through the separation, recovery and sequestration of CO_2.

Initiative 1 and 2 should be conducted as a national project, based on a partnership between industry, government and academia. In particular, Initiative 2 should incorporate an evaluation program with specific targets for achievements (period, performance and cost), while introducing a project that involves strict interim assessments of technological development in accordance with a roadmap for commercialization - a means to fill the gap between state-of-the-art coal gasification technology and commercial technologies.

In addition, the following are recommended to ensure the security of coal supply and to develop human resources specializing in CCT:

It is necessary to further develop coalmining and improve the production/transportation infrastructure in coal producing countries by conducting extensive surveys of their status and mobilizing financial resources so that the main advantage of coal - low and stable prices - can be exploited over the medium and long term. Japan is expected to play a leading role in organizing and managing the "Asia Coal Forum" (provisional name) in cooperation with APEC and ASEAN+3 (Japan, China and Korea) to share and exchange information regarding prospects for the Asian coal market and CCT promotional measures.

Medium- and long-term support measures should be in place at universities or graduate schools to develop human resources in CCT: interdisciplinary educational programs. With regard to such programs designed for graduate schools, internship training should be provided by future employers (companies engaged in CCT) so that students can learn expertise in commercializing technological achievements. Universities and graduate schools are expected to foster human resources specializing in advanced CCT and coal science, who can present new ideas and understand their technical viability. Companies, meanwhile, should come up with better OJT programs to further strengthen the international competitiveness of Japan's CCT resources.

(Original Japanese version: published in November 2004)

Frontier

8 Research Trends in Space Environment Observation and Fluctuation Monitoring

p.106

Today, as we witness the full-fledged research, development and utilization of space, it has become increasingly clear that the space environment that surrounds us (solar activity, the earth's magnetosphere, space flight objects, etc.) is very much concerned with our existence and our activities.Typical objectives for space environment observation include space weather, space debris, and Earth Near Asteroids.

"Space weather" collectively represents the fluctuation in environmental factors, including the cosmic radiation and electromagnetic plasma that occur in space ranging from the electromagnetic sphere to the atmosphere. These factors naturally affect development activities in space, as the wind and rain affect our lives on earth, hence the term, "space weather." Cosmic radiation has been measured using radiation measurement equipment mounted on satellites that circle the earth in various orbits. Data on magneto-plasma have been collected globally using the inverse transformation of magnetic field fluctuation information that has been collected on the earth's surface. Research on the earth's magnetism, which protects the earth against the harsh environment of space, is conducted not only on a short-term basis (for daily and monthly fluctuation) but also on secular changes (in terms of tens of thousands of years). In recent years, an abnormal decrease in the earth's magnetism has been reported in Brazil, and adverse effects have appeared. Theoretical aspects of the research include the analysis of the effects of fluctuation in solar wind on the magnetosphere and the ionosphere using sophisticated numerical simulation techniques.

Japan has actively engaged in these efforts in the frame of a globally linked system, but still needs to enhance the observation network and to build a data-processing infrastructure.

Since the beginning of space exploitation activities, we have launched innumerous rockets and satellites into space, and the remains of the rocket heads and decommissioned satellites have finally become rubbish in space, or space debris. Space debris presents a serious threat to human space activities, causing damage to and malfunction of satellites, endangering astronauts conducting extravehicular activities. The need for basic studies to address this serious problem (observation, control, removal, and reduction of space debris) has become increasingly urgent. Japan has taken measures on its own initiative to reduce the elements installed in rockets/satellites that may eventually become space debris. It has also installed a unique ground-based space debris observation system, and has played an important role in securing its own place among other countries including U.S.A. and European countries. In this research area, the launch of a national project is highly desirable for installing a full-fledged radar observatory system that compares favorably with its counterparts in U.S.A. and European countries.

Near Earth Asteroids (NEAs) are small asteroids whose orbits intersect the earth's orbit. A number of NEAs have been reported. Although remote, there is a possibility, over the very long term, of their hitting the earth, causing an enormous disaster. Continuous effort is needed to discover and track them to obtain information on their orbits. Japan has so far relied upon the volunteer works of amateur astronomers. Compared to the U.S.A, where many dedicated groups are constantly tracking these asteroids, more organized effort is required here in Japan by establishing several groups with dedicated telescopes to monitor NEAs.

For the efficient implementation of this research, the overall tasks of space environment observation and fluctuation monitoring can be categorized into several sections and assigned to a number of domestic research institutes according to the nature of the task. This is an urgent research issue for the security of human beings; active national-level engagement is required for putting an observation network in place and for the steady continuation of monitoring.

(Original Japanese version: published in October 2004)

Science and Technology Policy

9 The Current Argument between Scientists and Government for Science and Technology Policy in U.S.

p.120

In August 2003, the Office of Management and Budget (OMB) in White House released its proposed "draft peer review standards for regulatory science." The standards are intended to improve the quality, purpose, realism, and fairness of peer review when public funds are invested in research related to regulations carried out by the Federal Government. In objection to the OMB proposal, in February 2004 the Union of Concerned Scientists (UCS) published a report entitled "Scientific Integrity in Policymaking" that was signed by 60 scientists, including Nobel laureates, a former Presidential Science Advisor, and former directors of the National Science Foundation and the National Institute of

Standards and Technology. At the same time, the UCS published a statement declaring that the Bush Administration has distorted scientific fact for its own convenience in policymaking concerning the environment, health, biomedical research, and nuclear weapons. The report pointed to cases such as climate change, mercury discharge amounts, public health issues related to reproduction, lead poisoning in fetuses and children, workplace safety, and nuclear weapons, and objected that proposal by OMB is biased towards the Administration and has many other problems. The report stated that new regulations and laws are needed to resolve the situation, that the trends seen in recent policy shake the foundations of science, and that the situation must be addressed quickly.

In reply to the UCS statement, Presidential Science Advisor John H. Marburger responded that the current Administration in fact strongly supports science. He noted that the overall science and technology budget has increased to an unprecedented degree, and that a program on climate change has been in place since 2001. Furthermore, the President created the US Climate Change Science Program (CCSP) to receive and respond to comments from a large and broad group of scientists and stakeholders, including a two-stage independent review of the plan, set a high standard for government research programs. In this way, the Administration is using concrete examples to voice its objections to the UCS assertions. However, scientists are dissatisfied with other issues in addition to those noted by the UCS.

In July 2004, many more UCS member scientists, over 4,000, including 48 Nobel laureates, signed a statement criticizing the Bush Administration's attitude towards scientific advice. The UCS issued the statement to criticize the Administration for not adequately examining its report submitted in February 2004.

Those scientists organized themselves and put their pride as scientists ahead of party loyalty and, in the form of the statements, objected to Administration policy. How the Administration will respond and how things will develop are the points worth watching now. We should always pay attention to the actions of scientists in science and technology fields in various foreign countries. The organization of scientists to point out problems to the government may happen in Japan in the future. It may be demanded or become necessary. It is desirable that complex issues such as the environment or embryonic stem cell research be resolved through debate based on scientific judgment and rational premises, with risk considered even if some uncertainty must be permitted. And the most important thing is that scientists, government, and the public share information, exchange opinions, and attempt to understand one another.

(Original Japanese version: published in December 2004)

1

Strategies for Reading and Writing Learning Difficulties (Dyslexia)

KAYOKO ISHII
Life Science and Medical Research Unit

1 Introduction

Advancements in brain research have made it possible to understand the functionality common to human beings, as well as to analyze the diversity of functions in individuals. It is widely accepted that there are people who display normal brain function and are able to live independently, but have difficulty in some types of task and require greater effort than other people to accomplish such tasks, which in turn disadvantages them. Looking back to one's elementary school years, many may remember classmates who could speak fluently in ordinary conversation, but when asked to read a textbook out loud in class, became flustered or struggled to answer a question about the content of the textbook. This is also true of reading English texts out loud in class in junior high school, high school, and college. Although people are required to read out loud less and less frequently as they become older, many preschool, school and college students suspected of having developmental dyslexia (hereafter referred to as "dyslexia") will have lifelong difficulties such as slow reading and writing speeds, frequent misreading, leaving out words while reading, and misspelling. Since oral and silent reading and writing hold an important position in school education, in many workplace activities, and for improving vocational competence, people with dyslexia are often deprived of the opportunity to demonstrate and promote their talents because of their reading and writing difficulties, even though they have normal or above-normal ability in other areas. Furthermore, lack of chances to make best use of their talents and being misunderstood by others as having little talent or ambition may lead to loss of self-confidence, anxiety, stress and alienation, and ultimately may cause psychosomatic disorders, which in turn leads to dropping out from school and withdrawal from society.

It is necessary to establish a support system that helps teachers to identify early children with reading and writing disabilities when they begin elementary school, and take necessary measures in a timely manner, to ensure that children with dyslexia are able to learn in normal classes, develop their potential, and live fulfilling lives. For this purpose, it is necessary (i) that research on the current situation of dyslexia in Japan be conducted, and (ii) that research on causes and cases of dyslexia, as well as methods for early diagnosis with high accuracy and sensitivity, be promoted, and iii) that research and development of support systems and teaching materials for people with dyslexia be fostered.

2 What is Dyslexia?

2-1 Definition

Developmental dyslexia ('dyslexia' hereafter) is a specific difficulty in learning to read and write caused by perturbed development of neuronal bases for reading and writing, without accompanying intellectual sensory or motor disabilities, lack of concentration or motivation, or family or social hindrances[Note]. In the domains of neuroscience, clinical medicine, and psychology, the English term "developmental dyslexia," along with its Japanese translation "hattatsu-sei nandoku-sho (developmental reading difficulty)" or simply "dyslexia" have been traditionally used. These days, however, the terms "hattatsu-sei yomi-kaki shogai (developmental reading and writing difficulties)" and "dyslexia (written in Japanese characters)" are preferred by some people. The term "dyslexia" is used throughout this article because a plain term that does not implicate defect is desirable for the convenience of people with dyslexia and their families. It is recommended that in the future, specialists and knowledgeable people be invited to discuss and determine an appropriate term that can be commonly used in society.

2-2 Prevalence Rate of Dyslexia

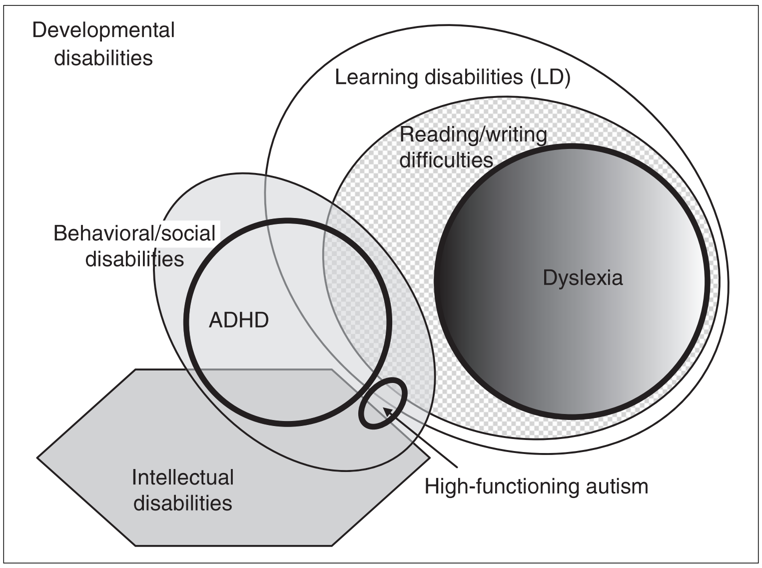
The prevalence rate of dyslexia from a neurological viewpoint is the same among different societies and nations, and reportedly, 6 to 10% of the entire population have a predisposition to some degree of dyslexia[3-5]. For people with dyslexia, it is especially difficult to read a language where the relationship between the orthography and the pronunciation of words is not consistent. The less consistent the sound-spelling relationship, the higher the risk that children with dyslexia have difficulties in the process of language acquisition. As far as the Japanese language is concerned, the relationship between kana letters and their sounds is consistent, and the meaning of fundamental kanji letters can be assumed from their structure even if their pronunciation is not known. For this reason, it appears that dyslexia difficulties manifest themselves as explicit problems less often in Japan than in other countries. However, because a comprehensive survey has not yet been conducted in Japan, this cannot be firmly concluded. Detailed research conducted at 3 public elementary schools (Grades 1 through 6) in two cities (with a population of 400,000 and 50,000, respectively) has shown that 1%, 2 to 3%, and 5 to 6% of students appear to be dyslexic when reading out loud hiragana, katakana, and kanji, respectively, and 2%, 5%, and 7 to 9% of students are diagnosed as being dyslexic when writing hiragana, katakana, and kanji, respectively[6].

2-3 Position of Dyslexia in Reading and Writing Disorders

Dyslexic people can read and write but only slowly and with higher propensity to make errors. Dyslexia is distinguished from alexia that is characterized by a complete inability to read.

Etymologically, dyslexia (dys + lexia) means "reading difficulties." In acquired reading disorders caused by a stroke, external injury, or tumor after language ability has been acquired, only reading may be disturbed by focal damage. When the damage is spread over diverse areas,

Figure 1 : Position of dyslexia relative to developmental disabilities such as reading and writing difficulties (basic concept)



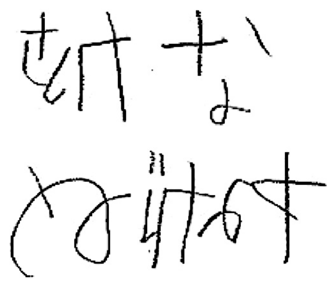
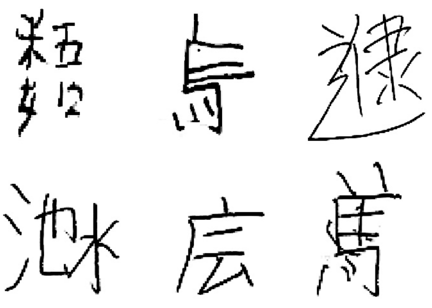
It is estimated that about 10 % of all children have a predisposition to dyslexia. The degree to which symptoms manifest themselves depends on the severity of the condition and the language. For theories on overlapping of the disorders, refer to related journal articles.

complex symptoms may occur. A symptom may be reduced to separate components, and each component is analyzed regarding functional localization in the brain[10]. Neurologists and language therapists specialized in acquired reading disorders take part in treatment. For developmental dyslexia, the ability to read and write, short-term memory and the retrieval of letters are affected, although there are individual differences in the degree of severity for each component. During the development of the brain, specialization of the common brain areas for linguistic abilities (the language area) begins in the fetal period, before children are exposed to spoken language. In dyslexia, a portion of the language areas responsible for reading and writing is selectively affected by certain inherent factors. These days, dyslexia studies focus on the relationship between the affected locus and aspects of difficulty. In this case, pediatricians, pediatric neurologists and language therapists specialized in the developmental stage are involved in treatment.

For children with attention deficit disorders, attention deficit hyperactive disorders (ADHD) and high-functioning autism, (i) there are many cases where the development of brain loci associated with reading and writing is affected, so that reading and writing difficulties appear as one of the complex symptoms, and (ii) there are cases where lack of concentration or interest in interaction or linguistic communication with others prevent the acquisition of reading and learning skills. Considering the current situation described below, it is necessary to immediately conduct a survey on the actual situation of dyslexia in Japan to clarify the distinction from other similar disorders, to provide proper diagnosis and support, and to disseminate accurate information to those in clinical practice and in education.

(i) Attention tends to be more directed to autistic children and children with ADHD, those who have problems with behaviour and social skills, as well as to children with hearing and speech disabilities. In contrast, for children with dyslexia who have no

Figure 2 : Examples of misreading and miswriting

		Fault	Correct
a. Misreading	1	*kona-o-atsumeru* (collect powder)	*kona-o-neru* (knead powder)
	2	*oniku-ga-oishii-desu* (this meat is delicious)	*oniku-ga-yasui-desu* (thid meat is inexpensive)
b. Miswriting	1 Hiragana		sakana (fish)
			megane (glasses)
	2 Kanji		(word, bird, health) (lake, garden. state)

a1: Example of confusion due to structural similarity
a2: Example of confusion due to meaning
b1: Example of a 7-year-old child
b2: Example of multiple children

Source: Author's compilation based on the database collected by Professor Toshihide Koike[11] social or conversational problems, the need for support tends to be overlooked.

(ii) In Japan, dyslexia is not yet well known by the public, and it is confused with autism and ADHA, and people with dyslexia may receive inappropriate treatment.

(iii) There is a relatively high prevalence rate of dyslexia; about 70 to 80% of children with learning difficulties are dyslexic.

(iv) If appropriate support is provided to children with dyslexia at an early stage, they can be integrated into normal classes more easily than children with ADHD or autistic children.

2-4 Symptoms

The features observed in people with dyslexia are not uniform; there are individual differences in terms of aspect and degree of difficulty. Reading problems include a lack of fluency and omission of words. Writing problems include mirror-imaged writing, distortion of letter forms, creation of letters, difficulty in recollecting forms of letters just seen, and difficulty in copying letters on the blackboard, etc. Generally, for people with dyslexia, hiragana is the easiest to learn, then katakana, and kanji is the most difficult to learn. As with kana, they have problems with numbers, for example, reversed numbers, poor handwriting, incorrect numbers, and misreading. People with dyslexia may have normal or above normal ability in the reasoning and logical thinking skills that are required for mathematics.

2-5 Test Methods

(1) Psychological tests

Currently, general psychological tests and aphasia tests are adapted to diagnose dyslexia based on the criteria that, “Generally, there are no perturbations of visual, auditory, or motor function, but only unexpectedly low achievement in reading and writing with respect to other functions.” These tests are not specifically developed to diagnose dyslexia, and it would be meaningful to develop a test with high sensitivity and accuracy to identify dyslexic individuals using the Japanese language.

(2) Achievement tests

Usually, skill in reading, writing and copying drawings is tested using letters and numbers that children have learned one or two years earlier at school. Children with dyslexia make significantly more errors with letters that they should have mastered two years before. Even if there is no difference in accuracy, children with dyslexia need much longer to respond[12]. Currently, there are no standard sets of Japanese letters (hiragana, katakana, and kanji) for the tests. It is necessary to establish a standard composition of the letters and their presentation protocols in testing so that common criteria are used in research, health checkups, diagnosis, training, etc.

2-6 Growing Process

(1) Early childhood

Generally, children begin to show interest in letters and numbers around the age of 4. Children with dyslexia tend to show little interest in them although they may like pictures or stories read aloud. In Sweden, longitudinal studies of children from families with a high prevalence rate of dyslexia (described later) and control families are being conducted from birth to school entry and throughout the school years. It is expected that findings from the study will help identify early indicators of dyslexia[3, 13]. It is also suggested that the first signs of dyslexia appear around the age of three and a half[14].

(2) Lower grades of elementary school

In Japan, many children at age six, when they enter school, can read almost all hiragana letters, and can write 60% of them[15-17]. Health checkups at school entry provide a good opportunity of identifying children with dyslexia, and of providing support, so that they can prepare for learning in normal classes. It is recommended that a test system be developed for this purpose. Reading and writing difficulties appear at the early stage of elementary school, but it is difficult to detect problems at the lower grades of elementary school, because the syllabus is still simple and children may be able to compensate for their difficulties by painstaking exercises if the dyslexia is mild. Sometimes, signs of dyslexia appear in such a way that children who have no significant problems with reading and writing letters cannot do math or struggle to answer comprehension questions. It is useful to prepare guidelines and make them available to parents and teachers so that they can identify children who have such unbalanced skills.

(3) Higher grades of elementary school

When children have to learn a growing number of kanji letters, especially those with abstract meanings, from around the 3rd grade of elementary school, children with dyslexia can hardly cope with learning more letters, no matter how hard they work and how many times they repeat the exercises, and signs of dyslexia become more evident. Furthermore, 10-year-old children begin to compare their own achievements with those of their peers, and try to imagine their future by considering their own talents and preferences. When they become aware of, or someone else points out, that they are slow to learn reading and writing, they may lose confidence and become anxious about the future[18]. If 10-year-old children believe that 'they cannot read and write, so they are not smart,' how can they imagine themselves living successfully as adults in present Japanese society? Osaka Medical College has a dedicated unit treating children with learning disorders. Most dyslexic children who visit the unit are in Grades 1 through 3. Why do higher-grade children not visit the facility for the treatment of learning disorders despite the fact that dyslexia manifests itself more strongly more at these higher grades? According to Doctor Shuhei Suzuki in the unit, "for dyslexic children, the problem of psychosomatic disorder has already become more serious than the problem of reading and writing, so they visit the psychosomatic disorders unit first instead of the learning disorders unit." It is essential to provide appropriate support for children with relatively serious dyslexia at the lower grades of elementary school.

(4) Junior high school

With English, dyslexia tends to manifest itself with higher probability because the language is phonologically complicated, contains a lot of inconsistent relationships between orthography and pronunciation, and requires visual and auditory processing that are difficult for people with dyslexia[19]. As a result, when Japanese children with dyslexia begin to study English at junior high school, those who have apparently had no problems in learning Japanese show difficulty in learning English. This is also the case in Italy, because there is high consistency between orthography and pronunciation in Italian. Up to now, few English teachers in Japan know about dyslexia. Furthermore, dyslexia is not yet known by teachers in English cram schools where students expect to make up for delay in learning at school. It is necessary that those involved in teaching English notice problems associated with dyslexia, learn from training strategies for dyslexic students used by native English speakers, and develop a support system appropriate for Japan.

Children with dyslexia have to spend more energy than other children on learning through reading and writing, at the cost of content comprehension and expansion of vocabulary and knowledge[20]. This burden tends to increase the gap between dyslexic children and non-dyslexic children, resulting in even mildly dyslexic children being more at risk of being left behind in learning at junior high school and in higher education.

There are also children who have difficulty in reading and writing numbers. However, logical thinking and reasoning, fundamental factors in mathematics, are not affected by dyslexia; in fact, some people with dyslexia demonstrate outstanding talent in this area[21]. Brain research suggests that two neural pathways are involved in mathematical thinking. It is important not only to provide support for children with dyslexia to compensate for their weakness, but to discover what they can do and encourage them to do it better, or to use their strong points to compensate for their weak points.

(5) High school and higher education

To succeed in examinations, students are expected to read questions accurately and write answers correctly within a limited time, so dyslexic students, who are slow to read and write and make many errors, cannot demonstrate their competence or skill. As a result, many dyslexic students have unexpectedly little success in college entrance exams and employment exams. In the UK, preferential treatment is given to dyslexic students by giving them extra exam time. However, even though they may enter college, some dyslexic students drop out because they cannot cope with the heavy burden of course content, and they cannot complete the required assignment papers. In a modern society where the workplace is flooded with information, people are required to accurately and quickly handle many documents when they get a job, and thus people with dyslexia have lifelong difficulties.

2-7 Causes of Dyslexia

When the diagnosis of dyslexia depended only on its psychological and/or pedagogic aspects, there was a risk of labeling other difficulties as dyslexia[22]. Through the development of neurological studies, more basic knowledge was obtained about the biological aspects of dyslexia. A convincing explanation of the causes of dyslexia has not yet been presented, so it is necessary to promote basic research to clarify the causes of dyslexia.

(1) Anatomical factors

In most people, the left hemisphere of the brain is dominant for language, and the language areas are bigger than their corresponding areas in the right hemisphere[23]. This left-right asymmetry is detectable in the fetus as early as 31 weeks of gestation[24], and this provides evidence for the theory that language ability is innate. Both anatomical[25] and brain-imaging[26] studies have confirmed that the asymmetry of language areas is reduced in the brains of people with dyslexia. Focal abnormalities of the cerebral structure (approximately 0.2 millimeters wide) have been observed in their brains, with a higher incidence in the language areas[27].

(2) Physiological factors

When skilled readers recognize a series of letters as language, they convert visual information into auditory information without explicit awareness of it. Rapid eye saccade and information processing in the order of milliseconds are required for fluent reading. When sensory information proceeds to the neocortex, rapid-phase information is carried by the magnocellular pathway, and slow-phase information is carried by the parvocellular pathway. Many studies suggest that both the anatomy and information processing of the magnocellular pathway of dyslexic people are different from those of non-dyslexic people[28].

Generally, when reading or writing, the language areas in the left hemisphere are more active than in a resting state. Studies using functional magnetic resonance imaging (fMRI) have shown that, in people with dyslexia, the activation of language areas during reading and writing is relatively feeble (Figure 3b)[29].

From a psychological point of view, the left cerebral hemisphere is dominant in processing rapid visual and acoustic information. Some studies have shown that the left hemisphere in people with dyslexia does not fully respond to rapidly changing stimuli and that the response could be enhanced through training[30].

(3) Genetic factors

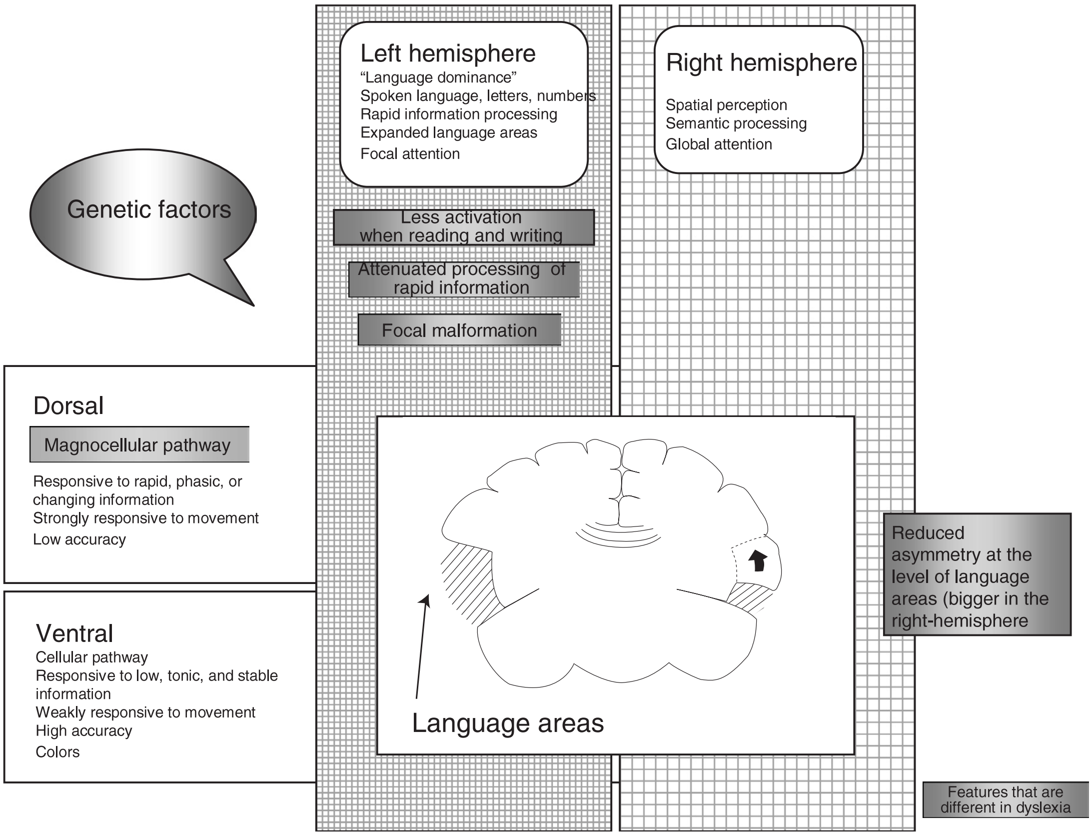
It has long been pointed out that dyslexia runs in families. Epidemiological studies suggest that dyslexia is caused by multiple genes. Studies in Finland, the UK, the US, and Canada have shown that there are high-risk families with a propensity to dyslexia. A study in Finland has shown that the concordance rate is 34% in high-risk families, whereas it is 9% in control families[3]. The concordance rate of dyslexia is reported to be 66% and 43% in monozygotic and dizygotic twins, respectively. A longitudinal study is being conducted for children born to high-risk families or control families from birth to an age when accurate diagnosis is possible through learning at school. Retrospective analysis shows differences between the two groups and the age of divergence. Recent studies suggest that genes related to dyslexia are located on chromosomes 1, 2, 3, 6, 12, 15, 18, and X, and special attention is being paid to those on Chromosomes 6 and 15. Candidate genes for dyslexia vary among different families living in different countries. In Japan, a genetic analysis of dyslexia has not yet been conducted, so it is necessary to conduct epidemiological studies on dyslexia.

(4) Factors 'Not' related to dyslexia

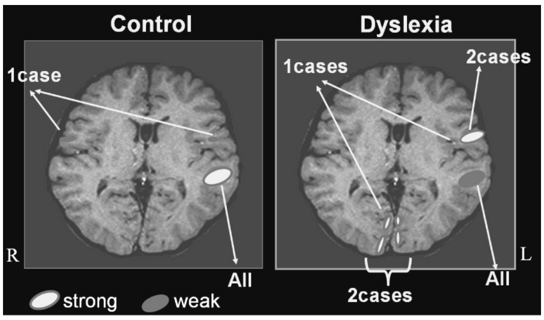
It is necessary to make the best use of TV programs and printed media to deliver the message to the public that laziness, and lack of concentration and motivation are not related to dyslexia.

In the 1960s, a hypothesis that a child's upbringing is related to dyslexia was widely discussed but rejected. However, in a society where knowledge about dyslexia is not sufficiently disseminated to the public, if children

Figure 3 : Indications of dyslexia



a. Illustration: Functional localization in the brain and indications of dyslexia



b. Summary of brain activity in dyslexic children and non-dyslexic children when they are reading

Strong activation was observed in the language areas of the left hemisphere in the group of non-dyslexic children when they were reading, while only weak activation was observed in these areas for all dyslexic children examined. Functional MRI was used to measure changes in the brain activity of five children aged 9 to 11 years old.

L: left brain, R: right brain

Source: Author's compilation based on the report by Seki et al [29]

Table 1 : Support methods

Support domains	Example
Educational materials	• Recorded textbooks • Printed copies of blackboard writing • Easy-to-read textbooks (concrete, concise expression and representation)
Normal class	• Avoid repetition of ineffective exercises • Teacher/student collaboration (role change intended to develop students' error awareness[17])
Supplemental class	• Demonstration of the elements of orthography and pronunciation • Demonstration of construction and relationship among these elements • Multi-sensory approach • Small-group learning for children with similar difficulties
Consideration	• Helping students to become aware of their errors by themselves when they are reading[17] • Praising students and encouraging other subjects that they are good at as well as their particular skills
Preferential treatment	• Prolongation of exam time • Oral tests instead of written tests • Multiple-choice tests instead of descriptive tests • Use of computers

cannot read and write well, mothers in particular feel guilty, deny their children's difficulties, and cannot act objectively. They thus risk missing the opportunity to obtain the support they need. Therefore, it is also important to consider the emotional aspects of the parents. Teachers, too, sometimes have mixed feelings about the difficulties of their students.

There was a hypothesis that dyslexia is more prevalent in boys than in girls. Recently, however, some studies contradict this. Girls tend to talk earlier than boys in early childhood, so it is not advisable to diagnose dyslexia based only on the criterion that language development is 1 or 2 years behind the average. A study has shown that dyslexia affects males and females equally, or slightly more females than males at college entry age[31]. However, it has not yet been determined whether the developmental profiles of dyslexia are the same in males and females, so it is necessary to conduct careful analysis while considering individual differences.

3 Support Methods

Educational materials such as recorded textbooks are useful not only for dyslexic students but also for visually impaired students. However, they have not been widely available because of copyright problems, etc. It is necessary to rapidly promote the development of teaching materials for dyslexic students.

As for English education, it is necessary to identify possibly dyslexic students and take proactive measures if there is a significant gap between Japanese and English learning ability. It is necessary to study and learn from special support methods in countries where English is the mother tongue, such as the teaching strategy of phonological processing in English that does not exist in Japanese. It is also important to develop an original support method appropriate for English education in Japan.

4 Position of Dyslexia Relative to Policy of Support for Developmental Difficulties

In 2002, the Basic Program for Persons with Disabilities was decided by the cabinet, and a directive was issued stating that "Children with special needs in education and remedial training, for instance, those with Learning Disabilities, Attention-Deficit/Hyperactivity Disorder, and autism, should be provided with appropriate educational support." On December 3, 2004, a bill for assistance for children with developmental disabilities was passed by the cabinet (and the Act was enforced on April 1, 2005). The Act says that the central and local governments must take responsibility for providing support for the early detection of and fostering the development of non-mentally retarded children with developmental disabilities, including, but not limited to, "autism, Asperger syndrome, and other pervasive developmental disorders, learning disabilities, attention-deficit hyperactive disorder, and other similar brain function disorders."

Meanwhile, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is currently reforming the education system "to prepare a system that provides special supportive education for children with learning disabilities in all elementary and middle schools by 2007." It is required that this special supportive education be based on scientific evidence, so it is important to promote scientific research providing such evidence.

The "Draft of Criteria for Identifying Children with Learning Disabilities (LD)" prepared by MEXT covers children "who have significant difficulty in acquiring and using particular abilities in hearing, speaking, reading, writing, calculating, and/or reasoning."[32] Dyslexia affects reading, and writing abilities and sometimes influences calculating ability. Studies in the areas of neuroscience and cognitive science increasingly focus on the structure of individual ability such as in speaking and reading, as well as the difference between calculation and reasoning functions in the area of mathematics. It is necessary to systematically promote studies to ensure that they provide a scientific basis for new methods of education.

5 Strategies for Dyslexia

5-1 Current Situation Survey

In Japan, a comprehensive survey on the current state of dyslexia has not yet been conducted, so this is an urgent task. In Japan, there is not even an official definition of dyslexia. Therefore, the following tasks are required.

- To immediately establish a definition based on scientific findings on dyslexia
- To determine standard test methods based on scientific evidence
- To review and improve test methods as research progresses
- To conduct longitudinal studies on dyslexia

5-2 Public Communication

It is urgently necessary for the government to make the best use of mass media such as TV, printed media, and the Internet to disseminate knowledge about dyslexia, and convince the public of the need for support and win understanding.

5-3 Establishing an Early Detection Method

The onset of acquisition of hiragana by preschool children has been getting earlier over the last several decades (Figure 4). Recently, most young children can read hiragana before they enter elementary school, and 60% can write it. Just after entering elementary school, even non-dyslexic children may confuse letters, but these mistakes are corrected in a year. Children with dyslexia make characteristic patterns of mistakes such as high frequency of mirror-imaged letters, and these mistakes cannot be corrected by conventional exercises. It will soon become technically possible to identify children at risk of dyslexia when health checkups are conducted at school entry. It may not be easy, however, to carry out tests to identify dyslexia at this early stage before knowledge about dyslexia is disseminated to the public and before parents are psychologically prepared to accept a diagnosis of their child's dyslexia. Teachers may be able to identify children who show poor performance in reading and writing by the end of the first term in the first grade of elementary school. As a preparation step, it is recommended that parents' attention be directed to 'dyslexia' by distributing printed materials that include the following information: (i) there are children who can learn reading and writing only with difficulty due to developmental problems, (ii) it is possible to undergo precise tests performed by a local specialist, and (iii) it is also possible to receive consultation and basic training in language schools operated by local governments, non-profit organizations, etc. For this purpose, schools are required to establish a referral system that allows local specialists, language therapists, language schools, relevant non-profit organizations, etc. to be contacted.

Young children are acquiring hiragana at an increasingly earlier age for two distinct reasons, i.e. forced learning and an improved environment for learning letters[16]. If young children are forced to learn letters, those with dyslexia must suffer mental distress during early infancy. As far as the mental problems of children are concerned, it is necessary to study the actual situation of teaching letters and numbers at school, at home, at kindergarten, and at daycare centers, as well as how teaching influences the development of the child's mind.

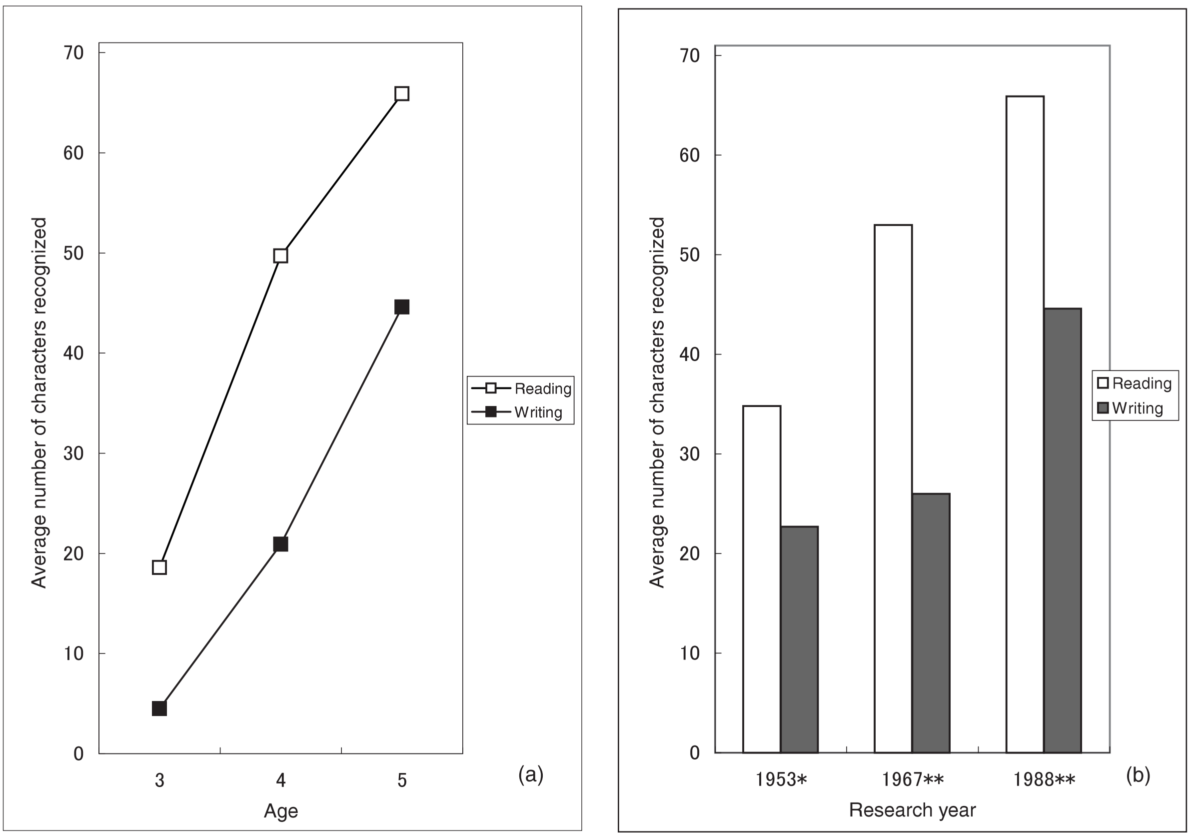
5-4 In the Medical Setting

(1) Clinical physicians

Up to now, most language problems encountered by clinical physicians are cases of adults suffering brain damage. It is necessary to train clinical physicians and medical researchers so that they can treat the complex language problems of children, which involve mental development and learning. For this purpose, medical schools are required to set up undergraduate courses in which neuroscience, cognitive science, behavioral science, and psychology are systematically taught, and competence in these areas should be evaluated in a national exam. It is also necessary to establish a system in which pediatricians, pediatric neurologists, and pediatric ophthalmologists who have passed the national exam participate in training that allows them to treat children with developmental reading and writing disabilities and the resultant secondary problems.

It takes about 1 hour or 1.5 hours to provide medical treatment or support for one child with a developmental disorder. Medical treatment or support for people with dyslexia, which involves psychological tests, guidance, and counseling, but

Figure 4 : Average number of *hiragana* letters recognized by preschool children



a. Development of letter recognition by age (according to a research paper in 1988)

The number of characters recognized is based on the total 71 *hiragana* characters.

Source: Author's compilation based on a report by Shimamura et al[16].

b. Historical changes in children's letter recognition

* Six-year-old children just after entering school, in April or May (regardless of whether they went to kindergarten or a daycare center)

** Five-year-old children at kindergarten or a daycare center, tested in November, 4 months before school entry

Soruce: Author's compilation based on a report from the National Institute for Japanese Language[15] and a report by Shimamura et al[16].

not medication, is rated low in terms of treatment fees. Even if good medical treatment and a guidance method are developed, they may not be widely practiced if there is no profit from the viewpoint of medical management. It is necessary to reconsider the medical system so that public medical institutions and private hospitals can commit themselves to the mental and learning problems of children within a framework of viable medical business operations.

(2) Language therapists

In Japan, there are only a small number of language-hearing therapists able to deal with developmental language problems. Currently, it would be effective for experts in acquired reading disorders and alexia take courses on specific developmental problems so that they can work with people with dyslexia. At the same time, it is necessary to train language therapists specialized in developmental disorders who have knowledge of brain science and psychology, and who can cope with the secondary problems resulting from reading and writing difficulties. As far as the training of personnel is concerned, there are currently only limited places for practical training. School boards and schools should recognize that it is necessary to involve language therapists to promote special supportive education, and that they should provide training places.

5-5 At School

(1) Training system for teachers

"A Vision of Special Support Education (Final Report)"[33] published in 2003 includes an estimation of children with reading, writing, and calculating difficulties, compiled based on a questionnaire survey for teachers. As a result, several papers on reading and writing disabilities were presented at the annual meeting of the Japanese Academy of Learning Disabilities held in 2004. The academy provides training and issues certificates for special support education specialists for children with Learning Difficulties (LD), ADHD, and related difficulties. It is useful to increase the quality and number of such experts, making a good use of knowledge from the National Institute of Special Education and centers of advanced research. It is also useful for educators, physicians, language therapists, and scientists to hold regular seminars to consolidate cooperation in the community.

(2) Translation Science

It is important to promote "translation science" and to train implementers who translate knowledge from science and technology studies, making it possible for teachers to understand and use it. It is effective to set up training courses in university faculties of education, or at graduate schools of life sciences and medical sciences. MEXT's promotion is increasing the number of degree recipients from graduate schools. It is therefore effective to select and hire degree recipients who are more interested in scientific writing and enlightenment work than laboratory work.

5-6 Developing Social Infrastructure

The Act for Assistance for Children with Developmental Disabilities encourages care for children after school. Local municipalities set up "language classes" to support the development of children's spoken language. Children with dyslexia have only reading and writing difficulties, and their speech is often fluent and rich, so in many cases, they are not accepted in languages classes. In some cities where dyslexia is well understood, children with dyslexia are integrated into language classes, and this should standard for every language class in the state. In addition, it is necessary that experts provide knowledge to parents' associations and related NGOs, and make efforts to understand what people with dyslexia and their families think about their problem[34] to understand the demand.

(1) Support system in the UK

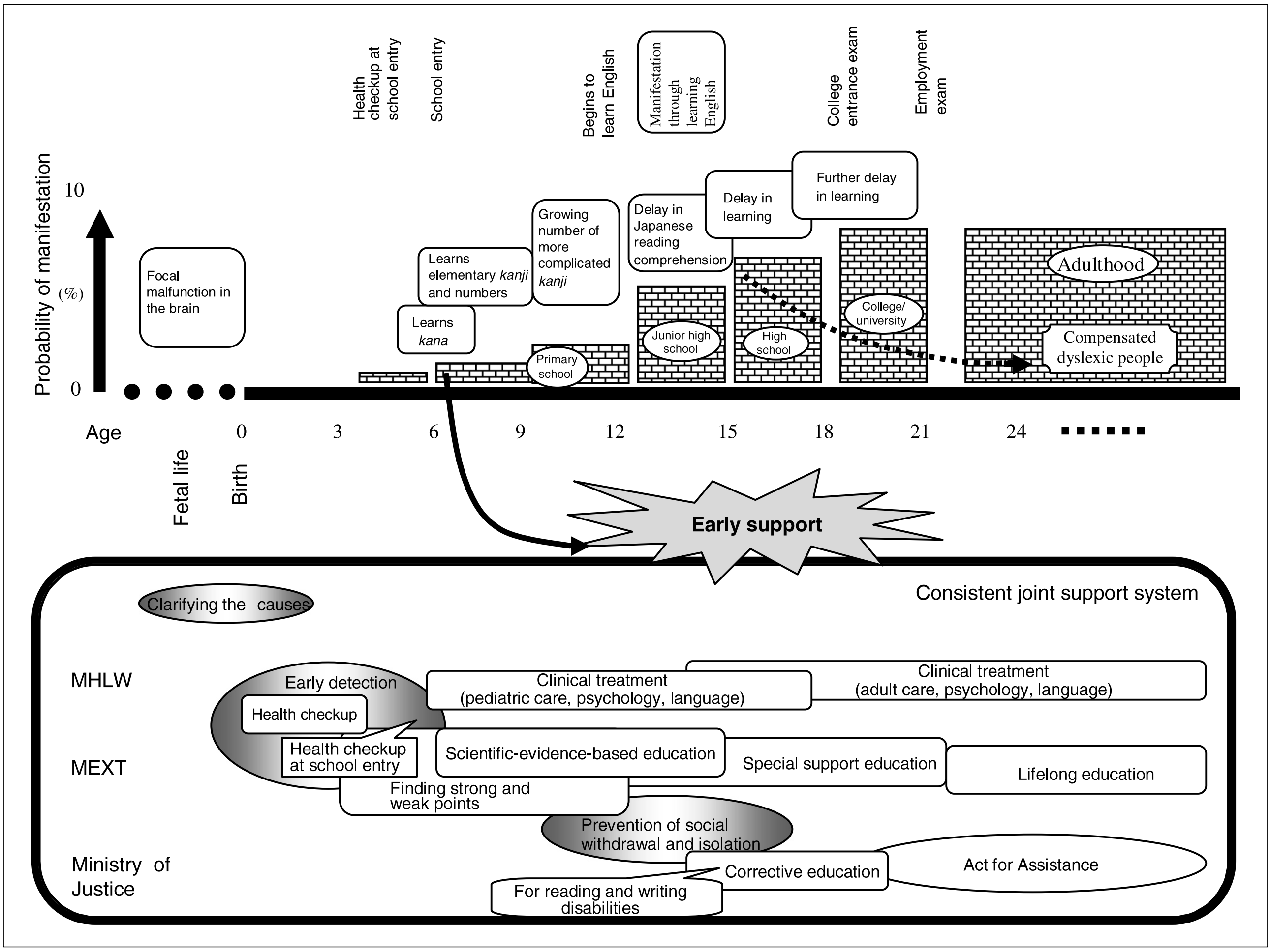
In the UK where English is the mother tongue and the problem of dyslexia is more evident, an NPO was established at the beginning of the 1970s to provide support for people with dyslexia. The NPO disseminates knowledge about dyslexia, provides special support education for individuals or for small groups, trains special education professionals, and develops support methods. The NPO also advises companies that need the knowledge for their product design, considering that about 10% of their customers may be dyslexic. There are private schools that are authorized as meeting the facility and system requirements for accepting children with dyslexia. State schools also provide special support education. In the UK, it is well recognized that children with dyslexia account for 10% of all children, and about 3% are certified as needing special support education, and schools receive subsidies from the government. However, parents must pay the certifiers a lot of money for certification. Therefore, there is a tendency that only children whose parents are wealthy enough to afford the certification or private school enjoy generous support. In October 2003, dyslexia was legally recognized as disability, and the right to receive generous lifelong support has been legally guaranteed.

Basically, schools prepare an Individual Education Plan (IEP) for each child and provide guidance according to the plan. There is a Special Educational Needs Coordinator (SENCO) at schools, who supervises the condition of the child, coordinates between multiple supporters such as the classroom teacher, special support teacher, and speech therapist, and evaluates implementation of the policy.

(2) Sweden

In Scandinavian countries where the welfare system is highly developed, countermeasures for dyslexia were implemented early on. In Sweden, a national research institute for education for children with disabilities was established at the beginning of the 1990s to develop, produce, and disseminate support materials, along with instructions on how to make good use of them. The institute also advised producers of

Figure 5 : Manifestation of dyslexia throughout the life cycle



The above chart represents the appropriate rates of people identified as having dyslexia in the same age group with the maximum rate reaching 10%. Compensated dyslexic people: people who overcame dyslexia by their own efforts, with support from their surroundings, and by innovating a job that does not need complicated reading and writing skills educational materials. In 2001, when the basis of the activity was complete, the national institute made the transition to a special education society[35, 36].

(3) Singapore

It is remarkable in Singapore that Senior Minister Lee Kuan Yew, a widely known and respected statesman who studied law and graduated from Cambridge University with a double First Class Honours and who served as Prime Minister from 1959 to 1990 was diagnosed at the age of 62 and revealed in 1996 that he is dyslexic, and donated private funds to a NPO helping people with dyslexia in Singapore. His revelation helped to disseminate knowledge about dyslexia to the public in Singapore, removed the sense of shame felt by people with dyslexia and the prejudice of the people, resulting in an improved support system. Admittedly, Singapore is different from Japan, being smaller, and politicians and policymakers such as Mr. Lee having immense power, for example. However, it is possible to swiftly establish a comprehensive support system in Japan if the government takes the initiative and promotes the dissemination of knowledge about dyslexia and the development of support systems.

(4) Philippines

In the Philippines where state finances are tight, the parents of children with dyslexia established an NPO, which persuaded the officers of a Catholic university to provide special support education and training for educators. A representative of the NPO said: “There are things one can do even on a small budget.”

5-7 Promotion of Scientific and Technological Research

Because dyslexia is clearly a phenomenon “caused by neurobiological factors,”[1] the promotion of neurobiological research is absolutely necessary to elucidate all of its aspects and to find a scientific basis for special support education. In addition, analysis of the mechanism of dyslexia that genetically produces a peculiar disability in language function serves as an effective clue in exploring the genetic background, origin, and biological foundation of language.

The difference in the left-right asymmetry of the cerebral language areas and local structural anomalies attributed to dyslexia have been described from 20 years ago, but little progress has been made since in analyzing its mechanisms. In Japan, on the other hand, studies with mutant animals, and lissencephaly (hypoplasia of the brain characterized by absence of convolutions of the cerebrum), etc., are proceeding to advanced analysis of cerebral neurogenesis, neuronal migration, layer formation, and specific neural network formation, etc. It is not currently clear what actual mental functions these studies aim to elucidate. It is important to explain the mechanism of linguistic ability and other higher functions by clarifying the cause of dyslexia.

The morphology of the normal brain is formed by the overproduction of neurons at the first stage of neurogenesis and the consequent programmed natural cell death. Anatomical analysis infers that the right hemisphere of the dyslexic brain is larger than normal as a result of a decline in natural cell death[37]. Detailed research is progressing concerning regional differentiation within the brain due to the expression of specific genes and the mechanism of natural cell death; it is anticipated that this will lead to research that clarifies left-right asymmetry and function localization of the brain.

Language is not something that suddenly appeared in human beings today, but is considered to have developed in combination with various functions shared by other animals. Currently, in Japan, studies are being conducted on the mechanism of the visual and auditory cognition of monkeys and on the neuronal mechanisms for learning syllables in birds. It is valuable to elucidate the biological origins and foundations of language by analyzing the genetic mechanisms of acquiring normal linguistic ability together with the aforementioned studies. It is desirable to develop optimal methods of producing, transmitting, and presenting linguistic information based on the cognitive and neural mechanisms of human beings.

Highly skilled speed-readers can read over 10,000 words per minute (the ordinary speed is approx. 500 words/min.) Although speed-reading is apparently the reverse condition of dyslexia, there is low activation of the language areas of the left brain as is the case for people with dyslexia[38, 39]. Elucidation of cognitive and neuronal mechanisms underlying this phenomenon is expected to lead the development of new circumventive training methods for people with difficulty in learning to read.

Academic organizations taking up dyslexia as their major research subject include the International Dyslexia Association (IDA, headquarters in USA)[40], Hattatsusei Dyslexia Kenkyukai (Developmental Dyslexia Study Group), and Ninchi Shinkeishinrigaku Kenkyukai (Cognitive Neuropsychology Study Group) in Japan. These societies present research results and give lectures in various fields spanning basic research, medicine, welfare and medical services, psychology, pedagogy, the classroom and other actual educational strategies, the press, non-profit organizations, etc., and proficient scientific translation is becoming ever more important.

In Japan, a tremendous amount of basic research is being conducted in the fields of information science and engineering on visual or voice analysis, and linguistic recognition, and the private sector is conducting research and development of information analysis and transmission. Devices that recognize the human voice and converts content into written language are effective aids not only for people with dyslexia but also for those with visual disability and elderly people. Although voice recognition and sight tracing for children are more difficult compared with those for adults, it is hoped that support equipment for children will be developed and commercialized. Manufacturing companies are increasingly required to consider easier operation by people with disabilities. Dyslexic-user-friendly products will very probably benefit people with other reading and writing disabilities, elderly people and small children. Development of special support educational materials and equipment is spurring innovation toward the development of new industries and markets.

5-8 Introducing a Comprehensive Perspective

An individual is not defined by his or her disability, nor is a person's life sectionalized into the educational institution or social organization that such a person is affiliated with at a particular time. It is necessary for the Ministry of Health, Labour and Welfare, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Justice, and other relevant ministries and agencies to cooperate with local public organizations to provide consistent support for people with dyslexia during their entire lives.

When the focus is on medical and educational issues, dyslexia is a "functional disorder," but when viewed in terms of brain function, it is "one of the facets in the diversity of human beings." Comprehensively considering an individual, it is insufficient to evaluate a person only by an aspect cumbersome to that person. If deviation from average brain function is relevant, then not only the disadvantages but also the average elements and the advantages should be evaluated. In terms of dyslexia, awareness of average or outstanding ability leads to recovery of confidence. It can also lead to the use of excellent abilities such as circumvention. Methods and measures to evaluate outstanding ability are also necessary. Some outstanding qualities may be observed in people with dyslexia such as "good understanding and fluency in spoken language, expressiveness, capacity for abstract thinking and logical thinking (early maturity in the use of conceptual frameworks, use of generalizations and visualization by manipulation of concepts, etc.), fast, flexible thinking, abundant information-processing ability, superb problem-solving ability, creativity (the ability to ignore the irrelevant among diverse elements and to integrate ideas and a creative, powerful imagination), visuo-motor coordination, artistic and musical talent" and others[41, 42].

6 Road Map to Establishing Support Systems for Dyslexia

The aforementioned tasks will be implemented, if the government exerts clear policies and

Table 3 : Road map for the organization of support systems for dyslexia

Promotion stage	Issues
1st stage	Public relations: Increasing awareness of the existence of dyslexia through the media (TV, printed media, the Internet) and nurture psychological readiness in parents and teachers toward the issue
	Committee of specialists: Establishment of a definition of dyslexia and a method of standardized test strategies based on scientific evidence (periodically verified and reformed)
2nd stage	Wide-scale survey Public relations: Promotion of understanding of dyslexia by all citizens
3rd stage	Early discovery (Preliminary stage): Identifying children with slow acquisition of reading and writing skills by the end of the 1st term of the 1st year of elementary school, calling it to the parents' attention and advising them to consult a medical specialist Medicine: In-service training concerning learning disabilities including dyslexia held at pediatric clinics, child neurology practices, and pediatric ophthalmology practices Education on cognitive science and behavioral sciences at medical schools Applying for training courses on developmental disability and support from language-hearing therapists specializing in acquired disability Organization of a system of fostering language-hearing therapists specializing in the developmental period (in cooperation with educational experts) Scientific and technological research: Language science to clarify dyslexia. Promotion of research in brain science, cognitive science, psychology and behavioral science Genetic analysis of familial dyslexia traits in Japan. Development of material and equipment for support education Education: Diffusion of evidence-based education on dyslexia (Education for undergraduates, graduate students, reeducation of teachers)
4th stage	Early discovery: Diagnosing the possibility of dyslexia at health check-ups on entering school Medicine: Enhancement of a medical system to enable the use of the latest strategies of diagnosis, treatment, and instruction. The addition of the subjects of cognitive science and behavioral science to the national examination for medical practitioners Fostering of developmental language-hearing therapists (support of classroom education) Scientific and technological research: Elucidation of the cognitive and neural mechanisms of reading and writing. Elucidation of the biological origins and foundations of language Developing an optimal method for the formation, transmission, and presentation of language based on human cognitive and neuronal configurations Education: Fulfilling evidence-based education for dyslexia

strong leadership from the initial stage. If the government frequently presents effective policies concerning highly visible issues for citizens such as mental health and education and discloses their process of implementation, citizens would trust the government more, and government promotion of science and technology would progress more smoothly. It would also be a good opportunity for researchers to gain public understanding on research in brain science and cognitive science and their benefits to social and personal life.

7 Conclusion

7-1 What Comes After Enhancement of Literacy

During the late half of the Edo Period, children of the general public received fundamental education in reading, writing, and abacus calculation according to personal proficiency at small private schools all over the nation. Literacy in Japan had already reached one of the highest levels in the world. The Meiji Government furthermore established as its objective "No illiterate person in the home and no illiterate family in the community," instituting mass entrance to school from a prescribed age, and endeavored to raise literacy further. This policy and its effects continued after World War II. The high literacy rate must have contributed to the rapid introduction of modern science and technology after the Meiji Restoration and the spectacular reconstruction of the nation after World War II. The method employed under this policy was repeated practice in reading and writing large amounts of material. Japan has now virtually reached saturation point in terms of the conventional conception of "wider and earlier introduction of literacy" (Figure 4).

In Japan up to now, the structure of the Japanese language that is easy to manipulate for dyslexia has operated favorably to elevate literacy, but problems may also arise if the situation does not progress. English-speaking nations that have the disadvantage of dyslexia easily manifesting itself are turning it into the concept that "difficulty in reading and writing is not the same as inability to learn," preparing conditions for enhancing the learning of children with dyslexia who account for 10% of all children, and progressing in explicating the cognitive causes of other learning disabilities and providing support. The actual situation in Japan where on the surface there appears to be a high literacy rate should be reexamined, and a system should be created where children with dyslexia can learn to read and write without immense effort as in the past, and to direct this effort to creative activities, development of the capacity to define and solve problems, and acquisition of a wide range of knowledge. To this end, rather than adhering to conventional methods of arriving at mutual understanding, transmission of information, learning, and education, these should be conceived of as skills, and their mechanisms should be scientifically explicated to elucidate conditions for the development of the skills. In terms of information media as well, readily recognizable formats and means of presentation should be developed.

7-2 Diverse, Flexible Society

To develop one's own potential and make best use of it and to be able to esteem one's own abilities as well as to receive just evaluation from others are basic conditions or even requisite for the well-being of the individual. This is particularly important for the mental development of children. The pursuit of education that enhances individuality is not to instruct children in "activities considered to be individualistic" that already exist but to elucidate the necessary conditions for each child to fully exhibit his or her own abilities, to prepare these conditions, and to leave the rest up to the child. Diversity of the brain, innovative problem-solving, and creative thinking are also among matters most needed for a Japanese society that tends to make itself uniform. Detailed preparation of support systems for dyslexia would contribute to reform in this direction.

<Complementary notes>

Definition by the International Dyslexia Association (IDA)

Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge[1, 2].

Definition by the World Health Organization (WHO)

Specific Reading Disorder: The main feature is a specific and significant impairment in the development of reading skills that is not solely accounted for by mental age, visual acuity problems, or inadequate schooling. Reading comprehension skill, reading word recognition, oral reading skill, and performance of tasks requiring reading may all be affected. Spelling difficulty is frequently associated with specific reading disorder and often remains into adolescence even after progress in reading has been made[2].

In addition to the above, the diagnosis criteria from DSM-IVTR by the American Psychiatric Association are sometimes used in Japan.

Why only reading and writing?

Homo sapiens, to which all modern human beings belong, first appeared about 250,000 years ago. The biological requisites for the development of language appeared around the same time. The results of a phylogenic analysis of the similarities among the Indo-European languages support the hypothesis that they split from an Anatolian language between 7,800 and 9,800 years ago[7]. Their precursor language must be even older. It is thought that spoken language as we know it today emerged as late as about 50,000 years ago, when human beings began to leave on cave walls the oldest known symbols used by human beings, and began to develop a variety of technologies[8]. The appearance of written language, "a task to represent speech sounds by symbols (writing) and to convert written symbols to speech sounds (reading)," was not very long before oracle bone characters appeared about 3,000 years ago, and Mesopotamian characters appeared between 5,000 and 6,000 years ago. The history of reading and writing is very short compared with that of spoken language. Although one can find languages that have no written form, one would never find people who have no spoken language, even if you go deep into the jungle or visit a remote island. When children are born, they begin to speak spontaneously unless they have a heavy disability. Spoken language is an innate ability[9], although people must master reading and writing skills through explicit training.

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2

Information Systems Supporting Health-promotion Activities Focused on the Individual

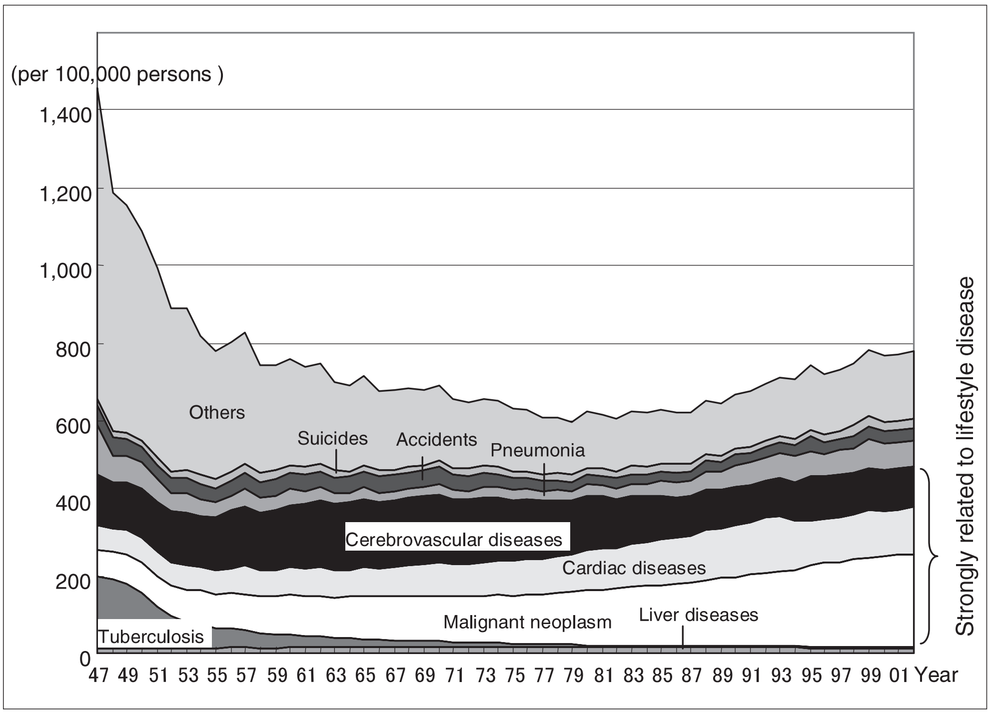
MAKOTO TACHIKAWA *(Affiliated Fellow)*

1 Introduction

With improvement in living environment and changes in lifestyle, particularly the Westernization of the diet, Japan's disease structure has shifted weight towards lifestyle-related disease such as hypertension and diabetes. As seen in Figure 1, deaths strongly related to these illnesses are increasing. Lifestyle-related disease is focused on in medicine in accordance with this trend, but as can be seen in Figure 2, Japan's healthcare costs are continually increasing both in total expenditure and as a percentage of the national income. To contain rising healthcare costs, the provision of effective and efficient care for lifestyle-related disease is necessary.

Care for disease requires activities not only from healthcare service providers, but also from healthcare consumers*[1] in general. These activities are necessary in treatment, and even more necessary in primary prevention*[2] (health-promotion) activities, where there are

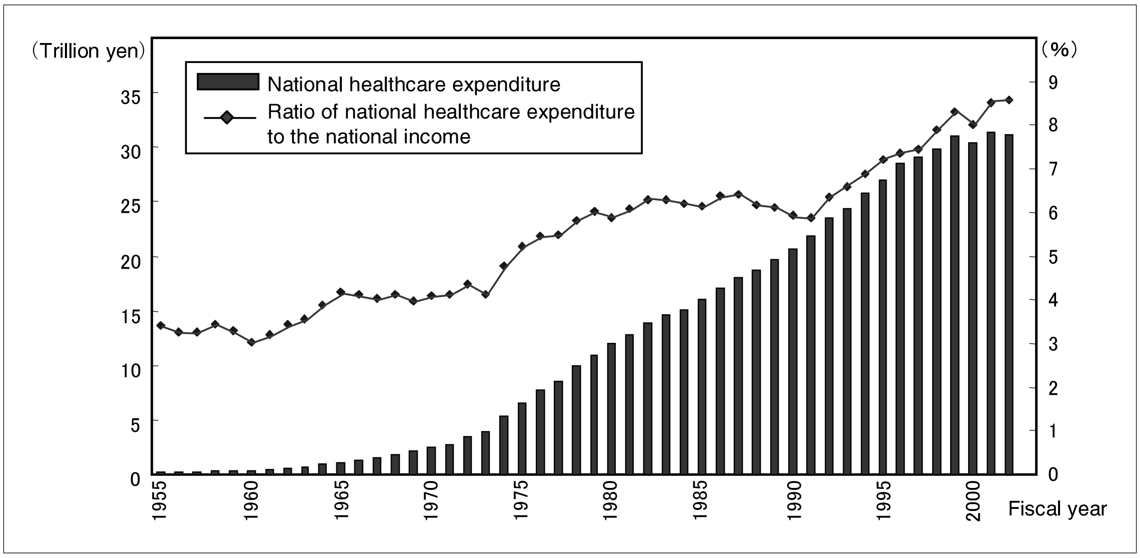
Figure 1 : Annual changes in mortality number classified by major causes of death



Source: Author's compilation based on 2004 "Annual Report on Health and Welfare" (Ministry of Health, Labor and Welfare) and 2004 "Annual Statistical Report of National Health Conditions" (Health and Welfare Statistics Association)

Makoto Tachikawa Senior Specialist, Research Institute for System Science, Research and Development Headquarters, NTT Data Corporation

Figure 2 : Japan's national healthcare costs



Source: Author's compilation based on each year's "National Health Care Expenditure" and "Annual Report on Health and Welfare" (both by Ministry of Health, Labor and Welfare)

fewer opportunities for intervention from the provider. As the term 'lifestyle-related disease' makes clear, these diseases strongly depend on long-term lifestyle habits, limiting the approaches of the healthcare provider side. Therefore, the individual healthcare consumer must proactively and voluntarily participate in his or her own healthcare. In fact, under the National Health Promotion Movement in the 21st Century (Healthy Japan 21) promoted by the Ministry of Health, Labor and Welfare since 2000, health is essentially achieved through the individual's view of health, and each individual should be active[1] in maintaining their own health. In addition, according to the Health Promotion Law enacted in 2003, Japanese people are required to take an interest in and understand the importance of a healthy lifestyle, to be aware of their health over their lifetime, and to promote their own health[2].

For most individuals, however, it is not easy to change the lifestyle habits of many years, even if it benefits their health. Furthermore, continuing and enhancing improved habits over the long term is difficult in practice, so it requires appropriate support from outside sources. This support cannot be merely moral support, but must also be science-based and rational. In other words, the support must enable individuals to assess their own health objectively, predict future health risks, and take appropriate action. Information is key in this support.

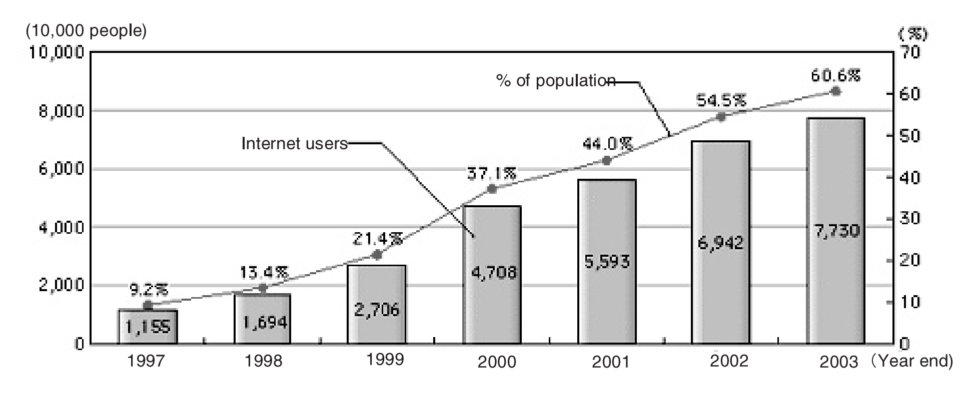
Considering this background, this article looks at information systems supporting individual health-promotion activities hereafter. The information technologies required in this field are not limited to the most advanced. Indeed, because the field requires the participation of the general public without specialized knowledge, the information technologies appliedmust be fully mature and available at lower cost .

2 Growing awareness of the role of information in health-promotion activities

(1) The penetration of evidence-based medicine (EBM)

In the field of medical treatment, the term "evidence-based medicine (EBM)" has been widely used for the past 10 years and more. EBM attempts to carry out effective treatment based on evidence obtained through a specific process. It is defined as the "conscientious, explicit, and judicious use of the current best evidence in making decisions about the care of individual patients"[3]. The EBM process comprises 5 steps: converting information needs into answerable questions; tracking down with maximum efficiency the best evidence with which to answer them; critically appraising this evidence for validity and usefulness; applying the results of this appraisal in practice; and evaluating its

Figure 3 : Number and percentage of Internet users in Japan



http://www.johotsusintokei.soumu.go.jp/whitepaper/ja/h16/index.html
Source: 2004 White Paper: Information and Communications in Japan (Ministry of Internal Affairs and Communications)

performance.[4]

EBM, which began in Canada in the early 1990s, was rapidly adopted in Japan, and in 1999, a specialized journal began publication*3. Since 2001, the Ministry of Health, Labor and Welfare has also been preparing and providing clinical practice guidelines as part of its promotion of EBM[5]. In accordance with these trends, the EBM approach has penetrated rapidly, not only in medical treatment but also in nursing and various other sectors of medicine[6]. The public health sector, which is mainly in charge of health-promotion activities, is no exception*4.

(2) Practical understanding of the effects of health-promotion activities

The effects of public health promotions are diverse and complex, and it is harder than with medical treatment to clarify the degree of contribution of each effect. Therefore, the cost effectiveness of health promotions has not been sufficiently assessed[6], while a certain amount of work has been already conducted. For example, according to research on the healthcare cost-saving effect of quitting smoking, based on statistical data on treatment rates, mortality, smoking rates, and epidemiological data on smoking-related diseases, the expected cost reduction rates over 15 years after quitting are 5.5-8.2 percent for men, and 5.1-8.2 percent for women[7]. Another example is a large-scale prospective cohort research project*5 jointly carried out by 11 public health centers nationwide, the National Cancer Center, the National Cardiovascular Center, universities, research institutions, medical institutions, and so on. To clarify the relationship between lifestyle and illnesses such as cancer, stroke, heart attack, and diabetes, this study has collected lifestyle and health information as well as blood samples from about 100,000 local residents and has followed them for more than 10 years[8]. Although some studies including the above are in progress and their results are accumulating, they are so far insufficient to solve the problems mentioned above. To promote public health research, basic data must be arranged as objective information so that an evidence-based understanding of the content and effects of health-promotion activities can be obtained.

3 Support for health-promotion activities through information systems

With the growing awareness of the importance of information in health-promotion activities, there is a movement to respond through the use of information systems. As an underlying factor, we can point to the rapid penetration of information technology in society, exemplified by the Internet, as seen in Figure 3. This means that individuals are coming into contact with and connecting with a lot of information. Information technologies are being applied to health-promotion activities, now that the focus in information has shifted to individuals who can utilize their personal health information in various ways. Below, I describe trends in information systems supporting health-promotion activities in terms of inputting information, processing it, and outputting it.

3-1 Collection and aggregation of health-screening data on an individual basis (data input)

Health screening (checkup) begins with health screening for newborns, and is carried out by demographic category such as region, school and employment. Traditionally, there are a number of checkup methods by various checkup organizations. There are few interchangeable checkup data among the different methods and the different organizations holding the data. This is why when a person moves to a new area, school, or job, data transference from the previous organization rarely occurs even during a single life stage.

In solving this problem, there is a movement to gather and preserve checkup information on an individual basis and to manage it using information systems. Both from a medical and an information-processing perspective, checkup methods and data transfer protocols need to be standardized to facilitate this movement. Regarding standardization from a medical perspective, the Ministry of Health, Labor and Welfare is planning research to prepare the foundations for effective secondary prevention(See *2) by designing checkup categories, precise control of checkups, and criteria for checkup data[9] under its new health-promotion initiative Health Frontier Strategy set to begin in fiscal 2005. From the perspective of information systems, the Japanese Association of Healthcare Information Systems Industry (JAHIS) has proposed a "Health Data Markup Language (HDML)" as a standardized data transfer protocol[10].

The construction and operation of databases that chronologically accumulate individual checkup data, grasp changes over the years, and permit remote access have already begun*6. Currently, the main users of such services are members of the National Federation of Health Insurance Societies. Insurants (employees) who receive checkups can understand their own health condition, see changes in it over time, and predict future changes using the database. In the future, such services may link with individual disease data on electronic medical records that enable changes in health condition over the years to be seen.

3-2 Calculating individual disease onset risk (data processing)

Managing individual checkup information in unified way by, for example, quantifying physical changes with aging could make a major contribution to raising individual health awareness. To obtain scientific and practical effects, the accumulated health data must be used to clarify the individual risk of disease onset.

In October 2004, Kyushu University and NTT Data Corp. jointly developed a system for predicting the onset risk of lifestyle-related disease individually through personal checkup data[11]. The system used the method of the Framingham Study*7 with the data of about 2,600 participants' over the past 12 years as part of an epidemiological study carried out by Kyushu University in Hisayama Town, Fukuoka Prefecture, over almost the past 40 years. This Hisayama Town study has extremely high rates of physical examination (over 80 percent of all residents aged 40 and over), follow up (over 99 percent of those examined), autopsy (about 80 percent of those who die undergo autopsy to determine the cause of death), providing very precise epidemiological data. Based on a disease-risk-calculation formula derived from these data, the system takes checkup data such as age, weight, blood pressure, amount of exercise, electrocardiogram results, cholesterol, and blood sugar, then predicts the onset risk of lifestyle-related diseases (stroke, ischemic heart disease, diabetes, hypertension, etc.) over the following 10 years. Most existing systems for predicting the onset of disease based on epidemiological data handle a single lifestyle-related disease. In contrast, this system calculates the onset probability of a variety of lifestyle-related diseases on an individual basis and expresses the results in easy-to-understand graphs and charts.

Another approach to understanding onset risk through the relationship between individual genetic information and disease is also underway*8. The research is to identify specific genes related to the onset of lifestyle-related diseases. There are two major approaches in preventative medicine: population strategies that target entire groups such as regions and occupations, and high-risk strategies that concentrate medical resources on individuals at high risk. The disease onset risk calculation mentioned above would promote the latter strategy. It helps use healthcare resources more effectively, and not only the individual but also the groups to which he or she belongs will benefit,.

3-3 Support systems for health-promotion activities (data output)

Merely understanding individual lifestyle-related disease onset risk is insufficient. Learning how to avoid confirmed risks will produce real results. Most healthcare consumers, however, lack specialized knowledge about health promotion, so even if they understand the importance of health promotion in general, few know how to incorporate it into their own healthcare. Furthermore, most habits must be continued in the long term, even after the individual recovers well again.

Therefore, customized outside support based on each person's health condition and lifestyle is needed. Traditionally, customizing processes were extremely expensive, but with information technology, this can be done is relatively easily, with cost awareness and user friendliness. For example, there are now one-to-one services offering personalized e-mail and web pages using an interactive approach to support customized "health-building" programs that include information on smoking, drinking alcohol, exercising, and eating*9. There is an emerging system in which users take digital photos of their daily meals and send them by e-mail to a center where registered dieticians analyze the meals and provide advice on a better diet*10.

4 Issues of stimulating health-promotion activities usng information systems

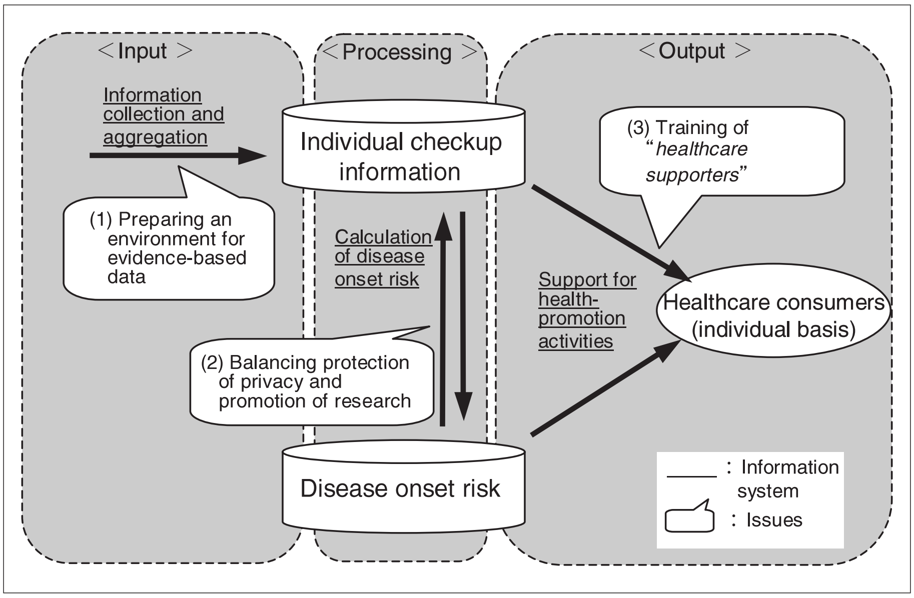
The interrelationships among the information systems supporting health-promotion activities that target individuals described so far are shown in Figure 4. Issues of stimulating health-promotion activities related each system are shown below; these issues can be divided into three categories: input, processing, and output.

4-1 Input-related system

(1) Preparing an environment for evidence-based data

Underlying the scarcity of health-promotion

Figure 4 : Interrelationships and issues with information systems supporting health-promotion activities



activities compared to treatment activities is the misunderstanding that health promotion is relatively less important. In addition, it is not sufficiently proved how health-promotion activities contribute to reducing medical costs as described above. A major cause is the lack of evidence-based data on the effects of health-promotion activities. The measures described in this article constitute some first steps, but this approach is still not widely diffused in Japanese society. Full use of evidence-based data requires aggregating data related to health management on the basis of each entity and epidemiologically verifying the effects of health-promotion activities based on these data. Neither activity cannot be accomplished by a single organization over a short period of time, so an environment enabling cross-organizational action should be prepared. To collect data for a much longer period in the future, a social system such as that shown in Figure 5 must be created.

4-2 Processing-related system

(2) Balancing the protection of privacy and use for research

Personal-information related health promotion is sensitive, so it should be handled very carefully. However, excessively strengthening the protection of personal information will hinder progress in research, interfering with social benefit. To advance research and promote individualized health risk understanding, we must be able to use personal information under agreed rules. Society must therefore reach a consensus concerning information usage between balancing the protection of privacy and the promotion of research.

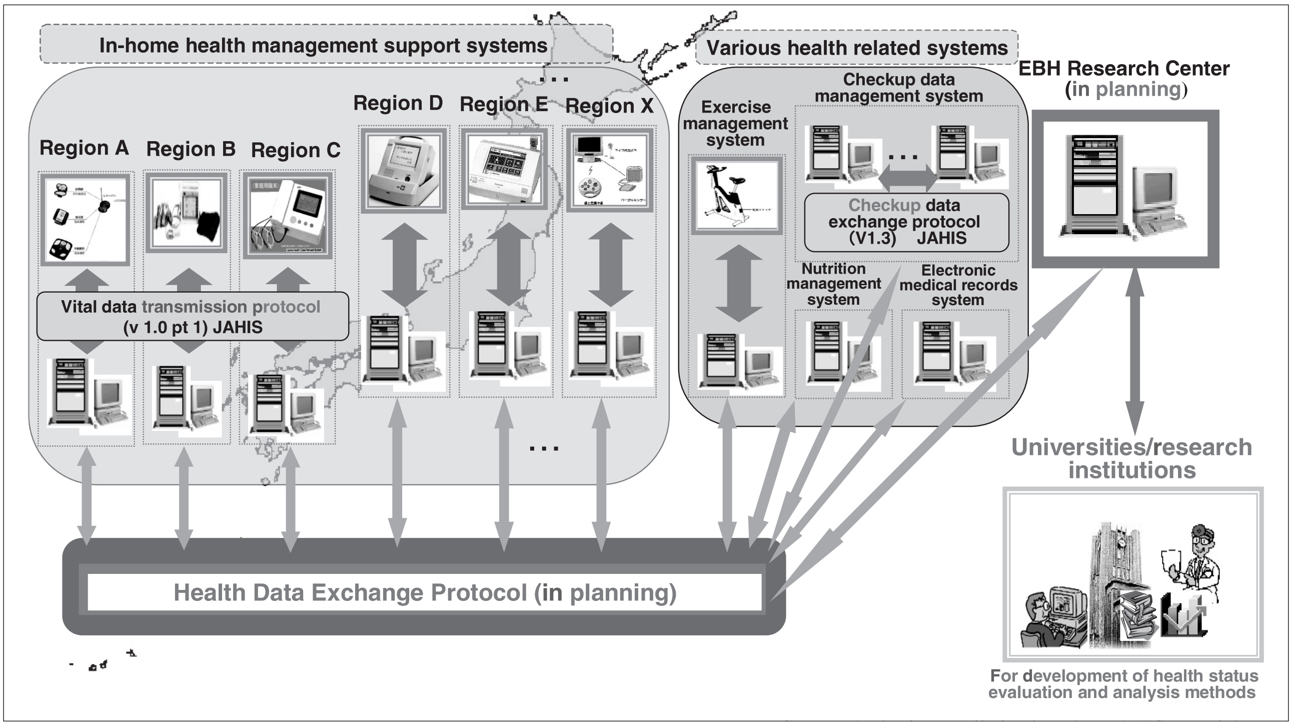
Expanding this concept, the BioBank Japan Project that establishes techniques for Personalized Medicine, is collecting DNA and blood samples from approximately 300,000 people to explore the relationships between genes and the effectiveness of medicine, and genes and disease. Those who provide medical samples are told not to expect any personal return but to consider that they are contributing to their children and grandchildren[12]. We need to spread the concept of making cross-generational contributions from genetic research to all medical research, making it a society-wide value.

4-3 Output (user)-related system

(3) Training "healthcare supporters"

Regardless of advances in information technology, person-to-person approaches are

Figure 5 : The vision of a social data infrastructure for evidence-based data collecting



Source: Author's compilation based on JAHIS materials still needed. Furthermore, those who can best support an individual's daily life health-promotion activities are not medical specialists or government agencies, but the family and others close to the individual. However, people do not always have such supporters nearby. As the onset of lifestyle-related diseases commonly occurs in middle or old age, health-promotion activities are most necessary at the life stages preceding this, the so-called prime of life. This age group, however, does not have sufficient support. Even if family members or other supporters are nearby, they must be able to select, understand, and obtain the necessary health-support information to support their loved ones. However, that this support cannot always be provided is an issue.

One solution would be to create a social system where a large number of personnel are trained as "healthcare supporters" who have the abilities needed to help individuals. Public health nurses already provide some activities of healthcare supporters, but their numbers are too few to be a familiar presence*11. Healthcare supporters might not need as much medical knowledge as public health nurses, but they might need higher ability than public health nurses to process information related to supporting health and to supporting the health-promotion activities of healthcare consumers through close communication. One strategy in training healthcare supporters would be to actively utilize enthusiastic volunteers by training them and having them work with public health nurses.

5 Conclusion

Even though the concept of regular health screening in United States is considered weaker than in Japan, the Federal Government is carrying out a number of public health initiatives, beginning with "Healthy People," which was established in 1979. Each initiative clearly addresses issues such as obesity and diabetes, and they are generally intended to show the public how to act from the perspective of prevention. The importance of preparing information is commonly understood, but more than information is provided. For example, in the "Healthier US" initiative that began in 2001, the "Pocket Guide to Good Health for Adults[13]" shows how to promote good communication with doctors and other specialists, record health-related data, daily health-promotion activities, and so on. A noteworthy point in such US initiatives is that they emphasize working on an individual basis.

In Japan, too, the importance of individual-based health-promotion activities is being stressed more than ever, and a number of information systems to support them are being developed. However, there are problems. The cost benefit analysis of health-promotion activities is not sufficiently clear, so services are fragmented. At the same time, to understand the cost benefit effects, a certain amount of growth in services is necessary. A practical means of overcoming this dilemma is to implement the test operation of advanced services and to expand the results obtained. As organizations that manage these operations, company health insurance societies, for example, may be ideal because they have many employees in the "prime-of-life" age group that are most likely to suffer from lifestyle-related disease in the future. They also are suitable from the perspective of quality research.

The market in health-promotion fields is expected to be huge. From now on, all stakeholders in society are required to participate in vitalizing health-promotion activities. Because the field involves individual lifestyles in all their diversity, the private sector should lead the way in providing diverse, creative services rather than the government providing a standardized service. This means the government should neither avoid leading the way, nor should it play a completely hands-off role. It is difficult for the private sector to directly profit from most of the policies stimulating health-promotion activities as described in this article, so the government should take an active part in building infrastructure.

When the government begins to build the infrastructure, it will further the collection of information regarding health promotion. As a result, the effects of health promotion will be widely recognized, stimulating further activities leading to the creation of a virtuous circle. This may bring not only economic benefit, but may also contribute to the national quality of life, which is a true improvement in social welfare.

Notes

*1 In relation to doctors, hospitals, and other healthcare service providers, patients, their families and those who are not currently receiving healthcare services are collectively referred to as "healthcare consumers" because they may obtain such services in the future.

*2 The field of preventative medicine is composed of: primary prevention, which involves preventing the outbreak of diseases and disorders through a healthy lifestyle; secondary prevention, which diagnoses and treats disease in its early stages; and tertiary prevention, which prevents the advance of disease and supports rehabilitation.

*3 http://www.nakayamashoten.co.jp/ebm/index.htm

*4 In the public health sector, it is called "evidence-based health-promotion or healthcare (EBH)," or "evidence-based public health-promotion (EBPH)."

*5 Research that designates and follows cohorts, identifies the occurrence of targeted disease and death due to that disease, and examines the relationships between those factors and disease

*6 For example, http://www.digi-beam.co.jp/demo/health_new/.

*7 The Framingham Study is a world-famous research study that has been carried out on residents of Framingham, a suburb of Boston, USA, since the 1940s. The primary purpose of the study is to understand the risk factors for cardiovascular disease.

*8 A large-scale research project in Japan attempting to understand the relationship between genes and disease is the BioBank Japan Project that establishes techniques for Personalized Medicine conducted by the Ministry of Education, Culture, Sports, Science and Technology.

*9 For example, http://www.sankenjin.ne.jp/ap/a/a0000.jsp

*10 For example, http://secure01.hs.kddi.ne.jp/shoku365.com/pro/index.html

*11 According to the Ministry of Health, Labor and Welfare statistics, approximately 38,000 public health nurses were employed in 2002. s(Figure 2-56, http://wwwdbtk.mhlw.go.jp/toukei/youran/indexyk_2_2.html)

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3

Technology and Policy Trends in Frequency Sharing

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HAJIME YAMADA *(Affiliated Fellow)**
AKIHIRO FUJII *(Information and Communications Research Unit)***

1 Introduction

We are using wireless technology more and more in our daily lives. Already, the number of mobile telephone subscribers exceeds the number of landline telephone subscribers. Wireless local area network (LAN) equipment is now standard on personal computers. The new application of electronic toll collection systems (ETCs) has also begun to spread through the market.

In order to utilize wireless technology, frequencies must be established. If a certain frequency band is in use and the same band is utilized for another purpose at the same time, interference will result. Based on the idea that authorities should designate the users of each of frequency band in order to avoid interference, since the 19th century governments in every country have managed the use of frequencies.

Once use of a given frequency is authorized, users purchase wireless equipment and begin using it. This imposes an economic burden, so it is difficult to cancel such authorization once it has been given. Those who desire new frequencies are therefore pushed into high frequencies. However, the higher the frequency, the more linear the wireless transmission (radio waves) and thus the shorter the range, making usage difficult.

In order to provide easy-to-use frequencies in response to exploding demand, a new movement to share frequencies is being born. This article will discuss trends in technologies and policies related to such frequency sharing.

2 Exploding wireless demand and frequency management

In Japan, the number of mobile telephone subscribers passed the number of landline subscribers in the spring of 2000. That trend subsequently continued, and as of the end of March 2004, the number of home and business landline subscribers was 50.94 million. In contrast, at 81.52 million, the number of mobile telephone subscribers, including Personal Handyphone System (PHS) subscribers, was 30 million higher.

People have also invented another wireless device: wireless LAN. Wireless LAN is becoming standard equipment on personal computers. It can also be used to connect with televisions and peripheral devices. Along with this, the market has rapidly expanded. According to Nikkei Communications (December 22, 2003), the 2003 market size was ¥48.4 billion, a 28 percent increase over the previous year.

The Japanese Government is promoting the e-Japan Program. The latest version of the program, e-Japan Priority Policy Program-2004, sets forth a policy of using wireless technology to aim for the achievement of ubiquitous networks enabling connection “anytime, anywhere, by anything.” “Ubiquitous” means “anytime, anywhere.” There is a great difference both in feeling and in performance between radio-cassette players that have to be plugged in and mobile music players. Equipment for

* Hajime Yamada Professor, Department of Social Economic Systems, Faculty of Economics, Toyo University

Table 1 : Two frequency control methods and their features

	Frequencies requiring licenses	Frequencies not requiring licenses
Example	Television broadcasts: 90-108MHz, 170-222MHz, 470-770MHz	Bands for industrial, scientific, and medical uses: 2400–2500 MHz (Shared by wireless LAN, microwave ovens, medical devices, etc.)
	Mobile telephones: 810-850MHz, 860-901MHz, 915-958MHz, 1429-1453MHz, 1465-1468MHz, 1477-1501MHz, 1513-1516MHz, 1920-1980MHz, 2110-2170MHz	
Designation of users	• Licenses are given to specific entities based on screening	• Freely used, without licensing
Management of usage conditions	• Purpose of use, technologies, wireless output, etc., are all regulated.	• Regulated to have 10mW or less of output
	• Managed by inspection	• Managed at the factory shipping stage

Source: Authors' compilation based on Ministry of Internal Affairs and Communications materials[1].

"anytime, anywhere" use will be achieved by moving towards replacing wired connections to communications networks with wireless.

Further movement towards the use of wireless technology can be expected. On the other hand, however, because of the problem of interference in wireless communications, frequencies are considered a "scarce resource" and they have been carefully controlled by governments.

In contiguous countries such as those in Europe, wireless spills over national borders. To avoid negative impacts from this, international principles for frequency use are set by the International Telecommunication Union (ITU). Based on those principles, each national government allows the use of individual frequencies. Thus, a twofold national-international regulatory structure is in place.

Following Marconi's invention of wireless transmission in 1885, in 1906 the International Radiotelegraph Convention was organized, and its combination with the International Telegraph Convention in 1932 led to the current ITU. In Japan, the Wireless Transmission Law was passed in 1915, and after World War II, in 1950, it was revised into the Radio Law. Under that law, with some exceptions, "those who would open a wireless station must receive permission from the Minister of Internal Affairs and Communications." Government control is taken for granted.

Wireless LAN is an exception. It uses special frequencies called unlicensed bands. Table 1 shows a comparison with areas where licenses are needed, and the different ways they are controlled.

The problem is that the majority of frequencies require a license, and unlicensed bands are few.

In Table 1, we can see that television is broadcast over bandwidth totaling 370 MHz, but bandwidth for industrial, scientific, and medical uses are even narrower at only 100 MHz. Moreover, there are frequency gaps between the channels of television broadcasting, so there is extra room within the frequency bands occupied by television broadcasting services. Meanwhile, the bandwidth utilized for wireless LAN is tightly packed and is already approaching its limits. The government is attempting to shrink the frequency bandwidth used by television broadcasting by switching to digital. However, it will take some time before that shift can be completed.

It is questionable whether exploding wireless demand can be met merely through continued strict government regulation. With that as the greatest point of debate, various countries are now reviewing their policies.

3 Trends in spectrum policy

3-1 Establishment of the SPTF in the United States

In the United States of America, the Spectrum Policy Task Force (SPTF) was organized in June 2002 according to the instructions of Federal Communications Commission (FCC) Commissioner Michael Powell. The mission of the SPTF is to examine the proper state for spectrum policy[2].

In the United States, frequencies utilized by the military have the highest priority. As a result, frequencies for the third-generation mobile phones that have spread so remarkably in Japan cannot be designated, and the opening of services

Table 2 : Proposals for drastic reform of spectrum policy (Summary)

i) In the past, attempts to make full use of bandwidth were limited by interference. With advances in technology, however, that is no longer a problem, and new systems with more efficient spectrum use are now possible.
ii) However, continuing the traditional system of spectrum regulation through the granting of licenses will limit users in many bandwidths.
iii) Spectrum regulation should be reformed in the direction of greater flexibility and market orientation.
iv) From the perspective of preventing interference, a new regulatory model should be constructed by clearly defining the rights and responsibilities of licensed and unlicensed users (users of the spectrum commons who do not need licenses, as with wireless LAN).
v) A single regulatory model should not be applied to all frequency bandwidths. Systems for exclusive allocation of bandwidth based on market principles and for the creation and free use of spectrum commons should exist alongside the traditional licensing regulatory model.
vi) New regulatory models should be applied not only to new frequencies, but also to already distributed bandwidth. A mechanism should be created for migration of the latter from the traditional regulatory system.

Source: Authors' compilation based on SPTF materials.

has been delayed. On the other hand, use of wireless LAN is greater than in Japan. These kinds of situations led to the formation of the SPTF.

The SPTF submitted its first report in November 2002. At the front of the report, it says, "While the Commission has recently made some major strides in how spectrum is allocated and assigned in some bands, principally through flexible rules and competitive bidding, spectrum policy is not keeping pace with the relentless spectrum demands of the market. The Task Force has begun the process of reexamining 90 years of spectrum policy to ensure that the Commission's policies evolve with the consumer-driven evolution of new wireless technologies, devices, and services."

Competitive bidding is the system of allowing the communications company that submits the highest bid to utilize a given frequency for a given use. In the U.S., competitive bidding was used in 1994 to determine the frequencies for the Personal Communication System (PCS). Subsequently, frequencies for third-generation mobile telephone systems were put up for competitive bidding in the United Kingdom and Germany. Awarding bandwidth to the highest bid invites the participation of enterprises that are aware of the risk and will utilize the frequencies. This is also called market-driven or market-based allocation of bandwidth.

The SPTF's concrete proposals are summarized in Table 2.

For example, in regard to wireless used for military purposes, it is appropriate for government to use its power to designate frequencies, as has been done for the past 100 years. On the other hand, fields where numerous vendors want to participate, such as mobile telephone systems, are opened to competitive bidding. In part, a shared area called a spectrum commons could be set up. This is the basis of the idea of having multiple regulatory models coexist.

"Commons" usually refers to shared land. In Japan, the concept dates far back in the idea of "right of common." The right of common is a common-law right codified in civil law as the right of residents to jointly use trees and brush from designated forested mountains and fields (commons) for firewood and so on.

The question is, which residents can enter the commons and harvest trees and brush for firewood. If people try to exercise their rights by harvesting too much, it becomes a serious problem for everyone else. Moderation in harvesting is required. In the case of a spectrum commons as well, anyone can use it. However, if someone therefore decides to recklessly boost wireless output, it will interfere with other communications. This commons therefore also requires moderation. Wireless LAN is a technology that utilizes a spectrum commons, and thus it must be used responsibly so that all can utilize that shared asset.

FCC Commissioner Powell immediately expressed agreement with the SPTF's recommendations.

Following the SPTF report, in June 2003 U.S. President George W. Bush announced the

Table 3 : Proposed spectrum policy reforms in Radio Policy Vision (Summary)

i) Quickly prepare a system for the reallocation of spectrum through an examination of spectrum use and an announcement of the results, as well as the creation of a payment system to compensate incumbent licensees for economic losses.
ii) **Because competitive bidding may lead to sudden jumps in bid prices, create a transparent and fair comparative examination method to establish transparency in spectrum use.**
iii) Increase spectrum allocation flexibility by expanding low-watt spectrum commons for unlicensed stations along with allocating unique regional frequencies.

Source: Authors' compilation based on Special Department for Radio Policy materials.

opening of the Spectrum Policy Initiative (SPI). Headed by the Secretary of Commerce with the FCC also participating, the SPI is a venue for policy discussion. In these ways, the United States is beginning drastic reform of its spectrum regulations.

Even as those discussions continue, the FCC is already working to adopt new regulatory models from the perspective of frequency sharing.

In June 2004, two technologies for low-earth-orbit satellite communications, code division multiple access (CDMA) and time division multiple access (TDMA), were approved to share the 1.6 GHz band. How the sharing is to be achieved was left to discussions among the communications vendors who will use each technology. This action was based on the intent of minimizing government intervention.

To more efficiently utilize licensed frequencies, in July the U.S. government moved to create a "secondary market" intended to create a mechanism allowing license holders to lease their frequencies to others. If the competitive bidding markets described above are "primary markets," the leasing to others at "market prices" of the frequencies thus obtained comprises "secondary markets."

Another startling proposal, the utilization of open channels below 900 MHz on the television broadcasting frequency band for wireless broadband service, was set out in May 2004 (FCC DA 04-341). We will address this again later in the article.

3-2 Japan's Radio Policy Vision

In Japan, the Special Department for Radio Policy of the Information and Communications Council has carried out activities similar to those of the SPTF.

The Department held its first meeting in September 2002. It submitted its final report in July 2003. Entitled "Radio Policy Vision," the report offered the proposals summarized in Table 3 regarding the redistribution and allocation of spectrum[3].

The direction of the report shares with the United States the idea of expanding the spectrum commons. In contrast to the United States' assertion of market principles, however, the report asserts some Japanese ideas, such as problems associated with competitive bidding. This is a major point of debate. However, since comparative policy is not the purpose of this article, we will not discuss it further.

Subsequently, in August 2004, the Ministry of Internal Affairs and Communications announced an action plan to smoothly and steadily reorganize spectrum based on an evaluation of usage of frequencies of 3.4 GHz and above. Regarding the 3.4 to 3.6 GHz frequency band, for example, the action plan says, "Currently, it is used for video and audio communications, but because it is suitable for mobile communications, shifting audio to other frequency bands will be examined." In addition, regarding the frequency band from 5.25 to 5.85 GHz, the plan notes that it is used for ship and weather radar and expresses the view that it is "suitable for spectrum sharing with wireless LAN."

In these ways, the Ministry of Internal Affairs and Communications is moving towards achieving the recommendations of the Special Department for Radio Policy for spectrum reorganization and commons expansion.

Furthermore, the government announced that frequencies in the 800 MHz band would be reallocated for third-generation mobile telephone use and called for opinions in August 2004. The sight of some communications vendors objecting to the plan for reallocation mainly to existing mobile phone companies was striking.

As we have described, in both the United States and Japan, policies are underway to share spectrum and utilize it as a commons. In the next section, we will discuss relevant technology trends.

4 Development trends in frequency sharing technology

In this section, regarding technology trends related to wireless systems, we will outline those technology trends particularly responsive to effective spectrum use. The literature points to (1) reorganization of spectrum in the 5GHz band and (2) the adoption of new ultra wideband wireless systems as important fields for research and development from the perspective of effective spectrum use[4].

(1) is R&D related to advanced wireless LAN. It brings the functions of the Internet to wireless systems. (2) is ultra wideband wireless systems (UWB). Communications systems have hierarchical structures. UWB technology provides a physical communications environment for the transfer of digital data, including audio. Expectations are high for UWB as a new platform.

Although we will not discuss it further in this article, the realization of such new services will require not only wireless technology, but also the simultaneous resolution of issues related to ensuring quality of service (QoS), arrangement of terminals, proper routing, and security.

4-1 The position of frequency sharing technology in wireless LAN

(1) Overview of wireless LAN technology

The United States Institute of Electrical and Electronics Engineers (IEEE) has studied and standardized technology for the reorganization of the 5GHz band for effective frequency use. Since there was worldwide participation in that standardization, it is seen as the international standard as well.

Wireless LAN is a type of local area network (LAN) technology. Systems have to meet the physical and equipment standards of the Internet protocol (IP) for data transfer.

Table 4 : Working groups in IEEE 802.11, 802.15, and 802.16 committees (part)

Working group		Study areas
TG11	a	Physical layer of 54 Mbps via 5GHz band OFDM
	b	Physical layer of 11 Mbps via 2.4 GHz band CCK
	c	Extension of 802.1D bridge specifications to 802.11
	g	Physical layer of 54 Mbps via 2.4 GHz OFDM
	i	Enlarging security
	j	Specifications for Japan's 4.9 GHz standard
	n	Next-generation wireless LAN
	p	High-speed mobile systems appropriate for trains and DSRC
TG15		Standardization of local area network PAN specifications
TG16		WiMAX, standard for licensed frequencies in the 2–11 GHz band

Source: Authors' compilation based on IEEE materials.

Wireless LANs can be constructed not only in offices, but also in specified locations (hotspots) in commercial areas and so on. The technology has even advanced to the point of communications control for mobile computers and other terminals. Against the backdrop of increasing demand for development of this wireless LAN technology, both Japan and the United States are moving towards deregulation as optimal for spectrum regulation.

(2) IEEE 802.11 standard and areas of application

The IEEE's 802 Committee is a working group that carries out everything from study to standardization of elemental technologies. Table 4 shows some of the standardization work performed by subordinate organizations of the 802 Committee. The chart shows not only 802.11, but also 802.15 and 802.16[5].

(3) Frequency sharing in wireless LANs

When many users utilize a wireless LAN in the same location, there is a danger that interference may occur. Carrier sense is a technology to avoid this problem.

In wireless LAN (802.11b), a maximum of

14 20-MHz channels can be set within a 2.4 GHz band. Three of those channels may be used simultaneously. Before data is transmitted, “carrier sense” scans for open channels, and then an open channel is used. This is carrier sense multiple access with collision avoidance (CSMA/CA), which prevents interference.

In addition, rules for allocating the timing of radio-wave retransmission and for orderly resending when transmission fails, in other words, a wireless access protocol, have also been set.

In the case of wireless LAN, data is transmitted in “bunches” called “packets.” The length and cycle generated differs with each transmission, so it is the proper assembly of packets and efficient response that enable the transmission of high-speed multimedia.

4-2 WiMAX and overlay

The widely disseminated wireless LAN is a technology for transmission over a range of a few meters to a few tens of meters and is therefore designed for use in homes and offices. In contrast, worldwide interoperability for microwave access (WiMAX) is a wireless technology being developed for use over a range of a few kilometers.

As seen in Table 4, the IEEE is working on the standardization of WiMAX technology, which is called 802.16 technology after the committee in charge of its standardization.

802.16a was released in January 2002. Work on the creation of standards for an upgraded version is underway.

Table 5 shows an overview of the 802.16a standards. If bandwidth is 20 MHz as shown in Table 5, at 5 MHz per channel with a maximum speed of 75 Mbps, a transmission speed of 15 Mbps can be achieved. Thus, it is suitable for services somewhat faster than an asymmetric digital subscriber line (ADSL). Although ADSL advertises a speed of at least 40 Mbps, that is a nominal value. At a distance of one kilometer or more from a station, a speed of no more than a few Mbps can be expected.

Various companies are already working to develop products that comply with the WiMAX standards. The first products are expected to reach the market in 2005. In addition, although WiMAX is a technology for fixed communications, improvements to enable its use with mobile communications have begun.

Table 5 : Overview of WiMAX (IEEE 802.16) standards

Frequency bands	<11GHz
	2.5, 3.5GHz (licensed)
	5.8GHz (unlicensed)
Transmission speed	75 Mbps maximum
	(20 MHz bandwidth)
Usage configuration	Fixed (outdoors/indoors)
Cell size	6–10 km radius (Maximum distance 50 km, depending on tower height and location)

Source: Authors’ compilation based on Intel Corp. materials[6].

In connection with WiMAX, study of “overlay” has also begun. This is a mechanism for allowing other users to utilize wireless on frequencies where there are already licensed users. It can be seen as a technology similar to CSMA/CA. This article looks at WiMAX because there is a movement to apply overlay to WiMAX.

The main targets of overlay technology are the frequency bands used for television broadcasting. Television broadcasting has many unused channels. The open channels vary by location, so it is proposed that they be dynamically detected and utilized. Even if a given frequency were being used by the licensee, carrier sense would detect it and instantly move to another frequency. Thus, interference would not be a problem.

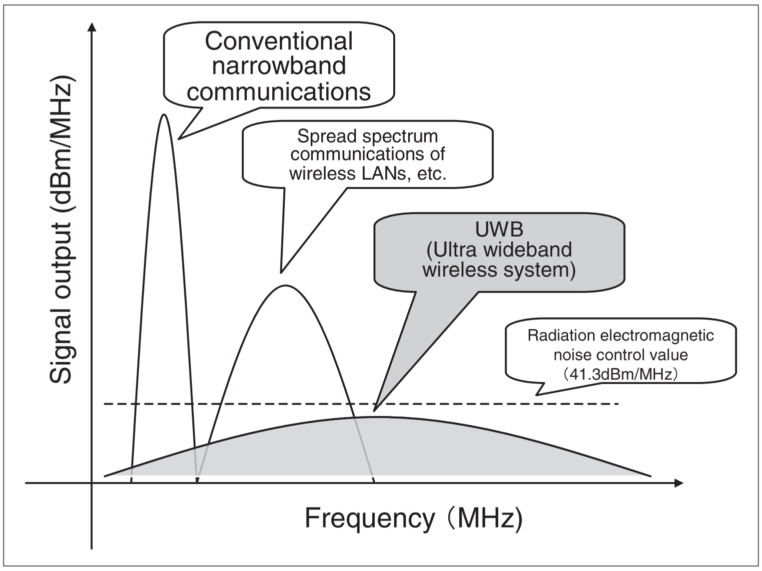
Because the technology has the “brains” to automatically detect open channels this way, it is sometimes referred to as “smart” or “agile” wireless. Some groups call technology that effectively utilizes unused frequencies “recognition wireless.” The name has not yet become fixed.

Television broadcasting frequency bands are being used for two-way data transmission and Internet access. As we described above, the FCC has begun seeking opinions on the use of overlay. Manufacturers have performed demonstrations with devices built with such technology.

4-3 Spread spectrum communication and UWB

Ordinarily, wireless communications use

Figure 1 : The principles of an ultra wideband wireless system



a narrowband system. Many readers have experienced turning a tuner (radio dial) and seeking a band where there is a signal. When the tuner matches a carrier wave frequency, a clear signal is obtained.

In spread spectrum communication, on the other hand, signals are spread across a broad width of 100 MHz or more. At the same time, the radio waves (signal output) on each frequency are weak, so wireless devices pick them up only as noise. Thus the communication is concealed.

Figure 1 shows an overview of the relationship between the frequencies used and strength of signal. Spread spectrum communication with its bandwidth widened to the extreme is UWB, as illustrated in the chart. The "radiation electromagnetic noise control value" in the chart is the value at which other wireless devices can receive it only as noise. Below that value, conventional narrowband communications will be completely undisturbed, so coexistence is possible.

The technology of spread spectrum communication was patented during World War II, in 1942. However, partly due to the times, a way to use the patent was not found. Subsequently, development of spread spectrum communication proceeded only with military applications in mind.

Only in 1985 was the technology first tested by being used in the personal computer interface Recommended Standard 232 C (RS-232C). Although it was not a commercial success by any means, civilian use of the technology was accelerated after that.

An example where it is widely used is in musical instruments used in concerts and so on. Musical Instrument Digital Interface (MIDI) uses spread spectrum communication for its wireless connections.

In wireless communications, signals output below the noise threshold do not disturb other devices. As we explained above, using this small signal output is the first point of spread spectrum communication.

Next, let us consider what happens when two or more spread spectrum communications are used at the same time. Encryption is used to avoid interference at that time. Encrypting data to be sent so that the contents do not leak to the wrong recipient is the second point of spread spectrum communication.

If we use the analogy of a party with international guests, languages such as English, Japanese, and Chinese, might be flying about the venue. Korean might be spoken right next to French. However, as long as no group breaks out in loud voices and intrudes on the others, conversations will not be interrupted. The limit of an acceptably loud voice is like the first point, the radiation electromagnetic noise control value. The different languages are like the second point, the encryption in spread spectrum communication. If a language cannot be understood, a conversation in that language cannot be understood either. If a number of encryptions are set and different ones are used, multiple communications can be separated.

In this way, spread spectrum communication can be used to allow different types of wireless communications to coexist.

CDMA technology has developed based on spread spectrum communication and is utilized in third-generation mobile telephones. In addition, spread spectrum communication will also be used in wireless LAN.

Furthermore, UWB technology has been in the spotlight, and R&D to put it to practical use is progressing. In part this is because the FCC approved limited sales of UWB products in February 2002.

In May 2004, an international conference on UWB was held in Kyoto. It was observed that a speed of several hundred Mbps was announced, and that an LSI chip set to support it would go on sale for about $10 next year.

Once a chip set is completed, making a small device will be simple. USB memory, tiny devices equipped with flash memory and a universal serial bus (USB) terminal inside are used as backup personal computer memory. In the same way, if a chip set is added to a small container with a USB terminal, UWB can easily be substituted for the personal computer communications process.

A newspaper reported that the National Institute of Information and Communications Technology, an Incorporated Administrative Agency, will undertake the development of practical UWB technology (Nihon Keizai Shimbun, October 22, 2004). Japan has also begun full-fledge R&D.

5 R&D and policy recommendations

The technologies mentioned here are only a small part of the wireless systems that can be expected to develop and spread from now on. Research and development in the field is multifaceted, with many new R&D needs appearing. Here we will touch on some important points regarding research and development in this distinctive field.

(1) Characteristics of wireless technology

Only when spectrum can be used does wireless technology become practical. From another perspective, if spectrum appears unlikely to become available in the future, resources for development will not be invested. In this way, spectrum policy has a major influence on wireless technology research and development. In the field of information communications, the direct influence of government policy on technological development is a unique characteristic of wireless technology.

As we mentioned at the beginning of this article, wireless technology is one of the keys to achieving a society with ubiquitous network connections. To further the development of this wireless technology, it would be effective if policy authorities were to show a concrete direction for technologies such as overlay technology and UWB technology.

An aggressive review of technology policy supporting wireless technology research and development in light of changing technology should be performed in connection with regulatory policy. For example, if the UWB technology described above becomes widely used, the traditional regulatory concept of “specific systems must be licensed to use specific frequencies” will no longer be useful. New regulations should look to the output of wireless devices, and regulatory policy should shift from regulation of frequency bands to regulation of radio-wave output. Research and development will follow this as it progresses.

Wireless is not the only technology field where policy needs to be comprehensively reexamined to promote R&D of frontrunners. In any field, policy should be proposed in light of the characteristics of new technological factors.

(2) Research direction and role clarification

At an international conference on communications during the mid-1990s, when mobile telephone use was rapidly expanding, a researcher in wireless communications said, “At last it sees the light of day.” Those words brought home the importance of continued general, basic research. Basic research connected to the fostering of human resources at the graduate level is at the root of the accumulation of broad knowledge, from modulation and other communications engineering basics to Internet communications methods to standardization to forms of computer terminal use.

University professors play a leading role in the above-mentioned wireless technology research of the National Institute of Information and Communications Technology. The leader of the special group on UWB, for example, is Professor Ryuji Kohno of Yokohama National University. The Institute's basic research is being watched as a test of linking basic research to practical application.

At the same time, R&D with an awareness of marketability is needed in fields where new applications appear in a short time. Competition for business hegemony in wireless systems is particularly fierce, and the capture of marketability at the final stage of R&D is strongly required.

It is therefore important that the R&D that should be carried out by universities and public institutions and that which should be actively performed by private sector enterprises be clearly divided so the most appropriate forms and goals can be laid out.

(3) Deregulation and the promotion of research and development

At the stage of providing wireless technology for actual use, preparation of an environment for practical testing is important. In Japan, a separate license must be obtained in order to perform outdoor experiments. Such licenses are issued only with very detailed conditions, for example, "At the aforementioned frequency, a test for other radar will be performed for one minute. If it exists, radio waves will be turned off within 10 seconds." Such regulations prioritize protection of those already using frequencies and form an obstacle to R&D.

One idea is to utilize outlying islands with a population of a few thousand as special wireless zones. Such zones already use mobile telephones, fishing radios, and so on, so they could be utilized to test whether new systems disturb existing ones. Compared with urban areas, the damage would be minimized if any problems should occur. If such experiment environments are created, wireless device manufacturers would build permanent testing facilities and universities with telecommunications programs would place labs there. This would bring economic benefits to the special zones.

In the United States, outdoor experiments are already actively conducted on indigenous peoples' lands and other places where impact is light. Japan also needs to prepare environments for wireless experiments through measures such as the utilization of special zones.

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(Original Japanese version: published in November 2004)

4

Trends in Optical Fiber Communication Technology and Industry, and Proposals for Future Directions
— Towards the Fusion of Seeds and Needs —

KIMIO TATSUNO
Information and Communications Research Unit

1 Introduction

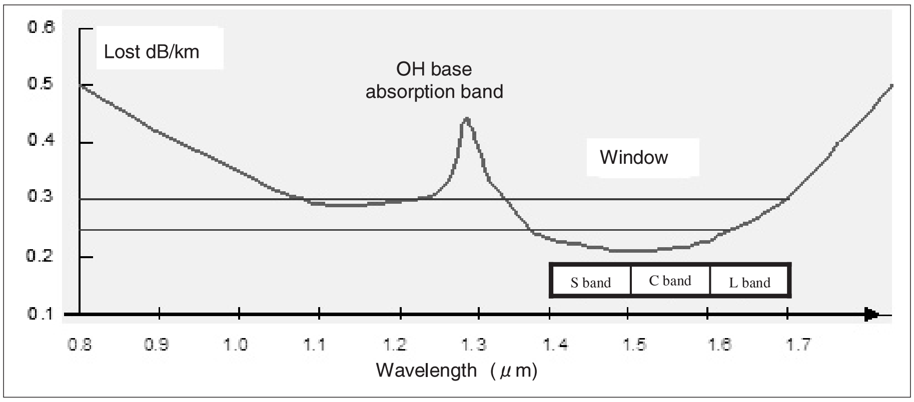
Optical fiber communication technology enables ultrahigh-speed, high-capacity, long-distance transmission. Because there is no alternative technology, it is indispensable basic infrastructure supporting society's information and communication functions. The spread and improved performance of photonic infrastructure therefore has a major influence on a country's overall social life. For example, mobile telephones using wireless utilize wireless communication to reach nearby antenna stations, but the stations utilize photonic networks among themselves, and optical-fiber cables on the ocean floor enable real-time communication with people all over the globe. In addition, while the asymmetrical digital subscriber lines (ADSL) now widely used for the Internet use metal wires, station-to-station transmission utilizes photonic networks, connecting the world's personal computers. The scale of the world market for the photonic device industry that utilizes this technology as its core is ¥10 trillion. If optical fibers are connected not only to backbones but also to ordinary homes as exemplified by "fiber to the home" (FTTH) and to information devices, the scale of the photonic device industry's market can expand even further.

However, for the past several years the optical communication industry has been confronted with the collapse of the IT or dot-com bubble, and with the world in the throes of a recession led by North America, demand for backbone in particular has cooled off and the market has stagnated. Meanwhile, traffic over Internet lines has been increasing since immediately after the collapse of the optical communication bubble. Led by peer-to-peer sending and receiving of motion pictures, the conversion of the work of business and national and local government is gradually spreading through e-commerce, e-government, e-education, e-medicine, and so on. These add up to the working of synergies that are peculiar to the Internet.

Therefore, at some point in the near future we may awake to find that traffic is congested at various points in society. The reliability and safety of communication may be damaged, and declining quality of service (QoS) may become a major social issue. In other words, bottlenecks may occur in the photonic networks that form the backbone of communications infrastructure. For that reason, we must not relax research and development efforts directed towards future photonic technology.

Based on the current awareness and future vision described above, this article discusses questions such as the following. (1) What is the background of the optical communication recession, and why did it occur? (2) In relation to the continuously increasing volume of traffic, what will the next bottleneck in photonic technology be? (3) Is a structure in place for creative research into new communications services actively utilizing broadband infrastructure made possible by photonic technology? In addition, the article offers proposals regarding the direction of R&D designed to fuse the seeds of optical communication infrastructure with the needs that require it.

Figure 1 : Optical fiber transmission loss bands and optical fiber amplifier operation frequency



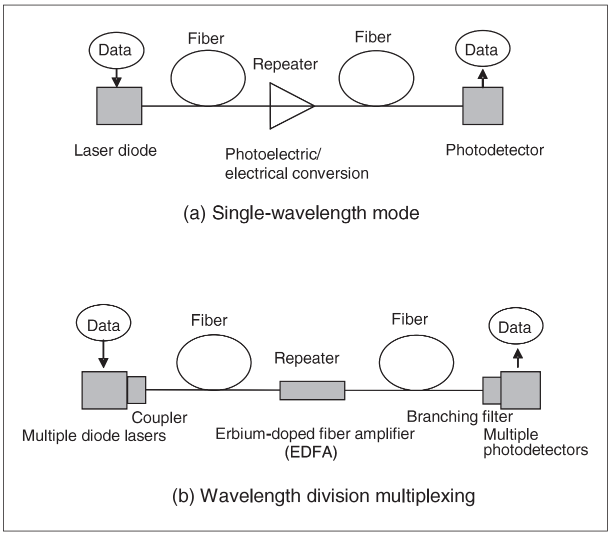
2 Optical fiber communication technology

2-1 Optical communication principles and wavelength division multiplexing

Within photonic technology there are modes such as the propagation of light through space, but this article discusses optical fiber communications utilizing optical fibers of glass materials with silicon oxide (SiO_2) as the signal transmission medium. For the sake of simplicity, the article will refer to this as "optical communication." Figure 1 shows transmission loss characteristics of optical wavelengths on currently installed typical optical fibers[1]. The peak in the center is the absorption band created by the harmonics of the OH base of residual moisture inside the fiber. Ordinarily, optical communication utilizes the wavelength bands, called "windows," that avoid the peak. The wavelength used at first was 0.85 μm to the left of the peak. That was because the materials for laser diodes of the time were GaAs-based. Later, InP-based laser diodes were developed, and the band from 1.3 μm to 1.6 μm, where transmission loss is lowest, came into use. Furthermore, optical fibers are low cost at under ¥10 per meter, they are long-lived and reliable, and their tensile strength is greater than that of steel. In practice, such optical fibers (125 μm diameter, approximately 10 μm core) are bundled by several hundred into optical fiber cables when installed.

Figure 2(a) shows the basic structure of optical communication utilizing optical fibers with characteristics like these. There is a laser diode light source on the data transmission end, and the strength of that light is digitized as an electrical signal that modulates on/off. The modulated light signals are propagated in the optical fibers, but absorption and dispersion in the optical fibers cause loss of data and attenuation. For long-distance communications, therefore, repeaters are placed every few tens of kilometers to transmit optical signals over long distances. On the receiving side, photodetectors and electric amplifiers are in place, and the optical signal is converted into an electrical signal and the original data are recovered. In conventional single-wavelength mode, repeaters temporarily convert attenuated optical signals into electrical signals, and reactivate a laser diode after electrical amplification. In other words, each repeater must perform photoelectric conversion and electrical conversion. This conversion must be carried out for each wavelength channel, so utilizing wavelength division multiplexing with this method is difficult.

Figure 2 : Principles of optical communication



In contrast, as shown in Figure 2(b),

wavelength division multiplexing (WDM) passes beams from multiple laser diodes for different wavelengths through a coupler before inputting them into a single optical fiber. Therefore the transmission capacity of a single optical fiber is the product of one wavelength channel's transmission speed multiplied by multiple wavelengths. For example, if the interval between wavelength channels is 0.4 nm, and the entire wavelength used is 400 nm, it can be multiplied by 1,000 channels. If each wavelength channel transmits 40 Gbps, 40-Tbps ultrahigh-capacity optical communication becomes possible. If we explain this astonishing communications capacity in terms of digital versatile discs (DVDs), the data stored in a two-hour movie on DVD is 4.7 GB (about 40 Gb), so the information stored in 1,000 DVDs can be transmitted to a destination across the Pacific in about one second.

Optical fiber amplifiers[1] such as erbium-doped fiber amplifiers (EDFAs) make this wavelength multiplexing transmission possible. Using them renders photoelectric and electrical conversion by repeaters unnecessary. This is because these optical amplifiers function like optically-pumped lasers, enabling them to amplify optical signals in batches as light and on a relatively wide wavelength band. Furthermore, it is fortunate that the operation frequencies of optical fiber amplifiers, referred to as the S, C, and L bands, happen to be the optical fiber wavelength bands with the least loss, as can be seen in Figure 1. As depicted in Figure 3, the cable across the floor of the Pacific Ocean has 180 repeaters equipped with optical fiber amplifiers strung together about every 50 kilometers.

2-2 The structure of optical communication networks

As shown in Figure 4, the extremely high performance optical communication method described above comprises a network constructed of a transmission system and exchange node system that ties it together. The transmission system can be roughly divided into three layers, the backbone system (10-40 Gbps)

Figure 3 : Repeaters for the Transpacific Cable

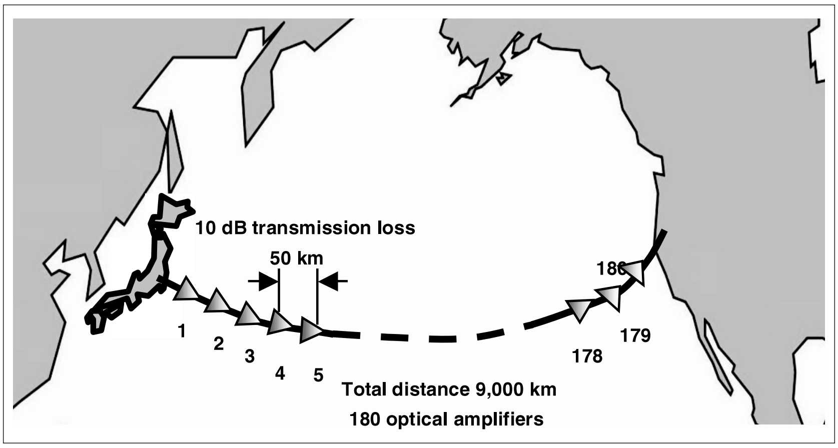
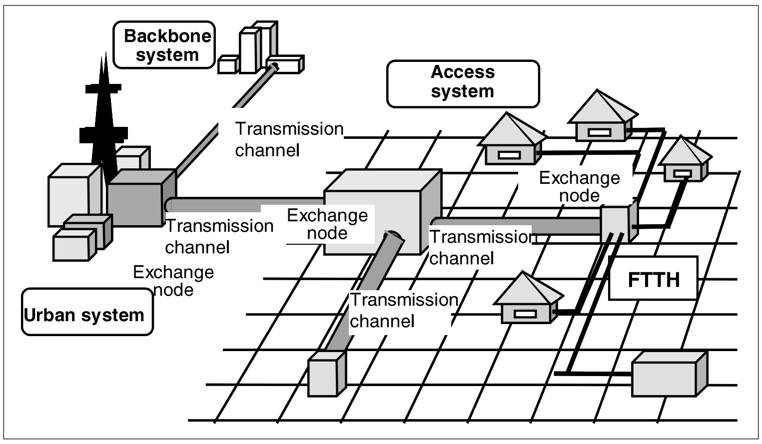


Figure 4 : Structure of the optical communications network



connecting cities and undersea networks, the urban system (1 G-10 Gbps) inside cities, and access system (0.1-1 Gbps) exemplified by "fiber to the home (FTTH)."

These transmission channels are connected to each other by exchange nodes. The exchange nodes are equipped with routers, which they use to control the destinations of traffic. If we liken exchange nodes to an expressway, they are the equivalent of interchanges. With the increase in traffic, faster switching throughput and higher capacity processing scale are needed. As I will explain below, in contrast to the transmission network, for which capacity has been sufficiently prepared through wavelength division multiplexing, the exchange node system may become the bottleneck for photonic networks in the future.

3 The optical communication industry and the collapse of the IT bubble

3-1 The beginnings of photonic technology

Regarding the high-performance photonic technology described above, a 1991 speech by Vice-president Al Gore[2] shows the great expectations the United States Government had for it as essential technology for Information Society infrastructure. "Now, the most important thing is to announce the creation of an information superhighway. This information superhighway will be the greatest single factor in raising the curtain on the Information Age. However, the United States' current policy of basing this on a network of metal wires is interfering with the dawn of the new age of optical fibers. This problem is nonexistent not only in advanced countries like Japan and Germany, but also in developing countries where metal telephone networks are under construction. If the United States does not break through this information bottleneck and retains the status quo, American technology will be left behind that of other countries. In the past, the quality of a country's transportation infrastructure determined victory or defeat in economic competition. Countries with ports that could handle large ships were the winners in economic competition. Ports, canals, railroads, superhighways, waterworks and sewers, and so on, were all invested in as infrastructure that would empirically increase national competitiveness. A corporate investment of $100 billion would be enough to lay optical fibers to every home, office, factory, school, library, and hospital."

Financial support for such expectations for photonic technology began in 1990 with part of the surplus US military budget created by the end of the Cold War. This ample budget was channeled through the Defense Advanced Research Project Agency (DARPA) to many US universities and companies, such as Bell Labs, the past Mecca of photonic technology, and research and development grew active. The US activity spread to Japan as well. At Japanese communications companies such as NTT and KDDI, communications device manufacturers like Fujitsu, NEC, and Hitachi, optical fiber manufacturers such as Furukawa Electric, Sumitomo Electric, and Fujikura, as well as at universities and national laboratories like NICT, the race to research and develop photonic technology grew heated. In Europe as well, it spread not only to public research institutes like the UK's British Telecom (BT), Germany's Heinrich Hertz Institute (HHI), and France Telecom, but also to the labs of companies such as Germany's Siemens, the Netherlands' Philips, France's Alcatel, and the UK's Nortel, and concentrated investment in the installation of optical fibers moved forward.

3-2 The WDM jump

The result, as can be seen in Figure 5, was that the transmission capacity of optical communication at a practical level took a sudden and remarkable leap forwards. In the Chart, the staircase-like line represents transmission speed per wavelength, while the line above that represents transmission capacity per optical fiber through wavelength multiplexing. The arrow indicates the so-called WDM jump, where the transmission capacity of multiplex wavelengths alone exceeded that of single wavelengths. The practical application of this technology advanced at a pace faster than that of Moore's Law, the accepted timescale (doubling every two years; the broken line in Figure 5), for advances in information and communications technology and electronics. LSI drives the laser diodes that are the light source for optical communication, and the modulation rate of LSI grows in accordance with Moore's Law[1], wavelength division multiplexing exceeds it in principle. The amazing technological innovation of wavelength division multiplexing sparked public investment by the above-mentioned DARPA, and numerous venture and investment companies gathered around it seeking business opportunities. At first, no one could have predicted that it would lead to excessive investment in optical communication that would cause a bubble effect. In addition, unrealistic expectations for the spread of the Internet and the unbundling of communications infrastructure through deregulation in the United States also contributed to such investment.

3-3 The optical communication market

Now we will look at the correlation between the rapid growth of wavelength multiplexing technology and participants at the annual Optical Fiber Communication Conference and Exhibition (OFC) as depicted in Figure 6. The OFC is held in the United States every year and is the world's largest exhibition at which optical communication businesses and technologies are exhibited all at once. Annual changes in the size of the optical communication can be seen in it. According to these data, participants increased rapidly to a peak in 2001. Clearly, this is because participants from major corporations and venture capital companies rushed in seeking the above-mentioned business opportunities in wavelength division multiplexing. I also attended for five consecutive years from 1997 through 2001. I gave an oral presentation each time, including the opportunity to deliver an invited

Figure 5 : The WDM jump (remarkable growth in transmission capacity through wavelength division multiplexing)

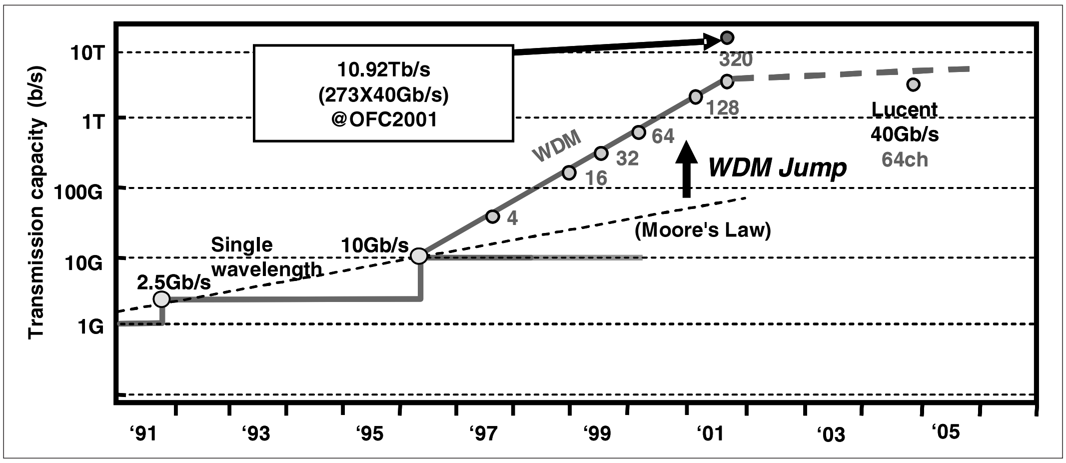
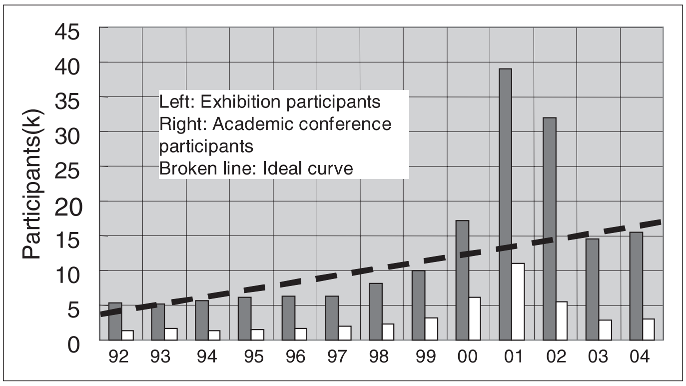


Figure 6 : OFC participants (Exhibition and Academic conference)



Source: Author's compilation based on data from Optical Society of America (OSA) address before approximately 1,000 people, so I personally witnessed that amazing expansion.

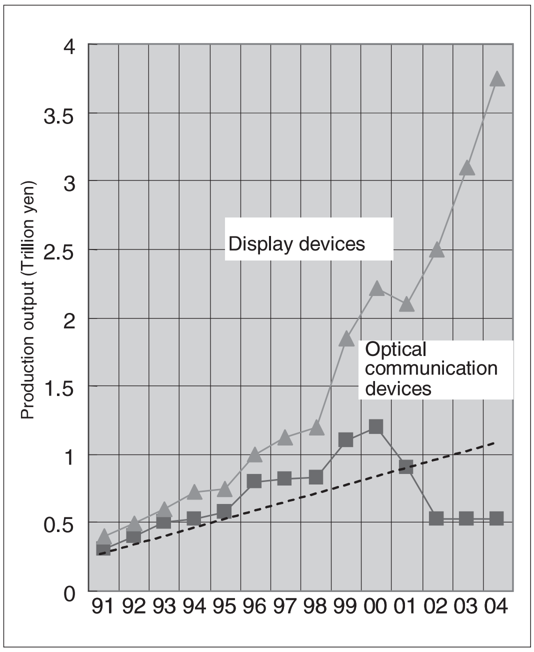
A majority of the new participants were from venture corporations spun off from universities, public research institutes, and major corporations. Venture corporations from universities and public institutions in particular were protected by the Bayh-Dole Act of 1980. Traditionally, when universities carried out research funded by the US government, the government retained any patents. The law made it possible for universities and researchers to retain patents. This enabled universities to own and patent the results of government-funded research, opening the way to technology transfer between universities and corporations through licensing agreements.

In addition, a 1996 revision to the Telecommunications Act provided for unbundling. Invested grew heated as deregulation of the communications infrastructure enabled companies to lease competitors' infrastructure to provide services.

Since the peak in 2001, however, the number of companies exhibiting and the number of participants in the academic conference have dropped sharply. This is clearly caused by the rapid decline in the formerly numerous venture enterprises. In other words, the communications systems companies that are the venture firms' most important customers have been hit hard by the collapse of the IT bubble and have had to stop ordering from the venture companies. This has destroyed the supply-and-demand that is the basis of healthy economic activity, and the venture firms that once sprouted like weeds are now facing the dismal fates of merger and acquisition, if not dissolution.

The cooled demand is the result overheated investment competition carried out without careful analysis of demand. At the time of the peak, it was reported that optical fibers were being laid at three times the speed of sound. It is said that globally 0.5 terameters of fiber have been installed, enough to circle the Earth 10,000 times. Ten percent of that is said to be in China[3]. The small optical communication infrastructure market that should have been grown over 10 years instead became saturated

Figure 7 : The markets for optical communication and display devices



Source: Author's compilation based on data from Optoelectronic Industry and Technology Development Association

in only a few years. As a result, the current optical communication market is merely treading water. Competitive market economies can bring out great power when times are good, but afterwards investors must always watch whether to keep investing and avoid bubbles created by speculation without substance. Ironically, the optical communication industry took a major hit from the WDM bubble that was created by the revolutionary technical innovation of wavelength division multiplexing.

Naturally, the influence of the North American optical communication recession spread to Japan as well. At one time, Japanese corporations were thriving on orders for parts and equipment from North American optical communication companies. Figure 7 shows annual domestic production of photonic devices in Japan[4]. Display-related devices are shown for comparison. After declining following a peak in 2000, production immediately rebounded and his grown steadily since then. In contrast, domestic production of photonic devices has not recovered since the 2000 peak, taking on the aspect of a bubble collapse. The project on mass production of transceiver modules for access-system optical communication[5-6] in which I was personally involved was no exception. It began in 1996, and by 2000 we had a production line capable of completing several hundred thousand units per month, but just after we began trying to sell them to customers, the project was canceled, to our great disappointment.

4 Trends since the collapse of the bubble

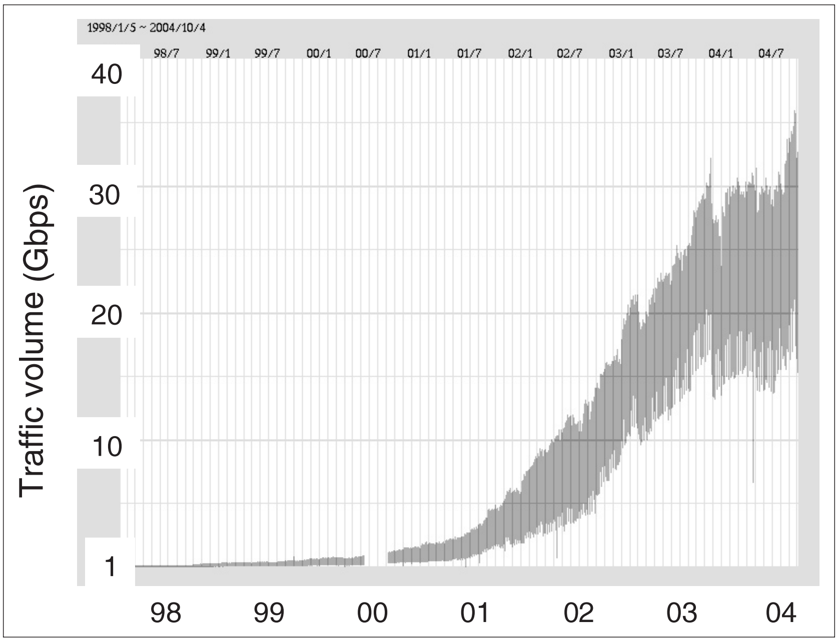
4-1 *Traffic growth and trends in communication services*

Will the optical communication market recover? To answer that question, I examined growth in Internet traffic and its causes. Figure 8 shows traffic measurements taken at a traffic measurement point in Tokyo's Otemachi[7]. Ironically, since immediately after the collapse of the optical communication bubble (Figures 6 and 7) in 2001, traffic has been doubling every year. If it continues at this pace, future traffic volume increases may put pressure on photonic networks, and traffic bottlenecks may occur, causing declining Quality of Service (QoS) to become a serious social issue.

The wave of information technology that has a major impact on economic system and industrial structure reform throughout the country is advancing in a number of fields, including electronic government, electronic trading, logistics management (IC tag systems), risk management, electronic medicine, electronic education, and "ubiquitous Internet." For example, looking at commercial transactions between companies, over the past few years the percentage of electronic transactions has been increasing by 11 percent annually[8] in accordance with the e-Japan Plan. Of course, several tens of percentage points of transactions such as individual stock trading, airline and hotel reservations, and individual bank payments are already taking place over the Internet, becoming a cause of the increasing traffic.

Conventionally, Internet connections were limited to personal computers and mobile telephones, but in the near future digital consumer electronics such as widescreen televisions, video recorders, digital cameras, portable movie cameras, and personal data assistants (PDAs), as well as home appliances such as refrigerators, microwave ovens, and washing machines will connect to the Internet by modem. In addition, automobiles will connect by wireless. Furthermore, if IPv6 standardization advances and a society of ubiquitous Internet connections is realized, almost all goods will have IC tags attached. The amount of information associated with each item will not be large, but the number of items will be enormous. It is estimated that in 2010 there will be 15 billion devices connected to the Internet[9], so traffic

Figure 8 : Traffic growth (doubling annually)



Source: Author's compilation based on data from the Japan Internet Exchange (JPIX)[7] volume may further increase.

Data volume is particularly high for moving pictures. The spread of video telephones that utilize broadband capabilities, or the Internet exchange of videos made at home or work are definitely expected to increase. Just as digital music transmission services that send ringtones to mobile telephones have become active recently, currently high-quality video services for consumers, such as video on demand (VOD) to replace DVD rental, as well as Internet transmission of high-definition video and digital cinema, are expected to spread.

VOD was actively researched and developed in the second half of the 1990s, and trials have been carried out in certain areas. At that time, though, both user fees and the set-top boxes (STBs) used as receivers were expensive, and the service did not spread. However, if broadband fees fall sufficiently from those prices, and if additional charges are less than those for a video shop, video-on-demand may reappear on the market. In fact, beginning next January, services[10-11] that transmit new movies on DVD over the Internet will open with fees equivalent to those of video stores. Although it is gradual, VOD services are beginning. They will begin with current DVD image quality, but Internet-distributed digital cinema with high definition (HD) and super high definition (SHD) is in sight. Digital cinema represents the digitization of the ancient 35-millimeter film system that has been in use for 100 years. Standardization work led by NTT and the University of Tokyo[12] in conjunction with Hollywood is well underway. In addition, NHK and other television networks all over the world have vast archives that are stored without ever seeing the light of day.

Protecting copyrights of stored data that is transmitted over the Internet in this way is not easy. Currently the Copyright Council is discussing the idea[13], and eventually a solution is expected. In fact, a number of waves are approaching. There is consumer demand for content that can be more conveniently and easily viewed over the Internet than any other way. There are immediate business opportunities for copyright holders and service providers to charge fees. More advanced technologies exist to prevent illegal copying of digital music distributed by Internet services, which are ahead of video services. Competitive markets for content have formed in the United States, where the business model is to use each window, from theaters to rentals to Internet distribution to pay TV to free TV, as a window to maximize sales. Therefore Japan must also quickly resolve the bottleneck to Internet distribution created by copyright issues.

In addition, in the future when each home will have a high-capacity hard disk drive (HDD) or a low-cost server bundled with a recordable high-capacity optical disk, desire for Internet distribution will be stimulated even more. In other words, the arrival of an era in which people can use specialized terminals and Internet terminals to enable electronic program guides (EPGs) to automatically reserve recordings and build collections of desired content is expected. Clearly, if Internet distribution and digital broadcast services fuse, and digital video travels back and forth all over the IP Internet, the photonic networks that underlie the communications infrastructure will be pressured.

4-2 New FTTH trends

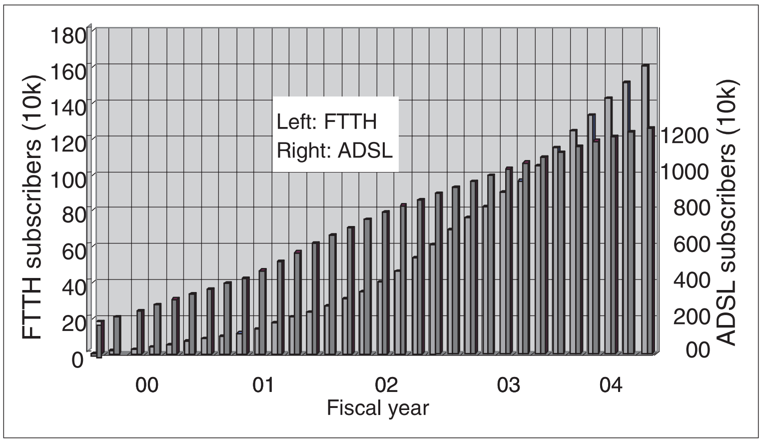
The traffic described above currently moves through communication lines such as the 72 million mobile telephone subscribers, 12.6 million ADSL subscribers, 2.8 million cable TV subscribers, and now 1.75 million FTTH households. Among them, the most notable recent development is high-speed FTTH. It may be preparing broadband users for the Internet distribution of video described in the previous section. Looking at the number of FTTH and ADSL subscribers as depicted in Figure 9[14], although ADSL growth appears saturated, FTTH growth is steep.

This is because at 100 Mbps FTTH transmission speed is faster than other types of broadband lines and that speed does not depend on transmission distance between stations and subscribers. Other reasons include high technical potential, with plans to expand soon to 1 Gbps. Regarding user fees, price-cutting and service competition are underway. In addition to NTT East and NTT West, Tokyo Electric Power Co. (TEPCO) is entering FTTH by utilizing the optical fiber network it uses to monitor electric lines, and thanks to unbundling policy, vigorous Yahoo BB is entering by renting NTT's optical fiber network[15]. Since the backbone market has cooled, FTTH is drawing investment instead. In November 2004, NTT announced its policy to switch 30 million telephone landline customers, about half the total, to FTTH by 2010. It is to invest ¥5 trillion over the next six years. NTT has also announced plans to replace all landline telephones with optical IP telephones.

With this progress in broadband infrastructure, Japan is leading the world in FTTH as communication and broadcasting fuse to create new services as shown in Figure 10. The concern that Vice-president Gore voiced in the 1991 speech[2] quoted in section 3-1 above, that Japan and developing countries will lead the United States on the information superhighway, may be becoming a reality. Japan is number one in FTTH subscribers in the world, so that trend is capturing the attention of concerned parties all over the world[3, 16]. This situation can be seen as an excellent opportunity for Japan to display even greater leadership on international standards for FTTH. With its existing cable television system (74 million households, a 67.7 percent penetration rate), the United States is advanced in terms of triple-play service, video, audio, and data. However, the actual service speed of cable TV's data speed of 30 Mbps slows when it is shared among 100-500 subscribers. In contrast, Japan's FTTH speed of 100 Mbps to 1 Gbps is shared among 32 or 64 customers, so the ability to provide service that is faster by a factor of 10 may prove superior.

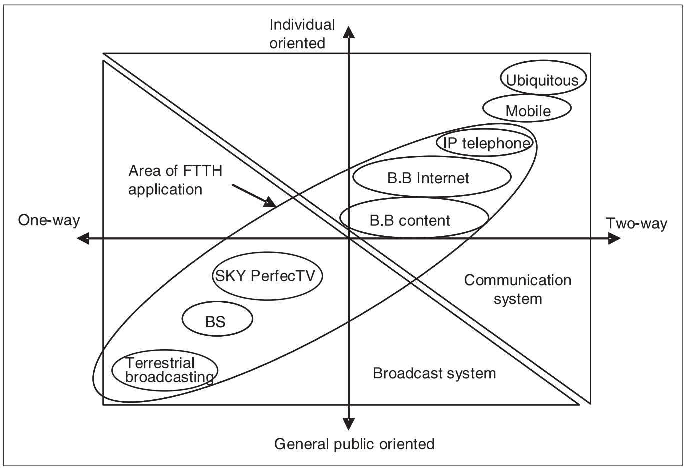
In South Korea[18,19], Taiwan, China, Singapore, and some countries in Southeast Asia, conditions are similar to those in Japan in that cable TV is not as widespread as in North America and

Figure 9 : Number of FTTH and ADSL subscribers



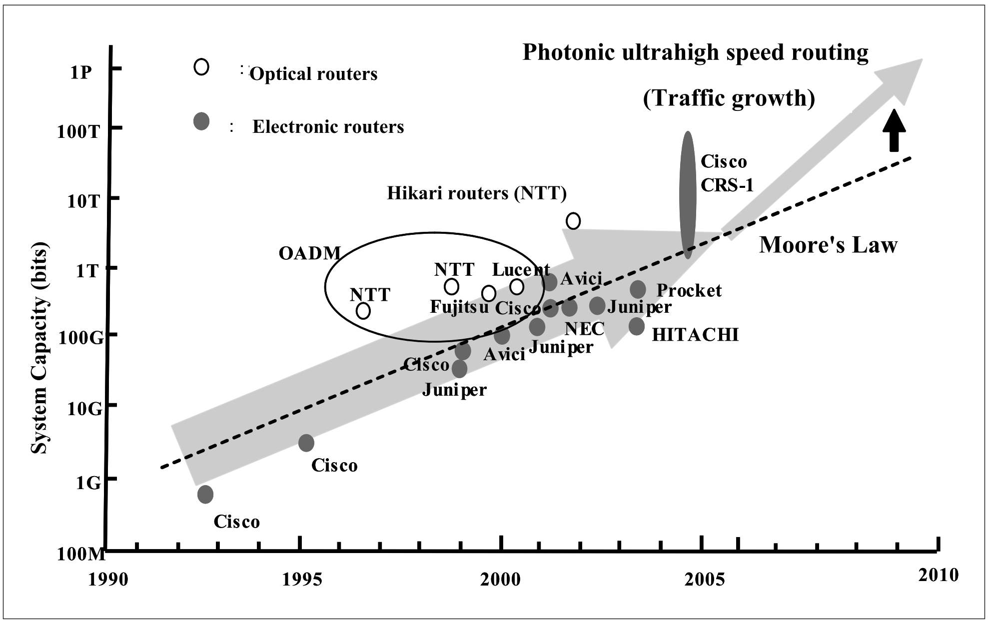
Source: Author's compilation based on Ministry of Internal Affairs and Communications data[14]

Figure 10 : The fusion of communication and broadcasting: applications for FTTH



Source: Author's compilation based on Opticast materials[17]

Figure 11 : Router growth (doubling every one and a half years) and router processing speed improvement in relation to traffic growth



Europe. Those countries are therefore tending towards implementing IP Internet broadband services through FTTH or low-cost fiber to the building (FTTB) + DSL for housing complexes or through hybrid fiber coaxial (HFC, a mix of optical and cable TV). Japan is likely to lead the East Asia region in setting standards for access systems such as FTTH. To do so, tie-ups with China and its gigantic 1.3 billion person market are vital. Indeed, an IPv6 project led by the governments of China and Japan in which Japan provides IPv6 routers for insertion into China's education and science networks is currently underway. Hitachi, Fujitsu, and NEC IPv6 routers have been placed in nodes in universities in Beijing, Shanghai, and Guangzhou. Applied research on connections to Japan and IPv6 networks is also developing[20]. Such achievements should be continuously utilized to promote standardization in access systems. The above section has described trends in access systems.

4-3 Router bottleneck

Looking at backbone systems, we find situations such as the following. As described in section 2-2, photonic networks can be divided into transmission systems and exchange node systems. The capacity of transmission systems has been radically expanded through the wavelength division multiplexing described above. Therefore, although the market for transmission-system transceiver modules has rebounded from last year's low and shows signs of a mild recovery this year, no sudden leaps forward can be expected from the market. The prevailing view is that demand will eventually recover and that only companies that patiently take on the challenge of mass production of 40 Gbps transceiver modules and the full-fledged technical development of 160 Gbps modules will be able to make it through the difficult period until recovery.

We must also look at routers, which affect the processing performance of the exchange nodes that comprise the other basic element of photonic networks. As shown in Figure 11, the processing speed of electronic routers is doubling every one and a half years. This speed may not be sufficient to keep up with traffic, which is doubling every year (see Figure 8). This is because, as explained above, wavelength division multiplexing that utilizes the properties of light is able to exceed Moore's Law, while the switching speed of electronic routers is decided by the performance of LSI circuits and has not been able to surpass Moore's Law.

As denoted in Figure 11, recently in this field Cisco Systems announced routers with the shocking system throughput of 92 Tbps[21]. The equipment links several electronic routers with an optical interconnection that uses laser diodes and optical fibers. Cisco succeeded in technical

Table 1 : Technical issues in the optical communications field

	Backbone systems	Access systems
Communications services	QoS, security, encrypted communication, multicasting, e-commerce, e-government, triple play, VOD, digital consumer electronics, ubiquitous, etc.	
International standards	GMPLS	FTTH (FSAN)
Exchange nodes	Optical routing Hybrids 0.1-1 Pbps	Electronic routers Low cost Energy saving
Transmission channels	160 Gbps and beyond	Low cost
	100-1,000 waves	Transceiver modules

development that leaped past previous trends. The system is a hybrid that adds the advantages of light to conventional electronic routers, and it may start a trend. As for optical routers, ultrahigh speed parallel processing utilizing two-dimensional wave fronts (e.g., Fourier transformation by lenses) is possible, raising expectations for the technology.

Currently, electric power, including air conditioning, consumed by photonic networks and other information communication devices is only about 5 percent of the whole. It is feared, however, that the spread of telecommunications equipment in response to traffic growth could lead to power shortages. Therefore it is extremely important to develop systems that consume little power. In that sense, technical development to take advantage of the low power consumption of light is also important. With the advent of optical fiber amplifiers, photoelectric/electrical transformation in repeaters in transmission systems became unnecessary. In the same way, challenging research to create all-optical networks in which light travels as light from transmitter to receiver by replacing electronic routers in exchange nodes with optical routers is making progress.

Generalized multiprotocol label switching (GMPLS), which requires advanced photonic technology prowess, is emerging as the next protocol for high-speed photonic networks. GMPLS carries out processing by using optical signal wavelength as a label to decide routing, preparing a specially controlled IP channel to route data as an optical signal[22]. Because transforming an optical signal into an electrical signal when performing routing causes a loss of speed and consumes power, ways to route data as unchanged optical signals are being sought. Table 1 is a summary of the future R&D issues just described. Recently, research and development in quantum communication and quantum cryptography communication[23], which are intended to surpass wavelength division multiplexing in optical communication capacity and security, have become active as well, but space does not permit me to address them in this article.

5 Future directions

5-1 Overseas R&D trends

Although the United States, like Japan, is in an optical communication recession, the National Science Foundation (NSF) and DARPA are funding R&D test beds using photonic technology. Joint government-private sector public projects to create new services utilizing high speed 10-20 Gbps optical fibers are being strongly pushed. Major projects[24] include the "vBNS+" project on IPv6, multicasting, and digital libraries, the "Abilene" project on QoS verification and security, the "TeraGrid" project on applying photonic technology to grid computing, and the "StarLight" project on Internet exchange (IX) points and optical switching and routing research. Emphasis is placed on projects involving services and applications using high-speed networks including optical communication. It is worthy of particular attention that a balance is being kept with projects on optical communication devices and equipment. In addition, numerous corporations and universities are actively involved in the projects, and cycles to transfer technology to the private sector through industry-academia tie-ups are in place.

Table 2 : With software at the top and commodities at the bottom

	Optical disks	Personal computers	Communications networks
Software, systems (content)	Motion picture companies (Hollywood)	4 Windows (Microsoft Corp.)	Communications protocols Services
Key devices	DVD disks Decoders MPEG standards	CPUs (Intel)	Routers (Cisco)
Hardware	Players	PCs	Transceivers, servers
Commodities	Optical pickups, semiconductor memory, circuits, mechanisms	Memory (HDD, DRAM)	Laser diodes, modulators, photodetectors, optical fibers

In Canada, "CA*net4," the world's first national optical network has been deployed, and research in broadband service like e-business, e-content, e-health, and e-education is being pushed. It is also connected to other R&D networks in Europe and the United States.

In Europe, from the perspective of emphasizing the public nature of information communications infrastructure, the EU and national governments are showing strong leadership and operating projects to create new services. The projects include "GEANT" on QoS and multicasting research. "6NET" on IPv6, and "SURFnet6" on interconnectivity, electronic corporations, and e-business.

In Asia, projects such as China's "CERNET" on IPv6 and distance education, South Korea's "KOREN" and "KREONet2" on QoS, multicasting, IPv6, and MPLS, Taiwan's "TANet2," and Singapore's "SingAREN" are being promoted. All of those test beds are linked to other test beds in the United States, and R&D on proving new services through international tie-ups is being advanced[24].

To begin with a long-term, panoramic view, underlying the economic success of the United States in the 1990s was a system driven by the revival of weakening hardware industries through the introduction of information technology along with the software industries that were already leading. The economy rode those two vehicles to sustained economic growth[25]. Naturally therefore, in the field of optical communication as well, along with hardware investment, the United States will not stop investing in the software and services that are its specialties.

As shown in Table 2, an overview of the industrial structure of information technologies such as optical disks and personal computers can be illustrated with the brains at the top in the systems and software where knowledge is most concentrated, the heart in key devices, and commodities as the extremities[26-27]. In this diagram, the higher one goes , the more knowledge is concentrated and business value is added. Of course, leadership on international standards is also closely involved. How well Japan's technologies and businesses can break into the top of this structure can be seen as an index of the success or failure of Japan's IT industry until the present and into the future.

5-2 Support for research investment by Japanese corporations

As described above, conditions surrounding photonic technology and industry have begun to change now that a few years have passed since the bubble collapsed. Indeed, the market seems to have hit bottom and to be showing signs of recovery (see Figure 6). We can hypothesize that because shortly after the bubble's collapse Internet traffic began increasing even more than it had been (see Figure 8), investment is gradually reviving in light of predictions of the arrival of a true IT Society.

Japanese corporations, however, were hit hard by the semiconductor recession that followed the bursting of the real estate bubble in the 1990s as well as the collapse of the IT bubble. Negative investment factors followed in succession, and the ability of corporations to invest in research is now weak. They therefore lack the ability to sustain very risky research themes, and a shift of resources away from optical communication fields to other research is also taking place, leaving the future uncertain.

If corporations are unable to perform research on themes for which the research phase carries great risk, the orientation of researchers towards leading-edge research issues that forms the most important element of research and development will be weakened, and opportunities for groundbreaking discoveries may be lost. Furthermore, if researchers do not have a grasp of R&D issues involving the most-advanced technologies, the vitality of corporate R&D, which has had the greatest impact, will be lost. When government, academics, or foreign researchers announce technical innovations, corporations will no longer have the ability to tackle them at the practical application stage. Moreover, a danger of having to accept miserable defeat in competition not only with advanced countries but also with developing ones will arise.

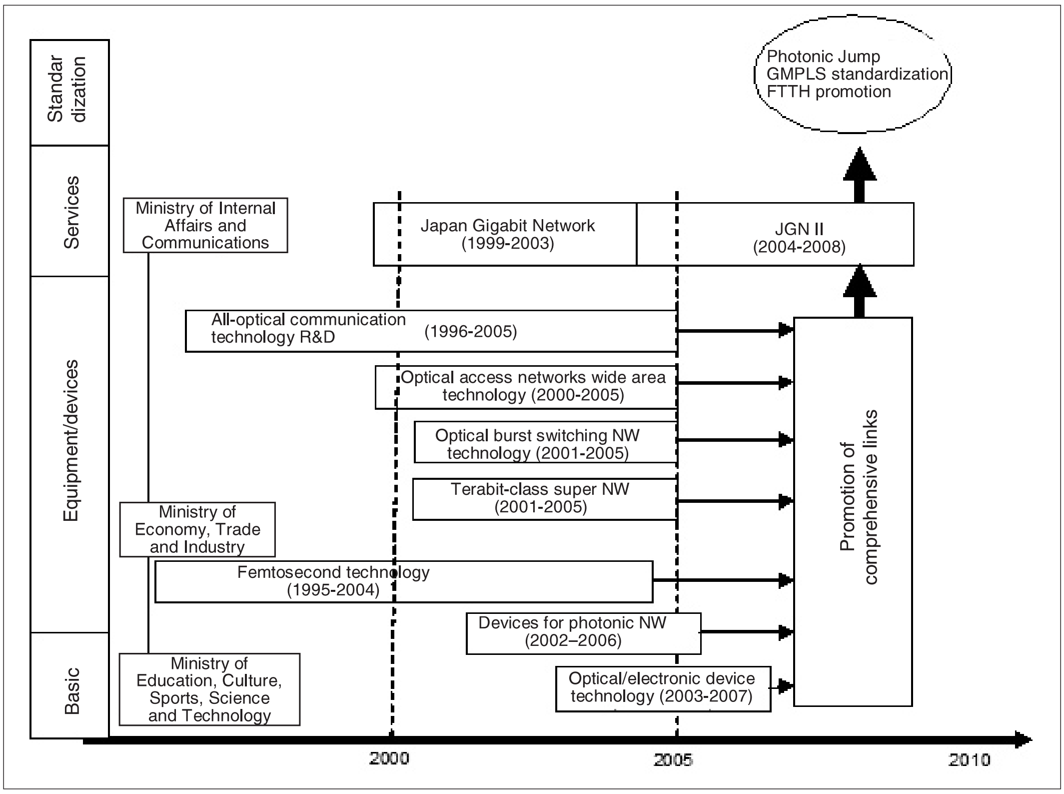
It is a time like this when public investment in research and development is vital. Continued support from public investment is required if Japan is to avoid losing its lead in the optical communication fields in which it has maintained its competitiveness.

5-3 The status of Japan's public projects

In regards to the situations described above, Japan is engaged in the public projects shown in Figure 12. The chart summarizes basic research that will be the foundation of future photonic technology, applications in devices and equipment, and research on systems and services. However, a tendency for the themes of this research and development to be biased towards research in devices and equipment, which has been Japan's specialty, is visible. It is as if the projects are designed to supply commodities to demand in the IT services and businesses that are progressing in the United States. Moreover, most of them began at the height of the IT bubble, and they seem as if they may end next fiscal year in the wake of the collapsed bubble.

Of course, Japan also has a world-class test bed for research and development on IT services utilizing high-speed optical fiber communication technology: Japan Gigabit Network (JGN). It was carried out from 1999 through 2003, with much success. It is being followed by JGN II, which is to be operated by NICT from fiscal 2004 through 2008. JGN II is a joint R&D system on a communication network with transmission

Figure 12 : Summary of major Japanese projects and future directions



speeds of 10-20 Gbps. Its purpose is to develop Japan's own communications services, security systems, and so. In addition, the National Institute of Informatics operates the Super SINET network. However, most participants in these projects are universities and public research institutes, and corporate participation is rather lukewarm.

If this continues, Japan will never be more than a parts store. The situation is similar to Microsoft's overwhelming power in personal computers and Hollywood's lead in providing content for optical disks, as shown in Table 2. American companies' commodity strategy for Asia appears to be operating in the field of optical communication as well. In other words, business focus and R&D on the communication protocols that will form the basis for international standardization, on services, and on applications remains centered on the United States, which takes leadership on international standards. Therefore, no matter how much Japan touts the technical prowess of its parts and equipment, if it is lacking in the software and service applications needed to operate them as systems, Japanese companies will lose out to European and North American firms in the competition for orders.

6 Conclusion

Based on the above awareness of the situation and view of the future, I will offer some proposals for the future direction of research and development in the field of optical communication as a whole.

The optical communication industry, which provides the basis for IT infrastructure, was hit hard by the bursting of the optical bubble. However, looking at the history of technological innovation in areas such as railways, broadcasting, and automobiles, in each of them bubble effects have formed and oversupply destroyed the balance with demand leading to an industry recession. Whenever society clearly needed that technical infrastructure, however, the technology gradually permeated society after the bubble collapse and became indispensable infrastructure for living in society[28]. If we look seriously at the recent rapid increase in traffic, and take the optical bubble as another example of the economic phenomenon, snuffing out research and development when the flame is burning low is not good policy. It is therefore necessary to remind ourselves that optical communication by nature is public infrastructure and to continue investing public funds in it.

Investment should not be made in the traditional way of simply prioritizing seed research themes in commodities supply. Instead, R&D to create demand should be set up through test beds such as JGN II and Super SINET to create new communication services, and that should be the vehicle driving research. Using that strength, Japan demonstrate leadership in worldwide technology and business, beginning with international standardization activities[29].

Regarding access systems, Japan's FTTH subscribers lead the world, having exceeded 1.75 million. This is an opportunity for Japan to have a stronger voice in initiatives for international standards. For example, The United States is taking the lead in the triple-play service of video, audio, and data with its existing cable television system. In Japan, on the other hand, high-speed FTTH, which has faster data speeds than cable TV, is more widespread and may lead to advantages through the creation of superior communication services. In addition, South Korea, Taiwan, China, Singapore, and some other Southeast Asian countries are similar to Japan in that cable television is not as widespread in as it is in Europe and North America. Therefore it is very likely that Japan could cooperate with other countries in East Asia to take the lead on standardization of FTTH and other access systems. In particular, Japan should build on the success of the joint government-led project on IPv6 with China to continue cooperation with that country.

In addition, copyright issues, which are one hindrance to developing the market for the Internet distribution of content, should be resolved quickly. This would stimulate the creative ambitions of content creators and vitalize the content market. The uniqueness of Japanese animation in particular is recognized worldwide, and the spread of Internet distribution would further vitalize such creative activities.

Regarding backbone systems, Japan should demonstrate leadership on GMPLS, the communication protocol that is advancing as the next-generation international standard in exchange nodes, where future bottlenecks are anticipated. The technology of Japan's world-leading parts and equipment, which have been boosted by Japan's technical prowess, will be a formidable argument.

For those reasons as well, the various device development projects under the jurisdiction of different ministries should be periodically checked from the perspective of JGN II as a test bed for the creation of new services, and the direction of new projects should be clearly announced. Concretely, the leader of each project should form a comprehensive committee spanning all their projects. There they could bring their results, exchange technologies, and seek future directions. They could integrate related technologies, as well as actively bringing together people from private, public, and academic research institutions more often.

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5

State of Japanese Research on the Ozone Layer

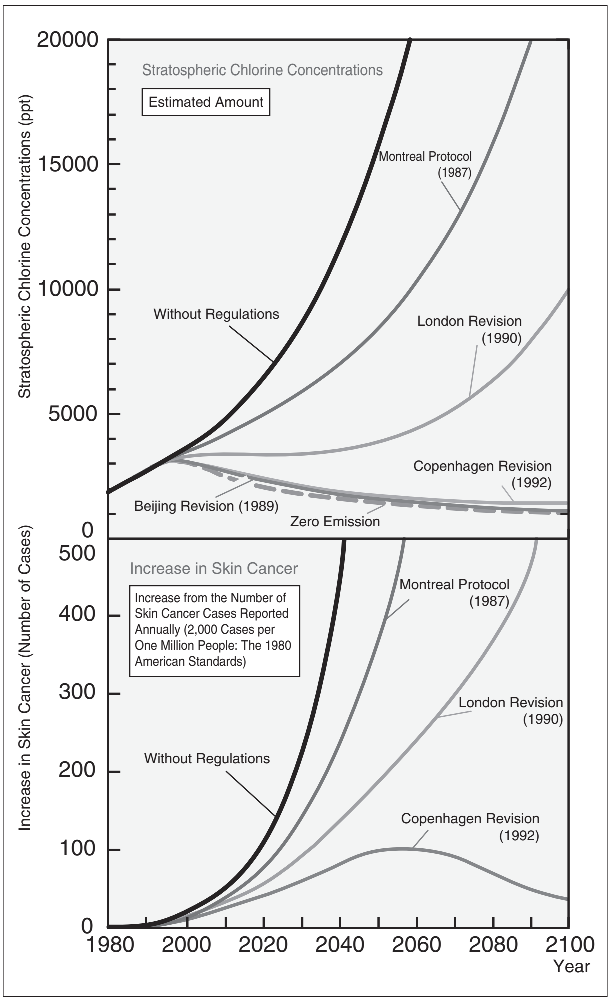
HIDEAKI NAKANE *(Affiliated Fellow)*

1 Introduction

Chlorofluorocarbons (hereinafter referred to as "CFCs"), which were invented as chemical compounds with great potential, later turned out to be involved in ozone depletion. A series of measures to protect the ozone layer have thus been put in place through an international cooperative framework, namely the Montreal Protocol and its amendments and adjustments. As a result, stratospheric chlorine concentrations are expected to decrease dramatically in the 21st century compared to the predicted levels without regulation of CFCs (see the upper part of Figure 1). The ozone layer problem, therefore, is considered the first instance where a global environmental problem has been successfully solved. In other words, this particular problem is now treated as if it were a thing of the past. However, quite a few problems remain, one of which concerns the need to carefully observe and monitor the effects of climate change and chemical substances other than CFCs.

In fact, a closer look at the predicted increase in the incidence of skin cancer reveals a very different situation. The lower part of Figure 1 shows an increase in the number of patients with skin cancer, which can be attributed to ozone depletion. Particularly notable is its incidence, which is expected to peak around 2060. This estimate is based on the assumption that the number of patients with skin cancer will increase if the effects of ultraviolet radiation accumulate over a lifetime. Only the rate of increase is peaking now. In short, we cannot be assured that the threat of ozone depletion is behind us, even if the depletion has peaked. With these factors in mind, this article features the state of the ozone layer, exploring the direction in which recent research efforts on this subject are heading.

Figure 1 : Past-Present-Future Scenario of Stratospheric Chlorine Concentrations (Upper Figure) and Future Scenario of Increase in Skin Cancer due to Ozone Depletion (Lower Figure)[1]



Hideaki Nakane The Atmospheric Environment Division, the National Institute for Environmental Studies

2 Factors affecting ozone changes in the stratosphere

CFCs are not the only substances that deplete the ozone layer. Other culprits include organic chlorine and bromine compounds and methyl bromide, which release chlorine and bromine into the stratosphere; nitrogen oxides such as NO and NO_2 (NOx) produced by oxidization of N_2O (a greenhouse gas); and hydrogen oxide such as OH and HO_2 (HOx) which are produced from methane and water vapor in the stratosphere. While methane itself moderates ozone depletion, stratospheric water vapor (partly produced by methane oxidization) increases polar stratospheric clouds, one of the causes of the ozone hole. NO_2, meanwhile, mitigates the polar ozone depletion in the Arctic and Antarctic in winter and spring.

Ozone depletion is not caused only by chemical changes. For instance, an increase in greenhouse gases results in a rise in ground-level air temperatures, while it lowers the temperature in the stratosphere and above; this may contribute to strengthening of the ozone hole in the Antarctic stratosphere and ozone depletion in the Arctic region, and at the same time weaken ozone depletion in the upper stratosphere (at an altitude of about 40km). Changes in large-scale wave activity (planetary waves) in the troposphere cause unusual weather patterns in the troposphere and the stratosphere, and have a significant impact on ozone transfer in the stratosphere (from the tropics to the high latitudes) as well as on the size of the ozone hole. In other words, tropospheric and stratospheric changes due to unusual weather patterns affect the ozone layer, changes in which then affect weather patterns. An increase in sulfate aerosols in the stratosphere due to volcanic eruption also depletes the ozone layer. The factors affecting ozone changes mentioned above are summarized in Table 1 (present trends in the factors are shown in the table).

2-1 Two ozone depletion mechanisms

Two major mechanisms are involved in ozone depletion due to chemical reactions. One is a mechanism where chemical compounds (CFCs, halons, etc.) that release chlorine and bromine into the stratosphere deplete ozone through gas-phase reactions, a phenomenon that was predicted in 1974 in the theory presented by Molina and Rowland. The other is depletion involving heterogeneous reactions in which surface reactions in clouds and aerosols play a major role, such as the depletion occurring in the Antarctic ozone hole. The former is important in the upper stratosphere (at an altitude of about 40 km), and the latter in the lower stratosphere (at an altitude of 15-20 km), with the latter posing a

Table 1 : Factors Affecting the Ozone Layer and Resulting Changes in Ozone Amount

Factors affecting the ozone layer	Upper stratosphere (altitude of about 40km)	Middle stratosphere (altitude of about 30km)	Lower stratosphere (altitude of below 20km)
Substance			
CFCs, Halons, etc.	—	—	—
NOx (produced from N_2O)	—	—	+
HOx	—	—	—
Methane	+	+	+
Water Vapor			—
Climate change			
Drop in stratospheric temperatures	+		— (Polar in spring)
Rise (fall) of the tropopause			— (+)
Decrease (increase) in the intensity of large-scale wave activity in the troposphere			— (+)
Increase in stratospheric aerosols due to volcanic eruption		+	—

+ : Factors increasing stratospheric ozone —: Factors decreasing stratospheric ozone greater threat to the ozone layer. Details of these two mechanisms are explained in the following sections.

(1) Mechanism of ozone depletion in the upper stratosphere due to gas-phase reactions

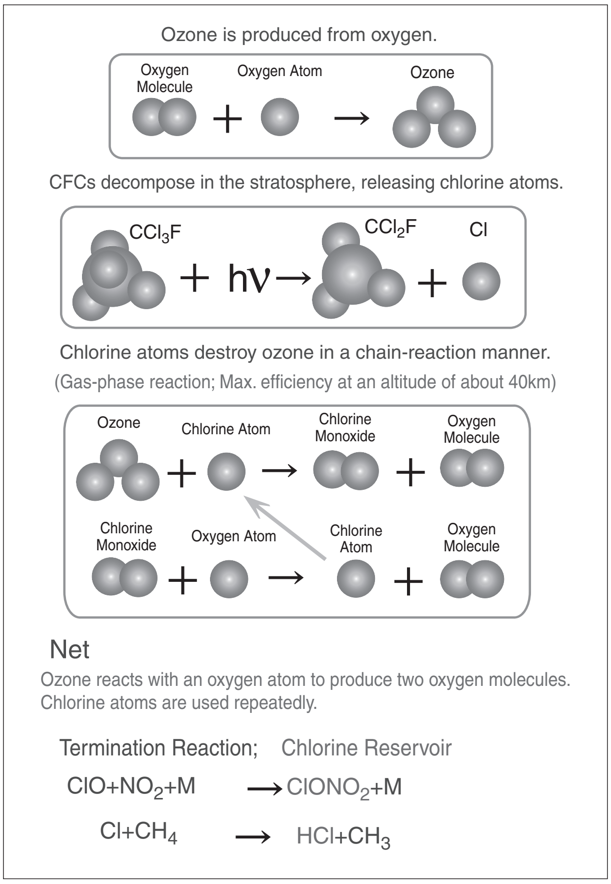
The short-wavelength ultraviolet radiation in the stratosphere decomposes substances such as CFCs, resulting in the release of chlorine atoms, which react with ozone to produce chlorine monoxide (ClO). Chlorine monoxide subsequently reacts with an oxygen atom to produce an oxygen molecule and a chlorine atom, which in turn reacts with ozone. This catalytic cycle, which converts an ozone molecule and an oxygen atom into two oxygen molecules, consists of relatively simple gas-phase reactions involving only gaseous molecules, radicals and atoms. Ozone depletion through this mechanism is efficient in the upper stratosphere (at an altitude of about 40 km), where concentration of oxygen atoms is high. This catalytic cycle, however, is not permanent; chlorine and chlorine monoxide, through reactions with methane and nitrogen dioxide, are incorporated into “chlorine reservoirs” such as HCl and $ClONO_2$, thereby losing their activity. Most of the chlorine atoms in the upper stratosphere take the form of HCl. In this case, chlorine depletes the ozone, while methane and nitrogen dioxide mitigate the depletion.

A similar catalytic reaction cycle is possible with Cl replaced by NO. It was this catalytic reaction cycle involving NO that frustrated a project for a supersonic jet traveling through the stratosphere; it occurs most significantly in the middle stratosphere (at an altitude of about 30 km), with NO_2 depleting the ozone layer.

(2) Mechanism of ozone depletion in the lower stratosphere involving heterogeneous reactions; cause of the Antarctic ozone hole

The second mechanism of ozone depletion is that involving “heterogeneous reactions” that occur on the surface of liquid and solid particles (clouds and aerosols), a typical phenomenon observed in the ozone hole.

Figure 2 : Mechanisms of Ozone Formation and the Gas-phase Catalytic Reaction Cycle through Chlorine Atoms Released from CFCs



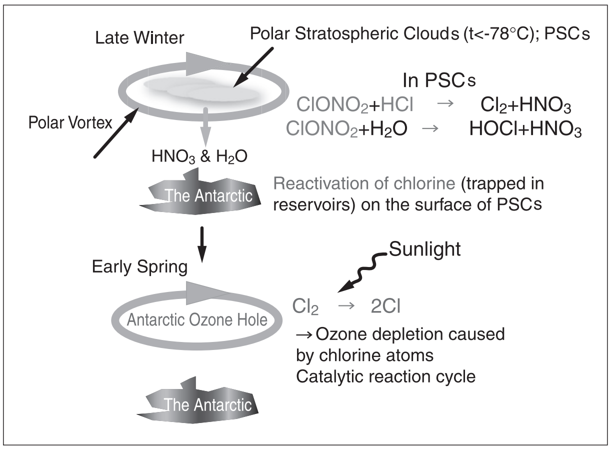
This cycle terminates, with chlorine atoms and chlorine monoxide converted into reservoirs.

While heterogeneous reactions are known as the mechanism responsible not only for the ozone hole but also for ozone depletion caused by stratospheric aerosols (originating from volcanic eruption) and cirrus clouds, this article focuses on the mechanism of the ozone hole. In winter and spring, a strong west wind blows in the Arctic and Antarctic stratospheres; this is the circumpolar stratospheric jet steam called a “polar vortex.” In the Antarctic region in particular, this polar vortex covers an area more than twice the size of the Antarctic Continent. (Refer to the website of the National Institute for Environmental Studies for a daily polar-vortex forecast[2].) Since the air inside and outside the vortex does not mix well, the temperature inside the vortex tends to drop; “polar stratospheric clouds” (PSCs) build up if the temperate drops below minus 78 degrees Celsius (195 degrees Kelvin). Under these conditions, chlorine reservoirs (HCl, $ClONO_2$, etc.) that prevent ozone-depleting catalytic reaction cycles are converted into active chlorine species such as chlorine molecules on the surface of PSCs. These chlorine molecules, if exposed to sunlight in spring, decompose into chlorine atoms, which continue destroying ozone through catalytic reaction cycles until ozone levels drop to nearly zero.

Ozone depletion through this mechanism is most efficient in the ozone-rich lower stratosphere. Thus, under the current situation where stratospheric chlorine levels are peaking, the ozone hole grows if stratospheric temperatures drop, creating areas with temperatures below minus 78 degrees Celsius (195 degrees Kelvin), conditions suitable for the formation of PSCs. An increase in stratospheric water vapor at a given temperature creates ideal conditions for the development of PSCs. It also contributes to the expansion of the ozone hole because it lowers stratospheric temperatures.

In the Arctic region, the area in which PSCs develops, there are dramatic changes from year to year. The Arctic polar vortex is relatively weak and tends to meander, which is why temperatures are higher in the Arctic than in the Antarctic. It sometimes splits, with the air inside spreading throughout the mid-latitudes. The Arctic polar vortex does not remain over the Arctic Ocean; it spreads as far as Northern Europe and Siberia, sometimes extending its reach into London and Paris. In fact, a split vortex is occasionally observed in the sky above Hokkaido in Japan. The Arctic vortex, therefore, interacts closely with the mid-latitudes, which raises the temperature of the air inside the vortex. In the meantime, global-scale planetary waves that develop in the troposphere and spread out to the stratosphere force the vortex to meander. Large-scale mountains such as the Alps, the Himalayas and the Rockies, and the non-symmetric distribution of continents and seas together produce large-scale waves in the troposphere, which propagate into the stratosphere to produce planetary waves. For this reason, planetary waves in the northern hemisphere are much stronger than those in the southern hemisphere. Ozone depletion is less serious in the Arctic than in the Antarctic because the Arctic stratosphere is not as cold as the Antarctic stratosphere.

Figure 3 : Mechanism of Ozone Depletion in the Ozone Hole



Although planetary waves also affect the Antarctic ozone hole, their impact is much less significant in the southern hemisphere; this is why the ozone hole continues to grow every year in the Antarctic. In 2002, however, the Antarctic polar vortex was seriously distorted because of extremely strong planetary waves. Coupled with higher Antarctic stratospheric temperatures, the ozone hole was much smaller and disappeared earlier. "An extreme weather event in the stratosphere" was the cause of this phenomenon; it is by no means a "sign of ozone layer recovery." In fact, the year 2003 saw the second largest ozone hole area ever observed.

2-2 Climate change and stratospheric ozone

The relationship between "climate change" and "stratospheric ozone" can be summarized as follows:

- A decrease in the stratospheric ozone affects the climate (Cooling in the troposphere).
- Climate change affects the ozone layer (A variety of effects are possible, including extreme weather events in the stratosphere).

Although there is a feedback effect between these two phenomena, they can be better understood if separated. Carbon dioxide, methane and N_2O, major culprits of climate change, are expected to increase for the time being, warming the troposphere and cooling the stratosphere. Stratospheric temperature decreases because the earth radiates more infrared radiation toward space in response to an increase in greenhouse gases. CFCs are both ozone-depleting substances and greenhouse gases that are on the decrease, while CFC substitutes (HFC and PFC) and SF_6 are greenhouse gases with no ozone-depleting properties. Controlling their emission, however, largely depends on countermeasures taken in the future. How climate change affects the ozone layer remains uncertain, but several effects on the stratospheric ozone are expected through changes in ozone distribution due to variations in transport in the stratosphere, changes in the amount of water vapor drifting up to the stratosphere, and unusual weather patterns in the stratosphere. The following are details of these phenomena.

(1) The impact of CFCs and ozone layer changes on the climate

Stratospheric ozone depletion due to CFCs and the resulting decrease in ozone levels in the lower stratosphere reduce atmospheric temperature since less infrared and ultraviolet radiation is absorbed by ozone. At the same time, the downward infrared radiation at the tropopause decreases, which in turn cools the troposphere. This effect, however, is less powerful than global warming caused by CFCs, and hence the release of CFCs results in net global warming. On the other hand, a decrease in CFCs leads to the recovery of the ozone layer, thereby raising tropospheric temperature, but this effect is smaller than that reducing global warming caused by the decrease of CFCs. Note that global warming due to an increase in CFC substitutes (particularly HFC and PFC) should be considered here. The net global warming over the next several decades, therefore, depends on how well CFCs are replaced by substances with lower global warming potentials.

(2) The impact of climate change on the ozone layer

The impact of climate change extends throughout the global climate system, affecting the ozone layer in a variety of ways. Among others, the following are considered essential:

- Tropospheric warming and stratospheric cooling due to an increase in greenhouse gases: lower stratospheric temperatures may result in a long-lasting Antarctic ozone hole and the development of an Arctic ozone hole (At the same time, ozone levels will increase in the upper stratosphere).
- Extreme weather events in the stratosphere may develop in both frequency and intensity due to changes in global-scale wave activity, particularly planetary waves, a result of climate change, which could affect the stratospheric ozone layer. Moreover, changes in transport in the stratosphere may alter ozone distribution.
- The inflow and outflow to and from the stratosphere of substances that could affect the chemical and radiative environment of the stratosphere may change. Specifically, they include water vapor and its precursors (formed by the union of methane and hydrogen, etc.), N_2O, chlorine and bromine compounds, and the precursors of stratospheric aerosols (sulfur dioxide, OCS, etc.).
- The amount of stratospheric ozone flowing into the troposphere may change (It is expected to increase, according to the results of some model calculations).

(3) Trends in international research on the relationship between the ozone layer and global climate change

The ozone layer, a heat source for the stratosphere, determines the vertical temperature distribution of the stratosphere and mesosphere. Therefore, it controls not only the chemical environment but also the climate/weather of the stratosphere. Thus, changes in the ozone alter climate/weather in the stratosphere, which also affects climate/weather in the troposphere because the stratosphere is part of the atmospheric climate system. The World Climate Research Program (WCRP) includes a project called the “Stratospheric Processes and their Role in Climate” (SPARC), which is an international cooperative project for studying the interactions between stratospheric changes (ozone depletion, increase in water vapor, drop in temperature, etc.) and climate change.

It is becoming clear that the tropopause (the bottom of the stratosphere) is not a simple boundary, which has created a research area named "upper troposphere and the lower stratosphere" (UTLS) that studies the unique chemical and dynamic-meteorological phenomena near the tropopause. This particular research area is considered an important part of SPARC since it addresses water vapor variability in the tropical tropopause region, ozone depletion involving cirrus clouds, global warming and ozone depletion caused by aircraft emissions, and inflow and outflow of ozone to and from the troposphere.

3 Observed changes and trends in the ozone layer

3-1 Global ozone amount

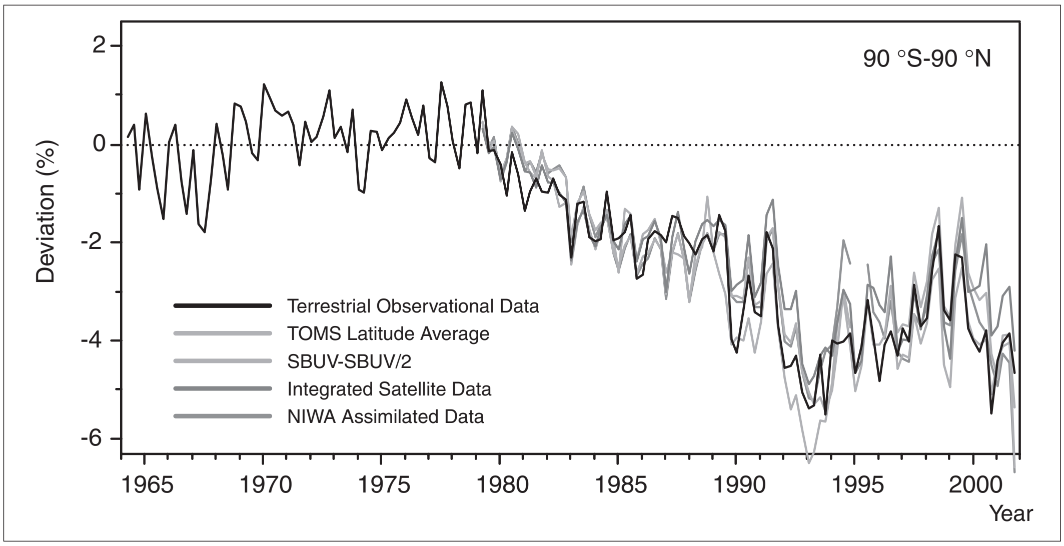
Figure 4 shows changes in the amount of global ozone over the past four decades. It should be noted here that the unit of "amount of global ozone" refers to the thickness of the ozone (at ground level up to the upper atmosphere) compressed at a pressure of one atmosphere and zero degrees Celsius. The ozone layer is, so to speak, a "3-mm-thick space suit," so called because its global average thickness is about 3 mm. With the measurement accuracy of the total ozone being three digits, the thickness of the ozone layer is expressed in centimeters and is then multiplied by 1,000, a unit called the "Dobson Unit (DU)" or "milli-atmosphere centimeter (m atm-cm)." Incidentally, the global average of the total ozone currently stands at 300 DU (m atm-cm). As shown in Figure 4, the total ozone continued to decrease in 1980 and in 1990, and the years 1992 and 1993 saw a record low, down 5% from pre-1980 levels, probably due to Mt. Pinatubo, which erupted in June 1991. It began to increase thereafter, and the upturn continued into 1999. However, the average amount in 1997 and in 2001 was down 3% from the pre-1980 levels.

Table 2 shows changes in ozone levels by region and season. The total ozone (between 1997 and 2001), when compared with pre-1980 levels (the average between 1964 and 1980), was down 3% and 6%, respectively, in the northern and southern mid latitudes. A significant decrease was observed in the northern hemisphere in winter and spring, while the southern hemisphere saw a decrease of the same magnitude throughout the year.

3-2 Detection of "early signs of recovery" in the upper stratospheric ozone

As shown in Figure 1, stratospheric ozone concentrations peaked around 1997 and decreased gradually thereafter. With this phenomenon verified, a new research area is emerging: efforts to detect "signs of recovery" in the ozone layer based on observational data.

Figure 4 : Long-term Changes in Total Ozone



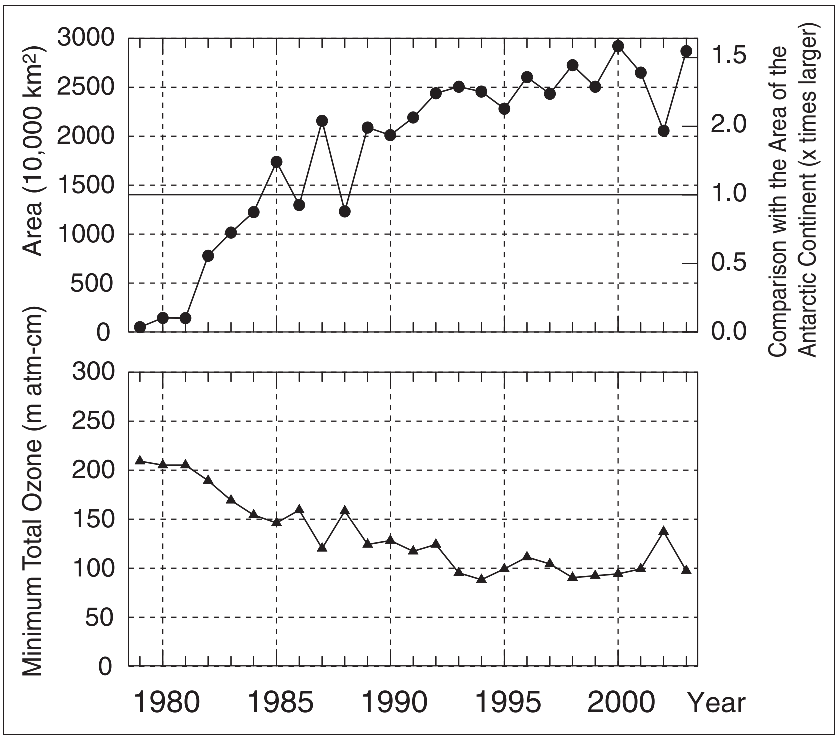
"Changes" removes known natural fluctuations in the total ozone such as seasonal variation, solar activity and quasi-biennial oscillation (QBO). Data obtained through five measurement/analytical methods are shown in the chart[1].

Table 2 : Decrease in Total Ozone (Pre-1980 Levels*1 versus Average between 1997 and 2001)[1,3]

	Full-year Basis	Winter to Spring	Summer to Fall
Global Average	3%		
Tropical Region (25°N - 25°S)	No Significant Decrease Observed	No Significant Decrease Observed	No Significant Decrease Observed
Northern Mid Latitudes (35°N - 60°N)	3%	4%	2%
Southern Mid Latitudes (35°S - 60°S)	6%	6%	6%

*1 Average of total ozone between 1964 and 1980 (winter to spring, and summer to fall).
*2 "Changes" removes known natural fluctuations in the total ozone such as seasonal variation, solar activity and quasi-biennial oscillation (QBO).

Figure 5 : Changes in Ozone Hole Area (Top) and Minimum Total Ozone in Ozone Hole (Bottom) between 1979 and 2003[4]



The upper stratosphere, where no heterogeneous reactions occur, is the region in which these signs can be detected most easily. Researchers at NASA, therefore, focused attention on the upper stratosphere and analyzed data on ozone and hydrogen chloride (HCl) concentrations, using satellite sensors. The results they announced were that HCl concentrations increased linearly before 1997, resulting in a linear decrease in ozone concentrations, while the pace of the increase began to slow after 1997. The "first step towards the recovery of the ozone layer" has been detected, according to the researchers[5].

3-3 Trends in the Antarctic ozone hole

Figure 5 shows changes in the Antarctic ozone hole area (the area with a total ozone level of less than 220 DU), the minimum total ozone (the lowest of the "minimum daily total ozone" in a year, i.e., the "minimum total ozone" in each year). In 2002, stratospheric temperatures were high, the ozone hole was small, and the minimum total ozone was high. This phenomenon can be attributed to unusually strong planetary waves that distorted the polar vortex; air flowed into the vortex and raised its temperature, which mitigated ozone depletion. In 2003, by contrast, the ozone hole grew to match the size observed in 2000, and the minimum total ozone remained low. The minimum total ozone has been relatively stable since around 1993, while the ozone hole area has been increasing since 1995. With the size of the hole almost matching that of the vortex core, however, there is little room left for the hole to grow further.

3-4 "Ozone hole-type" ozone depletion in the Arctic

Ozone depletion of the same magnitude as in the Antarctic ozone hole takes place in the Arctic polar vortex during winter and spring. In 2000, for instance, more than 70% of the total ozone was lost at an altitude of about 18 km. Figure 6 shows changes in the average total ozone between 1979 and 2003 (in March and April, in the area from 60 to 90 degrees north latitude); it decreased dramatically in the 1990s and picked up slightly thereafter. The significant fluctuation, however, makes it difficult to discern long-term trends.

3-5 Changes in solar UV radiation at ground level

Solar UV radiation at ground level changes dramatically depending on the amount of total ozone, clouds, etc. It has been only a decade or so since high-accuracy observations of solar UV radiation started in Japan (around 1990). Moreover, the eruption of Mt. Pinatubo, which resulted in a considerable decrease in ozone levels around 1993, makes it difficult to discern long-term trends in solar UV radiation. In the southern hemisphere, on which the impact of the eruption was much smaller, the total ozone continued to decrease throughout the 1990s. Figure 7 shows changes in the total amount of

Figure 6 : Changes in Total Ozone in Northern High Latitudes (from 60 to 90 Degrees North Latitude)in March and April[4]

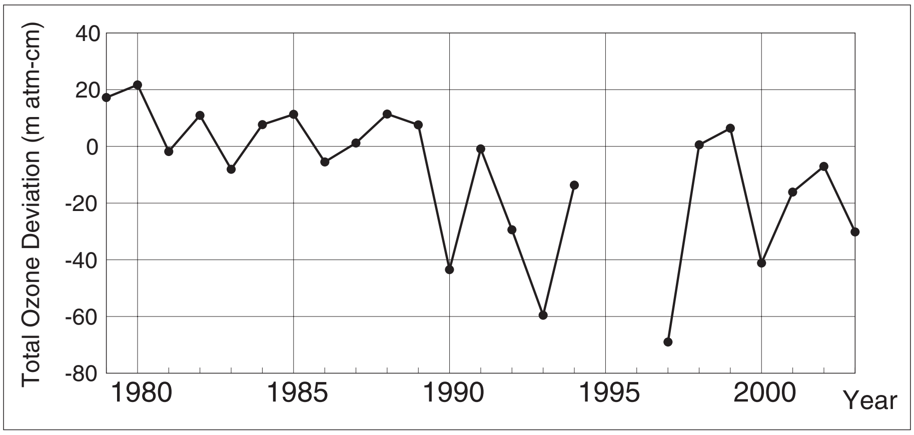
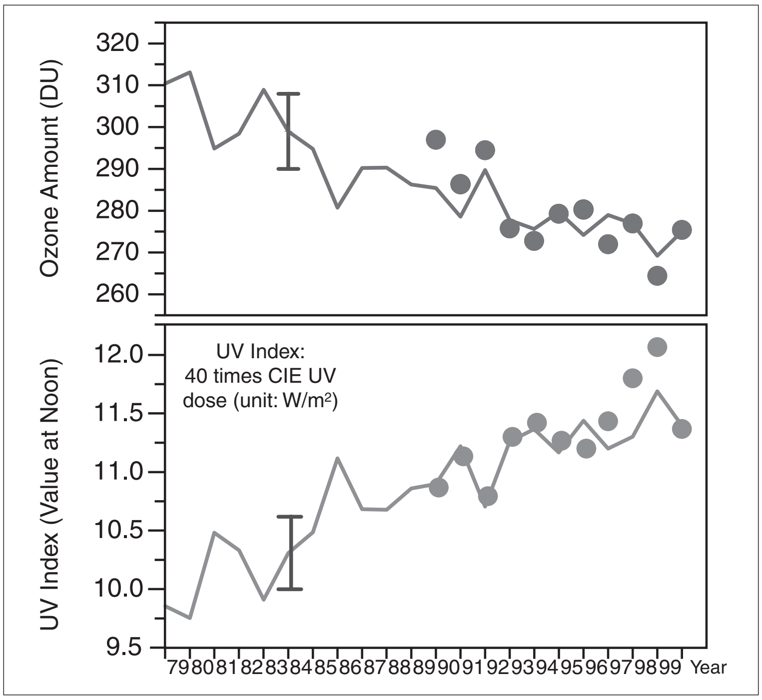


Figure 7 : Amount of Ozone (Top) and UV Radiation (Bottom) in Lauder, New Zealand, in Summer[1]



ozone and UV radiation (at ground level) in New Zealand; there is a clear anti-relationship between the decrease in the total ozone and the increase in UV radiation, which has reached a potentially dangerous level.

4 Prospects for the ozone layer

The "Scientific Assessment of Ozone Depletion: 2002[1]" includes a prediction of Antarctic ozone holes and the Arctic ozone depletion in spring, based on the current scenario of protecting the ozone layer through regulatory measures and other scenarios of greenhouse gases (carbon dioxide, methane, etc.), using three-dimensional models called "chemical climate models," which take climate change effects into account. According to this prediction, the Antarctic ozone layer will begin to recover around 2010 (not in 2000 as generally thought), but roughly in accordance with the scenario in Figure 1, while in the Arctic climate change will not produce "an ozone hole." It should be noted, however, that the current chemical climate models for the stratosphere have yet to be improved because they do not give full consideration to "other factors[6]."

Global-scale forecasts for the ozone layer, calculated by two-dimensional models (latitude and altitude), are also available, the results of which show that the ozone layer will recover almost in accordance with the scenario[1]. As in the case of the three-dimensional models, there is room for improvement in these two-dimensional models, as most of them do not fully take into account important factors such as an increase in water vapor, a decrease in stratospheric temperature, and dynamic/chemical processes in the polar regions.

5 Outstanding issues and challenges

The "ozone layer" is a fairly mature research area that is increasingly becoming an exact science. In fact, models used for data analysis well reproduce observational data. However, several issues and challenges remain, some of which are described below.

(1) It is necessary to continue observing and monitoring whether the ozone layer is recovering and whether UV radiation at ground level is decreasing according to the scenarios. If there are deviations from the scenarios, our understanding should be corrected.

(2) The impact of ozone depletion caused by "other factors" (excluding CFCs) should be elucidated. "Other factors" include an increase in stratospheric water vapor, a decrease in stratospheric temperature, an increase in N_2O, changes in atmospheric circulation, and wave activity due to climate change.

(3) The interaction betwesen the stratosphere and the troposphere should be predicted, and the impact of stratospheric changes on the chemistry of the troposphere should be elucidated.

(4) It is necessary to find out how much of the impact of UV radiation accumulates in the body, how much the damaged tissue can be repaired, and whether the incidence of skin cancer will continue to increase until 2060 as predicted.

6 Japanese and Western approaches to ozone layer research

Ozone layer research began to gain momentum in the 1920s, with Dobson inventing a spectrophotometer (Dobson Spectrophotometer) to measure the latitudinal distribution of the total ozone. Observation and research activities have since made great progress in shedding light on the mechanisms of the ozone layer. Specific achievements include improvements in observation through the "Dobson Spectrophotometer" and "Ozonesonde," taking the opportunity provided by the International Geophysical Year (1957-1958); the launching of TOMS (Total Ozone Monitoring Spectrometer) in 1979 by the U.S.; the discovery of the Antarctic ozone hole (1984-1986) and intensive observations to elucidate its mechanisms; and intensive observations to elucidate the mechanisms of "ozone hole-type" ozone depletion in the Arctic. Further improvements have been made through the launching of UARS (Upper Atmospheric Research Satellite) in 1991 by the U.S., the establishment of the Network for the Detection of Stratospheric Change (NDSC) in 1991, and the launching of ADEOS (Advanced Earth Observing Satellite) in 1996 by Japan. In the next five years or so, Envisat (a European Earth observation spacecraft launched in 2002) and EOS AURA (a U.S. Earth observation satellite launched in 2004) will most likely be the primary data suppliers.

Ozone layer research was originally designed to figure out latitudinal ozone distribution, understand the behavior of ozone as a tracer of atmospheric circulation, and investigate stratospheric transport models. In short, the research was in the discipline of meteorology. However, a series of breakthrough discoveries, ozone depletion (caused by CFCs) in 1974 by Molina and Rowland, the Antarctic ozone hole between 1984 and 1986, and decreasing ozone levels in the northern mid-latitudes in 1988, paved the way for modern ozone layer research as part of the approach to global environmental issues. Particularly shocking was the discovery of the Antarctic ozone hole.

6-1 Western approaches to the Antarctic ozone hole and research on the ozone layer

The U.S. took immediate action to investigate the Antarctic ozone hole, with NASA playing a leading role in implementing a series of national projects such as a pioneering small-scale ground-based observation in 1986 and an intensive and comprehensive observation involving airborne instruments in 1987, which found that:

- Chlorine atoms released from CFCs play a major role in creating the Antarctic ozone hole.
- Heterogeneous reactions taking place on the surface of the particles of polar stratospheric clouds play a central role in the ozone depletion mechanisms taking place in the Antarctic ozone hole.

Susan Solomon, who won the 2004 Blue Planet Prize, focused on heterogeneous reactions to shed light on the mechanisms behind the ozone hole, spearheading intensive observations implemented in the Antarctic in 1986. She not only took a lead in establishing a theory but also participated in outdoor observations in freezing Antarctic conditions[7]. With the sense of mission that comes from the seriousness of the problem and a sense of responsibility for the U.S. tracking down the cause of the ozone hole (and perhaps driven by intellectual curiosity), US researchers and the members of a support team seemed to have cultivated a strong sense of teamwork, as they would have felt if they had been on the battlefield or Olympic athletes in team sports. In the course of these efforts, the National Science Foundation (NSF) and NASA contributed substantially to organizing an open forum for researchers and making flexible budgetary arrangements.

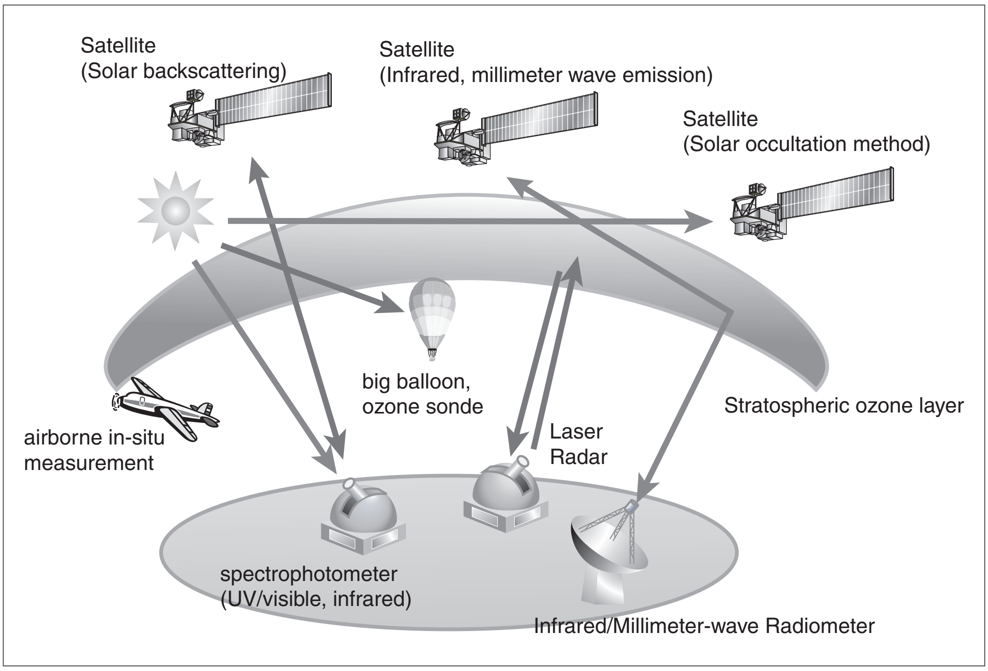
A European researcher told me back in 1987 that "We, European researchers, will focus on the Arctic, leaving the Antarctic to our US counterparts who are fully committed to it." In fact, European countries, although not as quick as the U.S. in taking action, jointly established a system for intensive observations, with each of them offering its specialty. At the same time, each country's budget was incorporated into the EU's budgetary framework, which resulted in intensive observation programs implemented four times during the period from 1991 to 2000. A system led by John Pile, a modeling researcher at Cambridge University, worked effectively in these programs, while observational data, the results of model calculations, auxiliary data, and analysis software were made readily available at a data center set up in Norway. In short, ozone layer research, which had been an "individual match" both in the U.S. and in Europe before the discovery of the ozone hole, developed into a "team sport" afterwards.

The U.S. launched the Upper Atmosphere Research Satellite (UARS) in 1991, which served as a major supplier of data on the ozone layer throughout the 1990s. While satellite observations are basically a "team sport," a broad base of "data users" who participate in "individual matches" came into existence. In line with this, a ground-based remote sensing observation network operated mainly by researchers was established in 1991 to complement satellite observations. Using laser-radar, microwave, infrared and visible/ultraviolet spectrometers, this network, called the Network for the Detection of Stratospheric Change (NDSC), has long been conducting unique observations together with satellite observations and ozone observations as part of meteorological observations in mutually complementary form. While it still contributes to verifying data provided by Envisat and EOS AURA, financial problems abound: a lack of long-term budgets for observations and budget cuts in research activities.

6-2 Japan's ozone layer research

Until the 1980s, Japan's ozone layer research efforts were focused on ozone observations as part of meteorological observations (by the Meteorological Agency), theoretical approaches to stratospheric dynamics from the viewpoint of atmospheric dynamics (by universities, etc.), and observations based on upper atmosphere research. These together have played a part in shedding light on the mechanisms of the sudden warming phenomenon in the stratosphere and in discovering the Antarctic ozone hole. Japanese researchers contributed in no small measure to ozone layer research, as systematic approaches were not widely adopted by researchers in other countries also. With the ozone hole discovered, however, research systems in the U.S. and Europe changed completely, which resulted in systematic research activities, a framework for "team sports." Unfortunately, flexible, systematic approaches were difficult in Japan in those days. It was not that "Japan took to the field to play an individual match, only to be smashed by a team gearing up for a team sport." Japan knew that it was going to be a team sport; it simply could not or did not organize a team. For one, both the Arctic and the Antarctic were much too far from Japan. The government's compartmentalized budgets, moreover, made it possible for each institution to conduct research individually without organizing an "All-Japan Team." In the end, Japan chose to participate in joint research programs with the U.S. and European counties, which was an appropriate, albeit forced, decision under circumstances where Japan's Western counterparts had established a "team sport" framework early on, considering "ozone depletion" as their own problem. More to the point, particular emphasis was placed on sensors on board ADEOS (particularly ILAS, the Improved Limb Atmospheric Spectrometer) in accordance with the priority order of stratospheric observation and research activities, which also turned out to be a good decision. Specific

Figure 8 : Satellite-borne, airborne and ground-based observations of ozone layer



achievements include:

- During the eight-month observation period, ILAS (a device of the Ministry of Environment) on board ADEOS (Japanese name: Midori) gathered comprehensive data on the Arctic ozone depletion (ozone hole-type depletion) and the relationship between ozone depletion and polar stratospheric clouds or nitrogen oxides, some of which produced important scientific findings through analysis by researchers at home and abroad[8].
- Long-term observational data have been accumulated, contributing to NDSC, etc. The National Institute for Environmental Studies (NIES) has been observing the vertical ozone distribution since 1988, using an ozone laser radar. The Solar Terrestrial Environment Laboratory of Nagoya University is observing chlorine and nitrogen compounds at Moshiri and Rikubetsu in Hokkaido, using FTIR and a visible spectrometer. The Meteorological Research Institute and the Communications Research Laboratory (the present National Institute of Information and Communications Technology) conducted laser radar observations of aerosols in Canada and New Zealand. In the Antarctic region, stratospheric observations at the Showa Station, led by the National Institute of Polar Research (NIPR), played a major role in discovering the ozone hole. In the Arctic region, meanwhile, NIPR and other parties conducted PSCs observations in Ny-Alesund, Svalbard, while Nagoya University, Tohoku University, the National Institute of Information and Communications Technology, etc., observed aerosols and trace constituents in the stratosphere above Alaska. NIES and other parties have been engaged in intensive observations of the Arctic ozone layer since 1995 (led by European countries) as well as joint research with Russia[9].
- Japan is now on a par with its Western counterparts in observation technologies using millimeter/sub-millimeter radiometers[10]. Its technological resources in developing and manipulating laser radar and aerosol/nitrogen-oxide sensors on board balloons and aircraft are also highly appreciated.
- Hokkaido University, Kyoto University and Kyushu University achieved a breakthrough in the analysis of stratospheric dynamics, such as analyses of data provided by UARS.
- With respect to the development of future prediction models for the ozone layer, a "proactive strategy" was adopted in the early 1990s to develop a stratospheric chemistry model based on the "CCSR/NIES General Circulation Model." The purpose was to create a three-dimensional model that was then considered "unpractical" because of the computation time involved. This strategy bore fruit: in the WMO and UNEP "Scientific Assessment of Ozone Depletion: 2002," the prediction of the future polar ozone depletion involving the effects of climate change by this model was treated as one of the most advanced results. It was possible because a large group committed to developing the "CCSR/NIES General Circulation Model" has been active.

With an "ample budget" (not a "modest budget") provided, albeit a compartmentalized one, and a handful of full-time researchers committed to observation activities, a team comprising dozens of staff members could be organized, which would enable Japan to take part in a "team sport." The ILAS team for ADEOS was one such example. It is unfortunate that the observation lasted for only eight months and that ADEOS-II malfunctioned and ceased to function prematurely. Neither the Arctic nor the Antarctic was a "remote place" for the ILAS team because ILAS was a satellite sensor specifically designed for high-latitude observations. The ADEOS projects, for that matter, had a relatively large budget and full-time researchers.

It is still uncertain whether a national project can be designed and launched in a year or so to address an emerging environmental problem such as the ozone hole. Japan's decision to cooperate with its Western counterparts turned out to be a good one, but it was not the consequence of comprehensive and open discussion among Japanese researchers; it was the choice for obtaining budgets from competent authorities. In relation to this, the absence of an open forum that transcends the boundaries of research areas and competent authorities has been a major issue. What is important now is that it has been overcome. Moreover, it is imperative that researchers improve themselves so that they can take advantage of an array of opportunities that can serve as an open forum (e.g., academic societies and Japanese committees on international research programs). The situation, however, has improved since 1986, with the Council for Science and Technology Policy in place to take the "initiative," which facilitates cooperation between government agencies. The next challenge is to fund the council properly to ensure flexible and dynamic research activities.

7 Towards the development of Japan's ozone layer research

While Europe's Envisat and the U.S.'s EOS AURA (satellites equipped with stratosphere-monitoring sensors) are gathering observational data, there are few options left for researchers engaged in observation and data analysis in Japan, which does not have a stratosphere-monitoring sensor of its own. In the short term, they are expected to pursue research efforts in the framework of "international cooperation," taking advantage of their specialty, while in the long term, it is necessary to capitalize on their own data that will accumulate over a long period. Super computers and Earth simulators are available for modeling researchers, and there are quite a few qualified researchers in this research area in Japan who together are expected to make satisfactory achievements.

The Earth Observation Summit II was held in Tokyo this April, and a 10-year plan for earth observations is in the pipeline. In Japan, a working group on earth observations was set up in the Council for Science and Technology Policy, and an ad-hoc group on the global environment is mapping out a long-term plan for global environment observations including ozone layer observations. With this as a backdrop, it is essential that "outstanding problems" be addressed and long-term approaches including international cooperation be maintained, based on the government's proactive measures. With respect to ozone depletion, the focus should be on "whether it is recovering according to our understanding," rather than on "whether it recovers or not." To this end, a strategic monitoring system should be created, and the following are suggested, with particular emphasis on observation activities:

(1) Evaluate the possible effects of "other factors" (substances other than chlorofluorocarbons that are not regulated by the Montreal Protocol) on the ozone layer, and incorporate the evaluation results into models for accurate prediction.

(2) Prepare a budget and create a system to support long-term observations of the ozone layer (including advanced observations that should be implemented by researchers). This is a means to monitor whether the ozone layer is really recovering according to the prediction based on a scenario of reducing chlorofluorocarbons, etc.

(3) Create a system (a data center), with a budget earmarked for it, to store long-term observational data, analyze variations or long-term changes in the subjects observed, accumulate models and their implementation results, and facilitate data utilization.

(4) Develop atmospheric chemistry sensors onboard satellites (a sensor that can monitor the concentrations of atmospheric constituents and meteorological parameters of the stratosphere and the troposphere, simultaneously and separately, is a promising means of keeping track of the stratospheric ozone layer and regional air pollution along with its impact on tropospheric air quality, and to gather information on interactions between the troposphere and the stratosphere).

A system should be in place to create an open forum attended by researchers and supported by flexible budgetary arrangements so that immediate action can be taken to address emerging environmental problems such as the Antarctic ozone hole.

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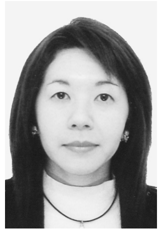
6

The US Strategy for Research on the Health Effects of Airborne Fine and Nano Particles — A Comparison with Japan



HIROSHI NITTA*(Affiliated fellows)
KUNIKO URASHIMA** (Environment and Energy Research Unit)

1 Introduction

The quantitative relationship between air pollutant concentrations and their health effects needs to be assessed to set environmental standards, which should be the central part of the environment administration. Environmental standards for five air pollutants including particles (so-called “traditional air pollutants”) were established about 30 years ago in Japan. From a scientific point of view, the scientific basis has nearly been established for the health effects of traditional air pollutants. This particular subject belongs to “old research areas,” and is considered unrelated to “rapid development,” at least in Japan.

As in Japan, it was understood in the U.S. that the atmosphere had been cleaned in the 1970s thanks to a series of air pollution preventive measures. The results of epidemiological studies, moreover, showed that air pollution did not have serious health effects. The number of research papers on the epidemiology of air pollutants continued to decrease until the latter half of the 1980s, as far as those registered in MEDLINE are concerned. However, it began to increase rapidly thereafter[1].

The Science and Technology Foresight Center is conducting a variety of technology forecasting surveys to develop the “3rd Phase Science and Technology Basic Plan.” One of these surveys concerns the quantitative analysis of rapidly growing research areas, using a database of research papers (e.g., basic research or scientific areas whose findings have been published as research papers)[2]. Among 51 research areas specified in this survey is the “Health Effects of Airborne Particles.” Because the majority of other areas concern state-of-the-art technologies (life sciences, etc.) on which Japan and other countries place a premium, it may seem strange that this particular subject was specified. This can be directly attributed to two factors that emerged in the U.S.: progress in research on the health effects of airborne particulate matters, and the establishment of environmental standards (the most important measure in the environment administration).

In July 2004, EPA announced that it would grant the largest subsidy ever (US$30 million or ¥3.2 billion) to the University of Washington for epidemiological research on the relationship between air pollution and cardiovascular diseases[3], a research area showing signs of further development.

2 Background

2-1 History of the analysis of the health effects of airborne particulate matters

Table 1 shows major air pollution incidents that took place in the first half of the 20th century, each of which raised public awareness of the health effects of airborne particulate matters.

*Hiroshi Nitta General researcher of the $PM_{2.5}$&DEP Research Project, the National Institute for Environmental Studies
http://www.nies.go.jp/index-j.html

Table 1 : Major air pollution episodes

Year	Location	episode	Damage
1930	Belgium	Meuse Valley	Sixty-three people died from air pollution along Meuse River, where a number of factories including iron mills were located, with each combusting coal. Calm, foggy conditions contributed to the increasing SO_2 concentrations in the atmosphere.
1948	Pennsylvania (U.S.)	Donora	Fluoride emissions from steel plants and zinc smelters located in the valley killed 20 people and left 5,910 seriously injured (about 43% of the local residents).
1950	Mexico	Poza Rica	A local factory accidentally released hydrogen sulfide (H_2S) into the ambient air while recovering sulfur from natural gas, killing 22 people and leaving 300 hospitalized.
1952	U.K.	London Smog	The concentrations of particulates and sulfur dioxide continued to increase for a week, killing some 4,000 local residents.
The 1960s	Yokkaichi (Japan)	Yokkaichi Asthma	A number of local residents developed asthma and bronchitis.

2-2 Health risk assessment

In general, health risk assessments of air pollutants are conducted based on several methodologies, the most popular of which are in vivo experiments (using laboratory animals) and epidemiological studies. Epidemiology is basically a non-experimental science; it is designed to find correlations between the incidence of diseases in a particular group of people and a variety of environmental factors. Taking into account correlations with other factors, for example, the incidence of bronchial asthma is compared between two groups of people: those exposed to high concentrations and low concentrations of air pollutants. Toxicology, meanwhile, investigates the development of various biological reactions and their mechanisms, exposing laboratory animals to specific environmental factors under certain conditions. For example, biological reactions to auto emissions are monitored using rats.

As far as health effects studies for airborne particulate matters are concerned, epidemiological findings are generally announced prior to the results of experimental studies that are usually conducted to corroborate epidemiological hypotheses. Where reliable epidemiological findings are available, epidemiological data is preferred to animal experiment data in assessing health effects. A report submitted by the Central Environmental Council last year reads as follows:

While epidemiological studies and animal experiments provide the quantitative data on toxicity needed to set numerical targets for environmental standards, the former are particularly important because they collect data directly from humans. Thus, in principle, environmental standards have been established based on human data obtained through epidemiological studies. Where reliable human data are not available, animal experiment data are usually extrapolated forward to assess the effects on humans in setting numerical targets[4].

Placing a premium on epidemiological data is one thing; emphasizing the results of a handful of epidemiological studies is another. As epidemiological studies are basically observatorystudies, consistency among reliable data, i.e., consistency among the results of different groups of people, is paramount in the field of environment studies.

2-3 Properties of airborne particulate matters and their effects on humans

Human respiratory organs comprise the nasal cavity, oral cavity, pharynx, trachea and bronchi, which bifurcate repeatedly into dozens of smaller bronchi before reaching the alveoli. The trachea is about 2 cm in diameter, while the bronchioles measure less than 1 mm, each of which is linked to the alveolus. When inhaled, particulate matters with large particle diameters*1 collide with or precipitate in the airway wall before accumulating there; particles with a small diameter, which reach the alveoli, accumulate on the alveolar wall through dispersion.

Airborne particulate matters differ in composition according to their diameter. In general, fine particles contain more components that are considered hazardous. Particle diameters, therefore, are a decisive factor in the health effects of airborne particulate matters in terms of both particulate accumulation in the respiratory organs and the composition of the particles, which varies depending on how they are formed in the atmosphere.

Of airborne particulate matters, those with a diameter of less than 10μm (SPM: Suspended Particle Matters) are regulated by environmental standards in Japan, whereas in the U.S., two types of particulate (PM_{10} and $PM_{2.5}$) are regulated. The aerodynamic diameters of $PM_{2.5}$ are less than 2.5μm. $PM_{2.5}$, however, include a certain amount of particles with a diameter greater than 2.5μm. Specifically, $PM_{2.5}$ refers to particles whose collection efficiency reaches 50% at an aerodynamic diameter of 2.5μm. Similarly, PM_{10} refers to particles whose collection efficiency reaches 50% at an aerodynamic diameter of 10μm. SPM in Japan, meanwhile, are totally free of particles with a diameter greater than 10μm. SPM and PM_{10}, therefore, differ in the distribution of the aerodynamic diameters of particles, and the average particle diameter becomes greater in the order of $PM_{2.5}$, SPM and PM_{10}.

In addition to these definitions of particles based on their diameters, there are various terms for airborne particulate matters used in a variety of laws and regulations (dust, soot, smoke, etc.). Dust includes suspended dust, asphalt dust generated by studded tires and specified dust such as asbestos. Many of these are termed according to their formation processes, measurement methods and sources of origin. “Diesel emission particles,” for example, refers to their source of origin. “Airborne particulate matters” and “aerosols” are almost synonymous in atmospheric science.

3 The US strategy for research on airborne particles in and after the 1990s

3-1 Impact of the $PM_{2.5}$ air quality standards

In the U.S., air quality standards for particulate matters were established for the first time in 1971, and they were later revised in 1987 and 1997. The original standards set in 1971 were designed to regulate TSP (Total Suspended Particles); PM_{10} were regulated in 1987, and $PM_{2.5}$, in 1997. Although there were no regulations for the diameters of TSP, the characteristics of high volume air samplers suggest that particles with a diameter of less than 40μm were collected. US environmental standards for particulate matters, therefore, have been revised twice to regulate smaller particles, from 40 to 10 and 2.5μm[5].

Environmental standards were set for $PM_{2.5}$ because of some new findings. First, a association was found between health effects (including diseases) and airborne particulate concentrations, even though existing environmental standards were met. In relation to this, $PM_{2.5}$ were considered to pose a greater risk than PM_{10}. Environmental standards are usually set for both the annual average and the 24-hour average. The health effects of long-term exposure to airborne particulate matters concern health indexes such as adult mortality, the incidence of childhood bronchitis, and the pulmonary function of children. It was also pointed out that short-term changes like daily fluctuation in $PM_{2.5}$ concentrations are related to premature death, increased hospital admissions, increased respiratory symptoms and disease, and decreased lung function. Particularly noteworthy was the finding that the daily average of $PM_{2.5}$ concentrations on a given day is related to the number of deaths of that day or the next day. More relevant, this correlation was found in daily fluctuation in airborne particulate matters (a common phenomenon observed in big cities), not in high-concentration phenomena such as the London Smog Incident - a finding that runs counter to the established theories.

In 1980, the American Journal of Epidemiology, one of the most authoritative scientific journals in epidemiology, featured an article by prominent British epidemiologists, which reported the health effects of air pollution caused by particles[6]; there was no evidence whatsoever that usual concentrations of particulate matters or sulfur dioxide (SO_2) caused mortality. Although the fact that the US steel industry sponsored this article aroused controversy, its conclusion was in keeping with common understanding in academic society in those days. Many researchers thought that health effects caused by short-term exposure to air pollutants no longer existed and that only long-term exposure to low concentrations of air pollutants mattered.

There has been great progress in computers and statistical analysis since 1987, when the environmental standards were revised, which opened up a new way for research on airborne particulate matters. At the same time, a series of notable research papers were published, each showing positive correlation between airborne particulate concentrations and daily mortality in some cities in the U.S. and Europe. Among others, research findings appearing in the New England Journal of Medicine[7] in 1993 raised public awareness of the health effects of airborne particulate matters, i.e., epidemiological findings regarding the health effects of long-term exposure to airborne particulate matters, based on the mortality reported in the "Harvard Six City Study," one of the most distinguished epidemiological studies on the subject. This particular period coincides with the increase in the number of research papers. With this as a backdrop, EPA began to review the environmental standards in 1994, which resulted in the second revision in 1997.

Similarly, EPA revised environmental standards for ozone (O_3). Volatile organic compounds (VOC), gaseous air pollutants such as nitrogen oxides (NOx) and sulfur oxides (SOx), and ozone, which is produced by reactions of these compounds in the atmosphere, all take part in the formation of SPM and $PM_{2.5}$ (see Table 1). Regulations designed to meet environmental standards for fine particles and ozone, therefore, extend to emission sources of an array of air pollutants including gaseous air pollutants. In other words, setting such environmental standards goes beyond regulating the emission of primary particulate matters; these standards have a substantial impact on those who emit air pollutants.

Setting environmental standards and their associated regulations often cause a conflict of interests. In the case of air pollution, for example, a large proportion of the population (including highly vulnerable people such as children, the elderly and invalids) could be exposed to risk, while industries and consumers alike can be polluters since the combustion of fossil fuels is a major source of air pollution. On the other hand, pollution prevention measures and health hazards result in substantial economic cost. EPA conducted regulatory impact analysis[9] in 1997 in parallel with the revision of the environmental standards; benefits derived from achieving the environmental standards were estimated to be US$19-104 billion a year, and their costs, to be US$8.6 billion. Benefits include a decrease in mortality, disease, labor loss, and activity constraints. Cost is primarily capital investment in air pollution control facilities to comply with the regulations.

With the environmental standards revised in 1997, the US industry took the case to court, questioning the validity of the air quality standards and, by extension, the scientific basis of the revision itself. Its allegations: the mechanism of the health effects of $PM_{2.5}$ has yet to be elucidated; the correlation between exposure to air pollution and its health effects cannot be confirmed, and hence is inappropriate as a basis of environmental standards even if epidemiological studies presented by EPA confirmed a strong statistical linkage between the two parameters. In the end, EPA won the case and the revised environmental standards for $PM_{2.5}$ took effect.

3-2 Selection of priority subjects and budgetary measures

The 1997 revision, particularly the addition of environmental standards for $PM_{2.5}$, is based on several epidemiological studies. EPA revised the environmental standards, emphasizing the consistency of epidemiological research findings. It is proven, however, that these scientific findings involve a lot of uncertainties. The US congress, in an effort to minimize such uncertainties, doubled the research budget for airborne particulate matters, while instructing the National Research Council (NRC), through the EPA director, to promote and supervise research on airborne particulate matters. In response to this, NRC selected priority subjects considered necessary to set environmental standards, presented research schemes for airborne particulate matters and set up a committee to monitor the progress in research activities.

Moreover, scientific uncertainties were identified in five major factors concerning airborne particulate matters: emissions, dynamics in the atmosphere, human exposure, inhalation, and development of health effects. There is also uncertainty in the correlations between these factors[10].

Naturally, the quantitative relationship between the exposure to the air pollutants concerned and its health effects (the exposure-response relationship) needs to be clarified to set environmental standards. At the same time, all processes from the formation of air pollutants to human exposure to them should be elucidated to meet prescribed environmental standards through the fair and efficient implementation of regulations[11] (Figure 1). For this reason, the US strategy for research on airborne particulate matters goes beyond achieving the immediate objective of meeting environment administration requirements (i.e., reducing uncertainties in the scientific basis of the environmental standards); they encompass basic areas in medicine, biology, atmospheric science and measurement technology concerning the lifecycle of airborne particulate matters (emissions, dynamics in the atmosphere, human exposure, inhalation, and development of health effects).

Priority subjects in airborne particulate research were selected based on three criteria: scientific value, decisionmaking value, and feasibility and timing. As a result, 10 priority subjects (see Figure 2) were selected in time for

Figure 1 : Formation of particulates and oxidants in the atmosphere[8]

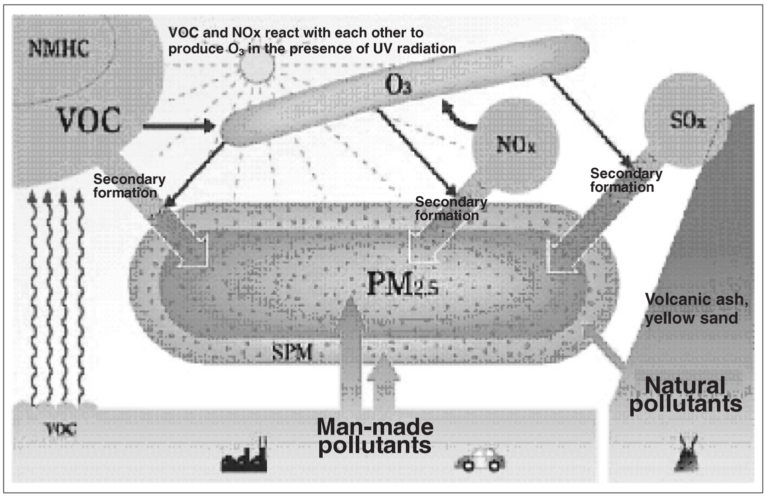
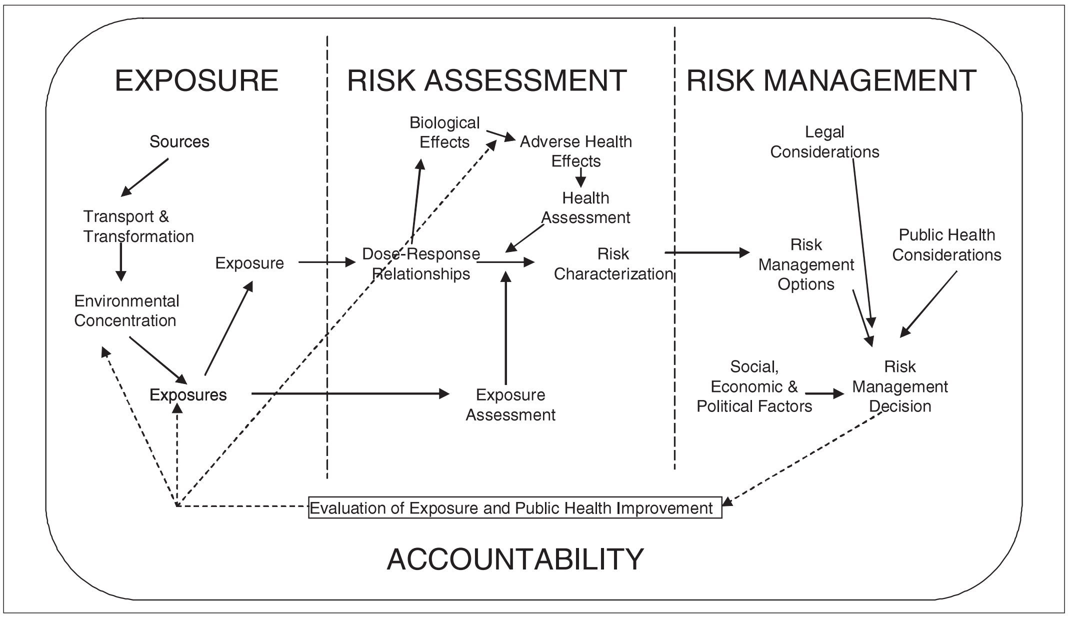


Figure 2 : Framework for US airborne particulate research that identified scientific uncertainties[10]



revision of the environmental standards in 2002.

A 13-year research portfolio was also set up for these 10 subjects, targeting the period between 1998 and 2010. EPA capitalized on the Science to Achieve Results (STAR) Program, a framework for providing competitive and non-competitive funds, to promote specific research activities, providing research funds to universities, external research institutions and EPA's research arm. In 1999, the Particulate Matter Research Center was established at the request of the US congress. Twenty research bodies applied for participation in the center's research programs, and five universities, Harvard University, New York University, University of Washington, U.C.L.A. and University of Rochester, were selected as COE, each receiving a total of US$8 million between 1999 and 2004 (The second recruitment is underway at the center).

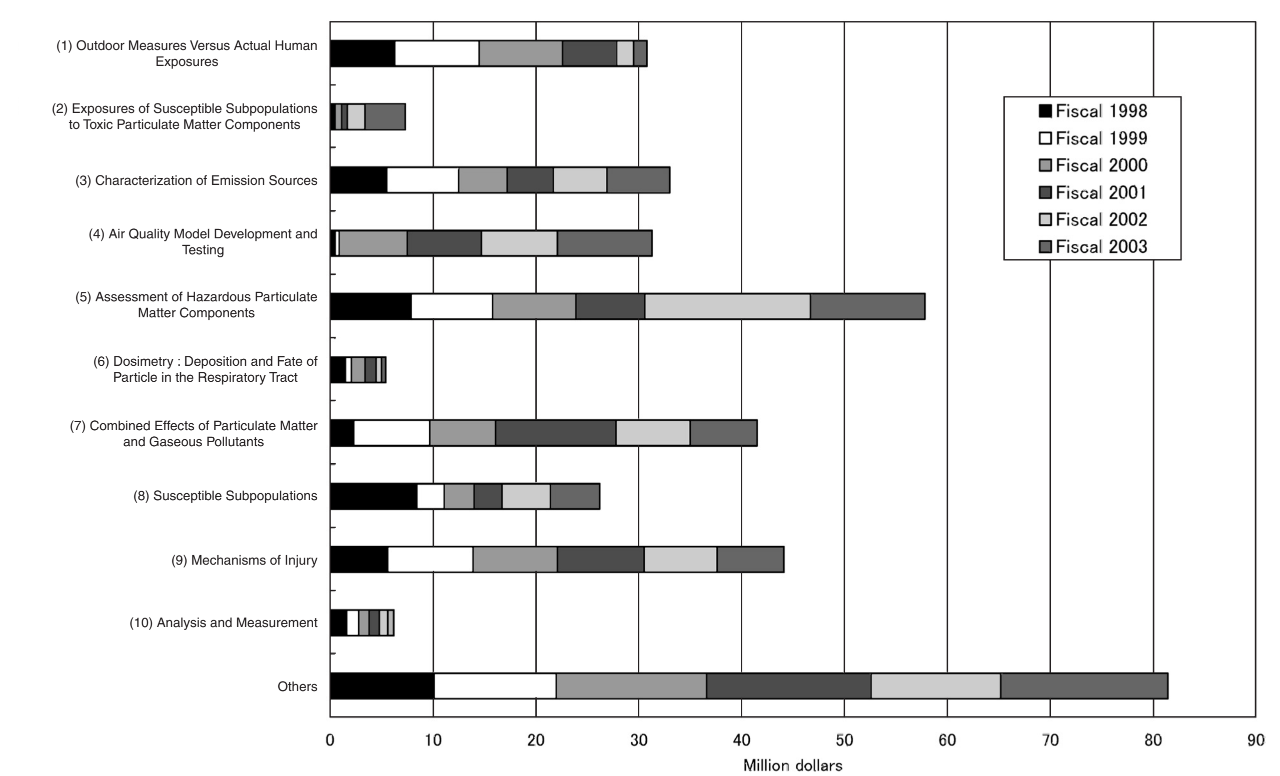
EPA funded a total of some US$370 million in airborne particulate research between 1998 and 2003, about US$60 million a year (see Table 2). Research funds for external research institutions such as universities account for about 32% of the total, with the rest provided to EPA's research arm including its affiliated research institutions. These funds were also appropriated to the basic research areas of the 10 subjects, e.g., review of a standardized measurement method for airborne particulate matters, development of methods to analyze the chemical constituents of airborne particulate matters, management of seven advanced monitoring facilities in the U.S. (Particulate Matter Super Site), and development of a database of emission sources.

In its interim reports released in 1999 and 2001[12,13], NRC made minor revisions to the research subjects and assessed progress in research activities. In 2004, it evaluated research findings published between 1998 and 2003[14], while releasing a report summarizing research findings over the past five years[15]. This report refers to some 700 items of literature funded by EPA and about 50 items of literature funded by other competent authorities.

Table 2 : Priority subjects regarding airborne particulate matters in the U.S.

Subject	Description
(1) Outdoor Measures Versus Actual Human Exposures	The purpose is to shed light on the quantitative relationship between measurement data provided by outdoor stationary monitoring stations and the actual personal exposure. This research is conducted in response to the criticism that data provided by outdoor stationary atmospheric measurement stations have been used as index of the exposure of the groups concerned.
(2) Exposures of Susceptible Subpopulations to Toxic Particulate Matter Components	Subject (1) is explored in greater depth, focusing on highly vulnerable groups and hazardous components. In principle, it is conducted based on the achievements in Subject (5).
(3) Characterization of Emission Sources	It is designed to make inventories and review their methodologies regarding the amount of primary particles originating from emission sources, distribution of particle diameters, chemical compositions and the amount of gaseous air pollutants that can be converted into secondary particles in the atmosphere.
(4) Air Quality Model Development and Testing	It is designed to model and verify the formation and dynamics of various airborne particulates (nucleation in the atmosphere, formation of organic aerosols, atmospheric chemical reactions, dry deposition, vertical mixing, effects of climate models, etc.)
(5) Assessment of Hazardous Particulate Matter Components	Physiochemical components of airborne particulates that have adverse effects on human health are identified.
(6) Dosimetry: Deposition and Fate of Particles in the Respiratory	The topics concerned are accumulation of particulates in the respiratory organs (the nasopharynx, trachea, bronchi and lung) of highly vulnerable people, and the elimination rate of the particulates and its mechanisms.
(7) Combined Effects of Particulate Matter and Gaseous Pollutants	The purpose is to distinguish between the health effects of particulates and those of other gaseous substances, and to shed light on the impact of exposure to the atmosphere in which these substances coexist.
(8) Susceptible Subpopulations	Groups highly vulnerable to exposure to particulates are identified.
(9) Mechanisms of Injury	It is designed to elucidate the mechanisms explaining the correlation between exposure to airborne particulates (demonstrated by epidemiological studies) and mortality/morbidity.
(10) Analysis and Measurement	The purpose is to review how statistical approaches designed to analyze epidemiological data affect estimates of the health risks of particulates, and how measurement errors and miscategorization interfere with improving statistical approaches or estimates of the health effects of air pollution.

Figure 3 : EPA's research budgets for airborne particulate matters



4 Japan's air environment administration and research trends

4-1 Japan's air quality standards

Japan's environmental standards for airborne particulate matters were first established in 1972. The following year, additional standards for other traditional air pollutants (sulfur dioxide, carbon monoxide, photochemical oxidants and nitrogen dioxide) were promulgated, while those for nitrogen dioxide were revised in 1978. The "Health Effects Index," which is the basis of Japan's environmental standards for airborne particulate matters, concerns parameters such as mortality, increased bronchitis, and decreased lung function; it was established based on epidemiological findings in the U.S. and Europe, complemented by scientific findings in Japan.

Japan's environmental standards for airborne particulate matters and traditional air pollutants, as well as critical decisions in the air environment administration, have been based on an array of scientific findings from the U.S. and Europe, with a few research findings obtained by the Ministry of the Environment (the former Environmental Agency) complementing them. The "Survey of the Health Effects of Smoke, etc.," conducted by the former Ministry of Health and Welfare before the establishment of the Environmental Agency, served as a basis for setting environmental standards for sulfur oxides, as well as for designating areas in accordance with the Pollution-related Health Damage Compensation Law. In relation to this, the "Survey of the Health Effects of Combined Air Pollution," conducted in 1978 in response to the revision of the environmental standards for nitrogen dioxide, and the results of two other surveys presented by the Environmental Agency to cancel the designated areas in accordance with the Pollution-related Health Damage Compensation Law played an important role in the air environment administration[16-19]. The Ministry of the Environment (the former Environmental Agency) set up investigative committees for each of these surveys, with their staff members assigned to universities and research institutions conducting the actual surveys. For instance, a survey of the health effects of $PM_{2.5}$ launched in 2000 by the Ministry of the Environment is underway, led by the Investigative Committee for the Health Effects of Exposure to Fine Particles, a framework that is not changing in any significant way.

4-2 Research funds for conventional pollution problems including air pollution

The competitive research funds provided by the Ministry of the Environment are not designed for research on such traditional air pollutants, except for pollution control in the framework of research on global environment conservation. This exceptional research, however, is participated in only by the research institutions of government agencies and of independent administrative agencies, with those of universities excluded. In fact, these competitive research funds are limited to research activities in global environment conservation, environmental technology development and waste disposal. The US strategy for airborne particulate matters, where both competitive and non-competitive research funds are mobilized, cannot be put into practice in Japan. In fact, the Ministry of the Environment has been conducting research on traditional air pollution using non-competitive funds.

5 Growing concerns over the toxicity of nanoparticles

The fundamental concept in assessing the biological impact of certain substances is that their biological effects (toxicity) increase linearly in proportion to the dosage (weight). It has been argued, however, that this concept may not be applicable to nanoparticles; some researchers point out that nanoparticles, even if their weight is negligible, may have health effects, depending on their counts or due to their large surface areas. Concerns are thus growing that nanoparticles could be different from other particles in their intake routes, dynamics in the body, recognition by the body's defenses and expression of toxicity.

The US strategy for research on airborne particulate matters, from the vantage point of setting appropriate standards for particle diameters, has already taken into account $PM_{1.0}$ (particles smaller than $PM_{2.5}$) and even $PM_{0.1}$ (fine particles with diameters of less than 0.1 μm) in assessing the health effects of airborne particulate matters. The University of Rochester, one of COE, focuses on research on ultra-fine particles[20], while review is underway primarily in Europe for the measurement of nanoparticles in auto emissions[21].

The National Institute for Environmental Studies of Japan, meanwhile, is setting up experimental facilities to assess the health risks of nanoparticles in auto emissions, with animal experiments, etc. scheduled to begin shortly. Nanoparticles are therefore becoming a subject of research in the field of the health risk assessment of airborne particulate matters.

Concerns are also growing over the toxicity of nanomaterials that are increasing along with progress in nanotechnology. The National Institutes of Health (NIH) recently added nanomaterials (single-layer nanotubes, titanium dioxide, quantum dots, fullerene, etc.[22]) to the list of the National Toxicology Program to evaluate their toxicity. In addition, EPA, NSF (the National Science Foundation) and NIOSH (the National Institute for Occupational Safety and Health) began to advertise for research proposals for the environmental and health effects of nanomaterials, putting up a total of US$7 million[23]. Research on the toxicity of nanomaterials is burgeoning in the U.S.

6 Prospects and challenges for research in Japan and policy recommendations

Airborne aerosols in the East Asian region and by extension in the world, which are beyond the subject matter discussed above, are receiving attention as a global environmental problem. Feature Article 4 (Research on the Impact of Aerosols on Global Warming - Approaches to Remaining Problems) in the Science and Technology Trends journal (November 2002) addresses this problem; competitive funds such as the Global Environment Research Funds (provided by the Ministry of the Environment) and research subsidies granted by the Ministry of Education, Culture, Sports, Science and Technology have played a part in promoting research in this particular area. On the other hand, the promotional framework for research on airborne particulate matters as a domestic problem needs to be reviewed and discussed.

To begin with, the extent to which Japan should have its own scientific findings on the health effects of airborne particulate matters needs to be determined. The scientific basis required to set environmental standards is usually derived from research findings in other countries (which is not the case with the U.S. and some countries in Europe); guideline values set by WHO are used in some cases as environmental standards. However, scientific findings on health effects on local residents exposed to airborne particulate matters are necessary to establish Japan's own environmental standards. Epidemiological findings have been emphasized as the scientific basis of environmental standards because epidemiology can keep track of exposure to pollutants in the real world along with its health effects. However, the reality is that both the financial and human resources needed to conduct research on air pollution and epidemiology related to environmental pollution are far from sufficient in Japan. Due to the absence of competitive research funds in this area, moreover, maintaining laboratories for developing human resources is not feasible, while a shortage of human resources makes it difficult to create a framework for competitive research funds; it is a vicious cycle. To gather scientific findings unique to Japan, therefore, it is imperative that short-term research funds be made available and long-term support programs be administered to develop the necessary human resources.

In the meantime, how much research fund is needed, and whether the scale of fund made in the U.S. is needed in Japan, should be thoroughly discussed. Following EPA's regulatory impact analysis, moreover, quantitative estimates should be made of the population exposed to air pollution, the significance of health risks and the cost-effectiveness of preventive measures, each of which should take into account health risks associated with other environmental pollution.

Secondly, research that is needed for the most efficient measures should be designed to meet prescribed environmental standards. As the US strategy suggests, there is a need to promote basic medicine, biology, atmospheric science and measurement technology regarding air pollutant emissions and their dynamics in the atmosphere, air pollutant exposure to humans, air pollutant inhalation and the development of biological effects, as well as research that sheds light on quantitative relationships between the amount of exposure and its health effects.

Lastly, research on the toxicity of nanoparticles should be promoted in the framework of Japan's R&D strategy for nanotechnology, encouraging participation of not only researchers specializing in nanomaterials but also those in the fields of biology, pharmacology, epidemiology and medicine. While research in this particular area is still in its infancy in the U.S., the authorities and research institutions concerned are beginning to discuss the health risks of nanomaterials in Japan[24]. There is a fair chance of Japan taking the initiative in this area through the concerted efforts of all parties concerned.

An international consensus regarding the concept "precautionary approach" or "precautionary principle" is being reached on methods of addressing environmental problems[25]. Specifically, it is generally agreed that scientific uncertainties should not be an excuse to postpone cost-effective measures when human beings and ecosystems are expected to suffer serious or irreversible damage. Decision-making based on precautionary approarch or principle is incompatible with current approaches to traditional air pollutants, where the toxicity of target pollutants is defined to closely assess the scientific uncertainties involved. A slim chance of nanoparticles having adverse effects on human beings and ecosystems may thus result in the enforcement of regulations based on precautionary principle, and those taking the initiative in developing next-generation products will likely benefit.

In the U.S., assessment methods based on "regulatory science" are being discussed and implemented to address quite a few environmental problems. Regulations related to health effects should be established on a scientific basis supported by basic research. In relation to this, problems associated with nanoparticles should be addressed properly according to regulatory science, achievements in which are expected to contribute to improving Japan's quality of life and its science and technology.

Glossary

*1 Particle diameter

A "particle diameter" does not refer to a length measured physically; it involves the inertial force of the airflow and hence is called an "aerodynamic diameter."

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7

Latest Trends in and Prospects for Coal Utilization and Clean Coal Technologies

TATSUYA OHIRA
Environment and Energy Research Unit

1 Introduction

Coal, a fuel used in the production of iron and steel, has played a major role in driving industrial development ever since the industrial revolution in the 18th century. Although oil took the place of coal following the energy revolution in the 1960s, the two oil crises in the next decade made the world rediscover the value of coal. Coal is abundant and hence is cost-effective; its widespread distribution (primarily in industrialized countries) ensures the security of supply. In Japan, which needs to reduce its energy supply vulnerability, coal is a primary alternative energy source to oil. Indeed, its consumption is on the rise, with low-cost imports increasing.

Japan consumes about 150 million tons of coal a year, which accounts for some 17.9% of Japan's primary energy supply (as of 2000)[1]. This proportion is estimated at 18.0% for 2010 and 17.0% for 2030, according to a long-term energy outlook released in October 2004. Coal, therefore, continues to be an essential energy source[2].

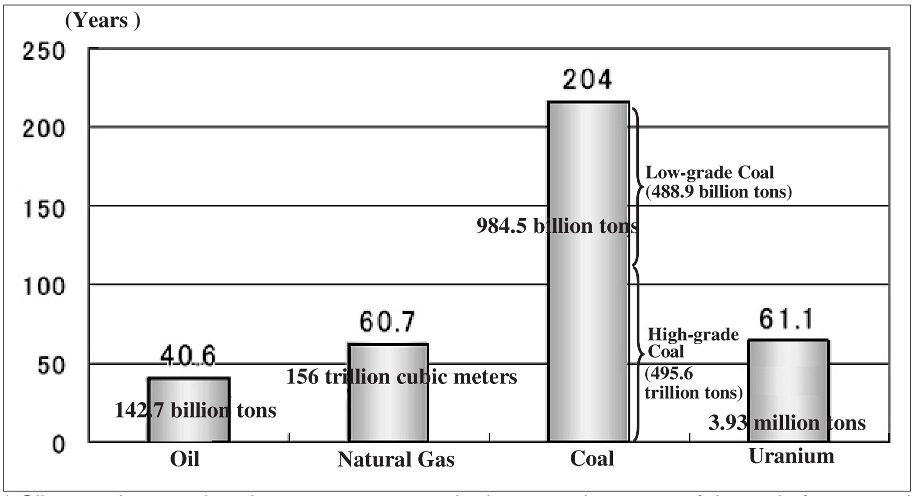
When combusted, however, coal produces a relatively large amount of CO_2 per unit calorific value, compared to other fossil fuels. In response to growing public awareness of global environmental problems such as global warming and acid rain, there is an increasing need to consume coal in an eco-friendly manner (i.e., reduction of SOx and CO_2 emissions) and to improve its utilization efficiency at power plants, etc. In Japan, meanwhile, coal is not being produced on a commercial basis, except for production for the sake of technology transfer - which makes Japan almost fully dependent on imported coal. With demand for coal rising in the Asia Pacific region, it is becoming increasingly critical that the security of coal supply be ensured for Japan.

Such recent trends translate into the growing need to develop eco-friendly clean coal technology (hereinafter referred to as "CCT") and take proactive measures to ensure the security of the coal supply. The Agency of Natural Resources and Energy organized the "Clean Coal Cycle" (C3) this January, which came up with an interim report this June. The monthly report of Science & Technology Trends (July 2004) refers to CCT as one of the key technologies that can be transferred to China to solve energy and environmental problems between the two countries[3]. Bearing these in mind, this article addresses: coal supply and demand trends; CCT overview; CCT development trends in Japan, the U.S. and Europe; and challenges in promoting CCT in Japan. It also provides an overview of policies to be adopted in the future. Specifically, Chapter 2 features the status of coal; Chapter 3, the outline and details of CCT; Chapter 4, technological development trends in Japan, the U.S. and Europe; and Chapter 5, challenges lying ahead and recommended policies.

2 Status of coal

This chapter summarizes the characteristics of coal, its supply and demand trends, and its position in Japan's energy policy.

Figure 1 : Proven reserves and reserve-production-ratio (RPR) of major energy sources



* Oil, natural gas and coal reserves represent the known estimates as of the end of 2002, and those of uranium, as of January 1, 2001. Proven reserves of high-grade coal (bituminous and anthracite coal) and low-grade coal (brown and sub-bituminous coal) are estimates based on References[13].
Source: Author's compilation based on BP Statistics 2003, OECD/NEA and Uranium 2001 (IEA).

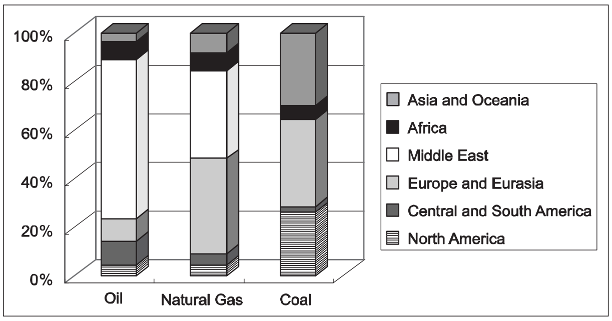
2-1 Characteristics of coal

Coal has clear advantages over other energy sources in terms of the amount of reserves and cost effectiveness. Figure 1 shows proven reserve-production-ratio (RPR) of major energy sources. Coal dwarfs other energy sources in the amount of reserves. BP Statistics 2003 estimates that coal reserves represent more than 200 years of production at current levels, which ensures a long-lasting, stable supply. By contrast, oil, natural gas and uranium are expected to last for only 41 years, 61 years and 61 years, respectively.

Energy prices have been fluctuating, with oil and natural gas prices swinging widely; they are increasing in the long term. Coal prices, meanwhile, have been relatively stable over the last three decades, though they showed a marginal upward trend before and after the oil shocks. Coal costs less than half the price of oil per unit calorific value. Coal's economic advantages, therefore, lie in its cheap price and long-lasting, stable supply.

Figure 2 shows the distribution of proven fossil-energy-source reserves. Oil reserves are concentrated in the Middle East, while natural gas is produced primarily in the Middle East and the former Soviet bloc. The supply of these energy sources, therefore, involves political and social uncertainties. By contrast, coal is widely distributed across the globe (North America, the former Soviet bloc, Europe, etc.), with some 30% found in the Asia Pacific region - a situation that ensures coal supply against political and social destabilization.

Figure 2 : Distribution of proven fossil-energy-source reserves



Source: Author's compilation based on BP Statistics 2003.

Although being abundant and cost-effective, coal has a major drawback: its high carbon content, compared to other fossil fuels, results in a large amount of CO_2 emissions when combusted. Specifically, oil and coal produce 1.2 and 1.5 times more CO_2 emissions (per unit calorific value), respectively, than natural gas. Of all the fossil fuels, coal places the largest burden on the environment. CO_2 emissions from coal combustion should thus be recovered and disposed of. It is also necessary to treat the combustion gas that contains SOx and NOx (the causes of air pollution and acid rain), and to make use of coal ash.

The better part of coal used for power generation, iron manufacturing and other industrial processes is high-grade coal (bituminous and anthracite coal)[4], which accounts for only half of the proven coal reserves, as shown in Figure 1. For that matter, low-grade coal (sub-bituminous and brown coal) should be exploited further.

2-2 Coal supply and demand trends

The world's coal production, which has been relatively stable since the 1980s, is estimated at 5 billion tons for 2002. Specifically, production in the Asia Pacific region, which is highly dependent on coal for its energy supply, is on the rise; it began to surge in and after 2000 in response to increasing coal consumption in the region[5]. Production in other regions is relatively stable or increasing gradually except for Europe and Eurasia, where production is declining.

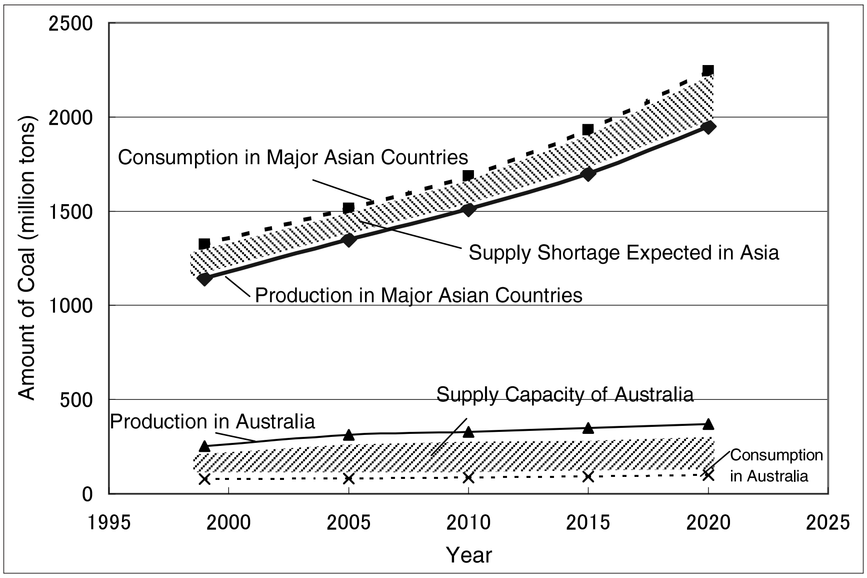
As shown in Figure 3, coal consumption in major Asian countries including Japan is expected to increase steadily, while Australia and Asian coal-producing countries are likely to cater for the regional demand. That said, the security of the coal supply as well as its efficient use remains a major concern for all Asian countries.

Figure 4 shows the recent trends in Japan's coal consumption by sector[6]. The consumption of steam coal by the power generation sector increased by an average annual rate of 7% from 1991 to 2002, reaching 38 million tons a year, whereas that of coking coal by the steel industry has been relatively stable at about 65 million tons a year since 1980. Other industries including the cement industry consume an average of 23 million tons a year.

Imported coal accounted for over 80% of Japan's coal supply throughout the 1980s; the proportion reached 99.2% in 2002 due to an increase in imports and a decrease in domestic production[6]. As shown in Figure 5, Australia commands a 56.5% share of the total imports in 2002, followed by China (19.1%), Indonesia (12.0%), Canada (5.8%) and Russia (4.3%). Imports from the top three countries together account for more than 85% of the total.

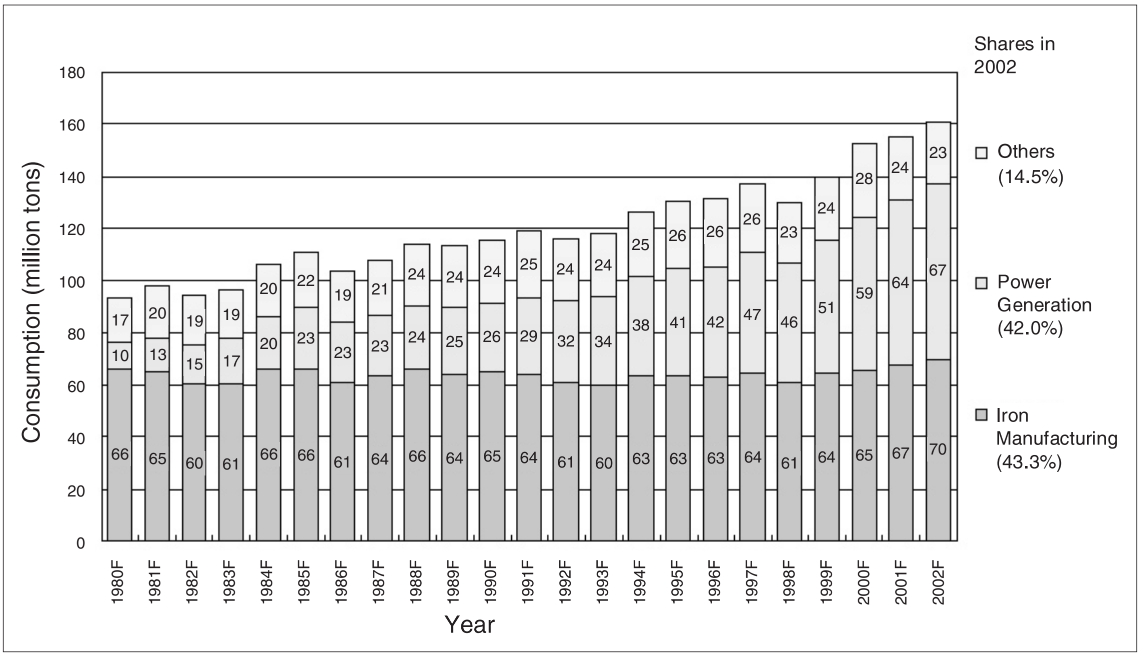
One of the challenges in ensuring the security of the coal supply is the need to improve the coal transportation infrastructure (including railroad and harbor facilities) in Australia, China and Indonesia. In Australia, for instance, more than 50 ships remained queued off the port of Newcastle in March 2004 due to a bottleneck in railroad transportation[5]. In view of growing coal imports, drastic measures should be taken to shore up and improve the infrastructure.

Figure 3 : Coal supply and demand outlook in major Asian countries



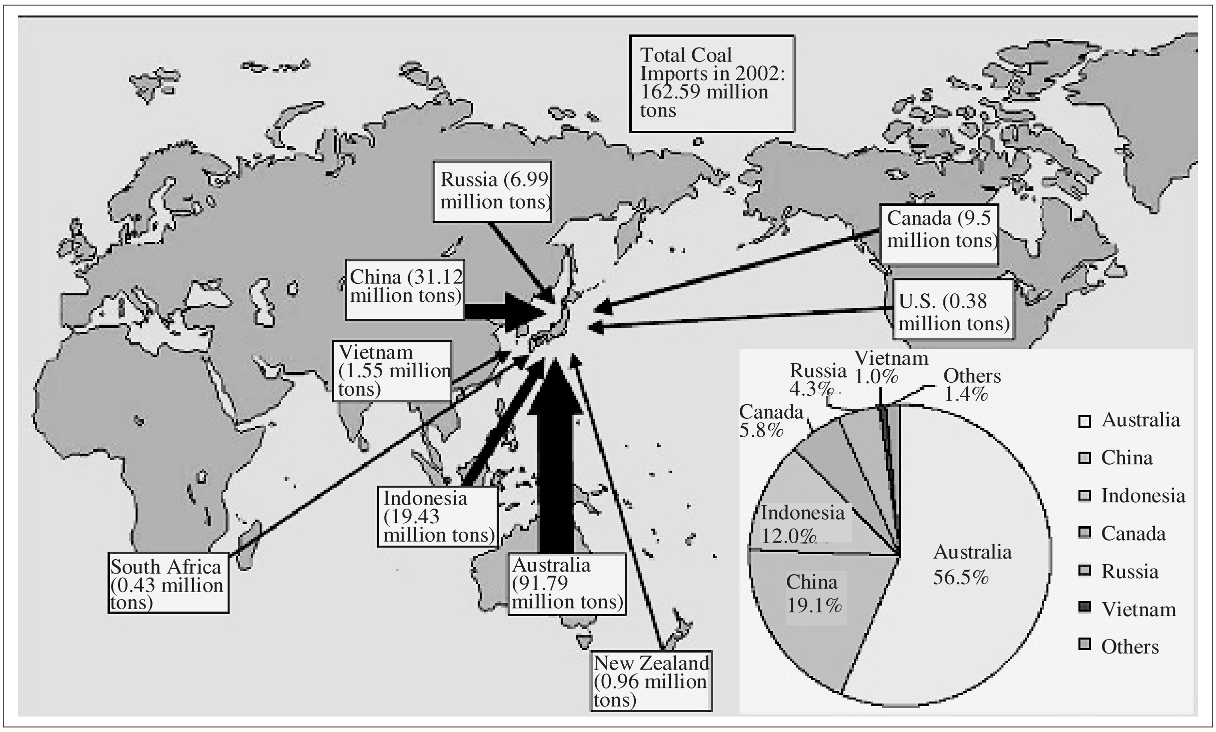
* Calculated based on the assumption that 1 kg of coal produces 6,000 kcal and 1 ton of oil represents 1.645 tons of coal. Major Asian countries include Japan, China, Korea, Taiwan, Indonesia, Malaysia, the Philippines, Thailand and Vietnam (not including India).
Source: Author's compilation based on APEC Energy Demand and Supply Outlook 2002 (APERC).

Figure 4 : Trends in coal consumption in Japan



Source: References[6]

Figure 5 : Japan's coal imports by country of origin



Source: References[6]

2-3 Position of coal

The position of coal in Japan's policy on natural resources and energy depends on its advantage over other energy sources and the magnitude of the challenges it faces. Although increasingly serious global environmental problems translate into an emphasis on the environmental disadvantages of coal, it is and will be an essential energy source because of its abundance and cost effectiveness, as mentioned in Chapter 2-1. Taken all together, coal is an eco-friendly energy source in the medium and long terms, and hence is expected to be a promising option in a well-balanced energy supply system, to which CCT development holds the key.

3 Clean coal technology (CCT)

This chapter refers to the elements of eco-friendly CCT and its technical specifications.

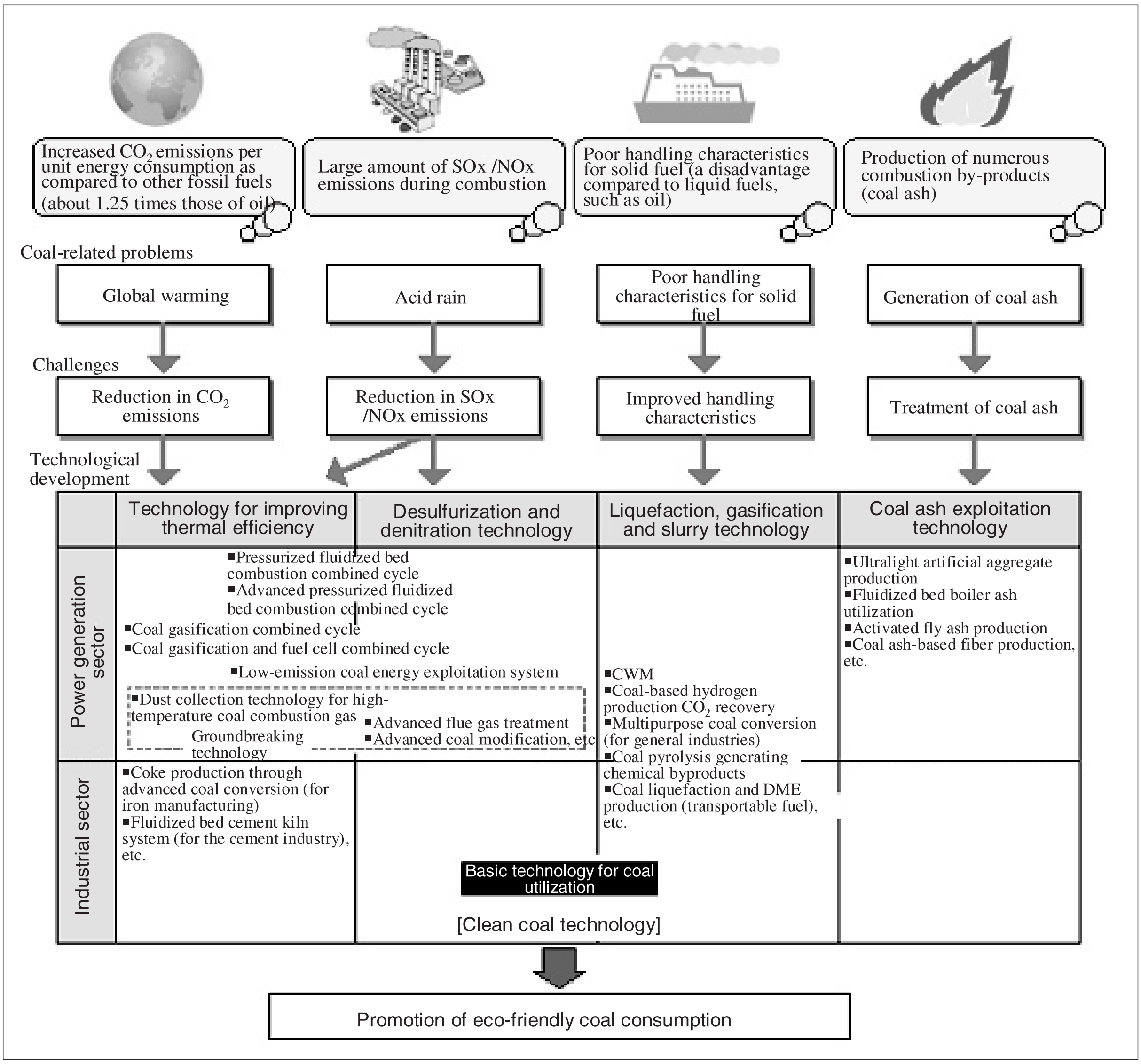
3-1 Overview

The two major coal consumers in Japan are the power and steel industries, each of which accounts for some 40% of the total domestic consumption and is capable of adopting CCT. The total installed capacity of coal-fired power plants stands at 33.77 million kW as of the end of 2002, with 78 units operating. A total of 9.8 million kW will be added, according to a power supply plan laid out in 2003. Moreover, 11-million-kW worth of power facilities (about 30% of the current capacity) will be replaced by 2030 on the assumption that their service life is 40 years. There is thus scope to introduce improved coal-fired power plants adopting CCT[2]. As for the steel industry, the total installed capacity of coke ovens stands at some 32 million kW as of the end of 2002, with 44 ovens in operation. Likewise, about 31-million-kW worth of ovens (more than 95% of the current capacity) will be replaced by 2030, assuming that their service life is 50 years. There is also scope to introduce next-generation, energy-efficient coke ovens adopting CCT[2].

CCT is comprised primarily of the following four elementary technologies (see Figure 6):

(1) Efficiency improvement technologies
(2) Desulfurization and denitration technologies contributing to environmental improvement

Figure 6 : Typical clean coal technologies



CWM : Coal Water Mixture DME : Dimethyl Ether

Source: Author's compilation based on References[12]

(including technologies for separating, recovering and sequestrating CO_2)

(3) Technologies for converting coal into liquid fuel, gas and slurry

(4) Coal ash utilization technologies

These technologies are designed to reduce the environmental load caused by coal combustion (through reduction of CO_2, SOx and NOx), develop new ways of using coal (through improvement of its handling characteristics) and dispose of coal ash. CCT also includes technologies for making use of low-grade coal.

3-2 Technical specifications

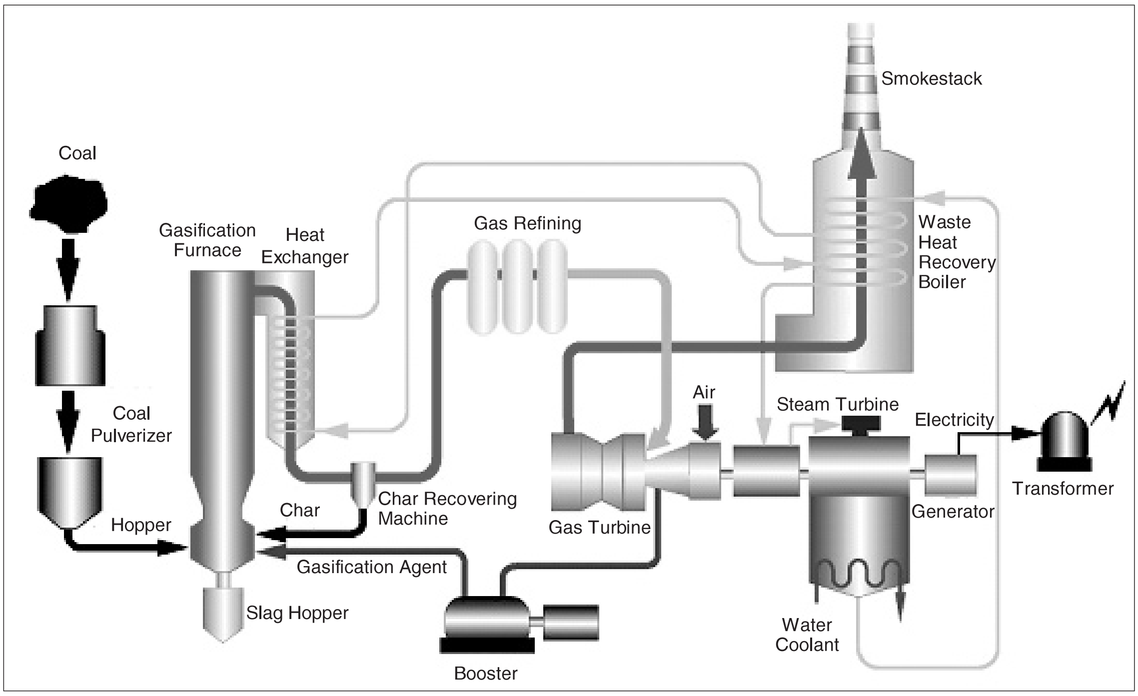
(1) Technologies for thermal efficiency improvement

With respect to technologies for thermal efficiency improvement for power generation purposes, (i) super critical pulverized coal-fired power generation (main steam with a temperature of about 540˚C at a pressure of 238 atmospheres) has been commercialized, while (ii) ultra super critical pulverized coal-fired power generation (main steam with a temperature of about 600˚C at a pressure of 241 atmospheres) and (iii) pressurized fluidized bed combustion combined cycle (PFBC) are nearing commercialization. PFBC involves combustion of coarsely pulverized coal in a fluidized bed at a pressure of about 10 atmospheres.

On the other hand, (iv) integrated gasification combined cycle (IGCC), which is shown in Figure 7, is scheduled for commercialization in around 2010. This technology utilizes both coal gas (composed primarily of carbon monoxide and hydrogen) and steam (produced by a gasification furnace) to drive a gas and a steam turbine, thereby achieving high power generation efficiency. There is also an advanced type of PFBC (A-PFBC), where PFBC is combined with partial coal gasification to further improve efficiency. In around 2020, (v) integrated gasification fuel cell combined cycle (IGFC), which incorporates a fuel cell fueled by coal gas, is expected to enter commercial operation[7].

The average net power generation efficiency of coal-fired power plants in Japan stands at 38% as of 1997, whereas those of the technologies outlined above are estimated at 40% for (i), 41% for (ii), 42% for (iii), 46% for (iv) and 54% for (v). Efficiency improves in the order (i), (ii), (iii), (iv) and (v). Figure 8 shows CO_2 emissions of IGCC per unit power generated as well as those of conventional coal-fired, oil-fired and LNG-fired power generation[8]. CCT contributes to reducing the CO_2 emissions of coal-fired power generation by some 24%, a level lower than that of oil-fired

Figure 7 : Integrated gasification combined cycle system (IGCC)



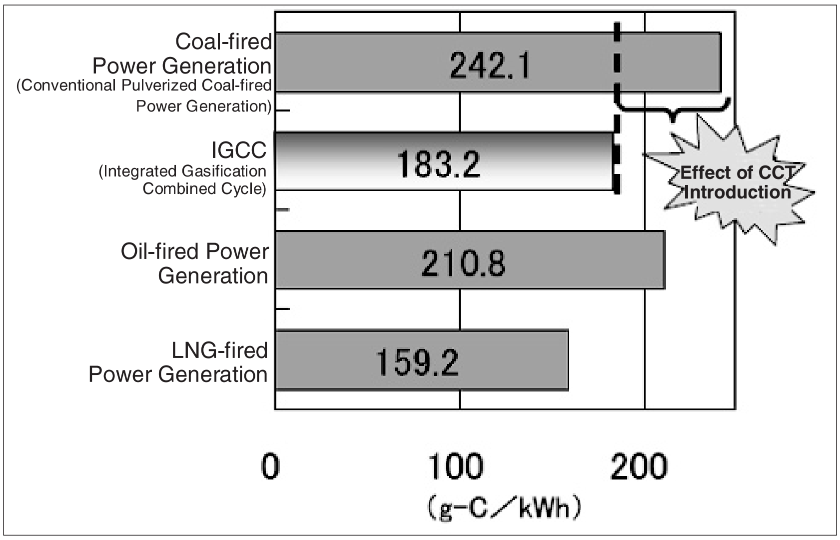
power generation.

Coke production through advanced coal conversion (SCOPE21: Super Coke Oven for Productivity and Environment Enhancement Toward the 21st Century) is a technology that improves the thermal efficiency of the iron-making process. Specifically, coal pretreatment processes contribute to reducing the energy consumption of coke production by as much as 20%.

(2) Technologies contributing to environmental improvement

Technologies contributing to environmental improvement include the treatment of SOx and NOx in coal combustion gas[9], and CO_2 disposal, where CO_2 emissions from large-scale sources such as power plants are separated and recovered efficiently for sequestration in the soil or oceans (see Figure 9)[9,10]. These technologies

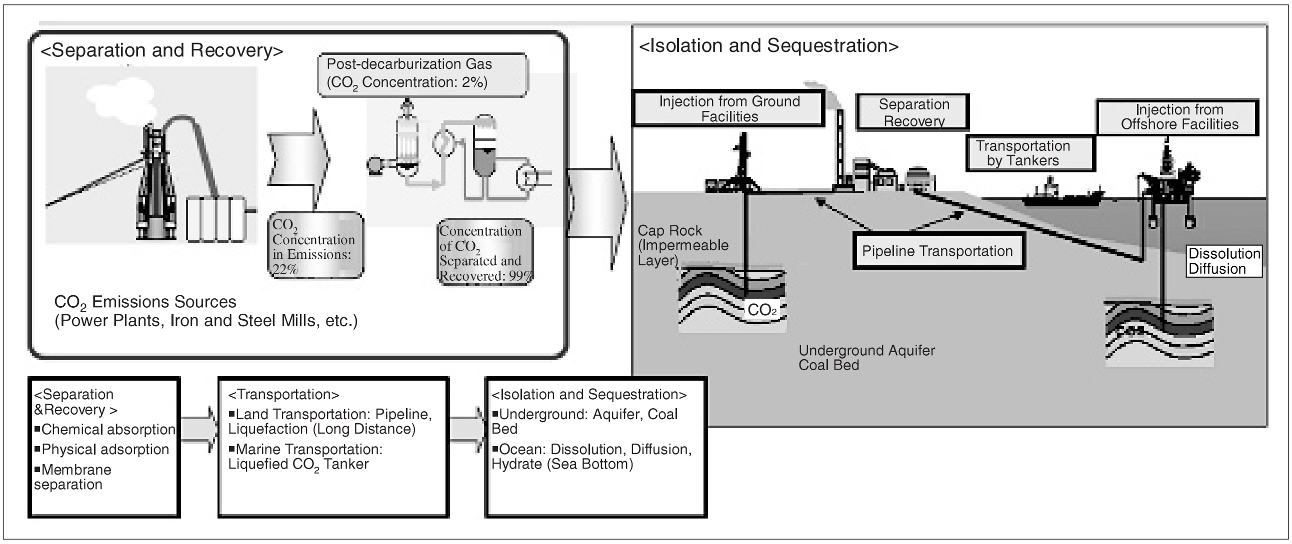
Figure 8 : CO_2 emissions per unit power generated



* The above figures are based on CO_2 emissions per unit energy produced (taking into account the combustion, production and transportation of fuels, according to a report released by the Institute of Energy Economics, Japan in May 1999) and the following respective net power generation efficiencies: Coal-fired, 40.1%; Oil-fired, 36.7%; LNG-fired, 41.9% (actual results in 2001 and power demand outlook in 2002, by METI). The power generation efficiency of IGCC is set at 53.0%, a target level.

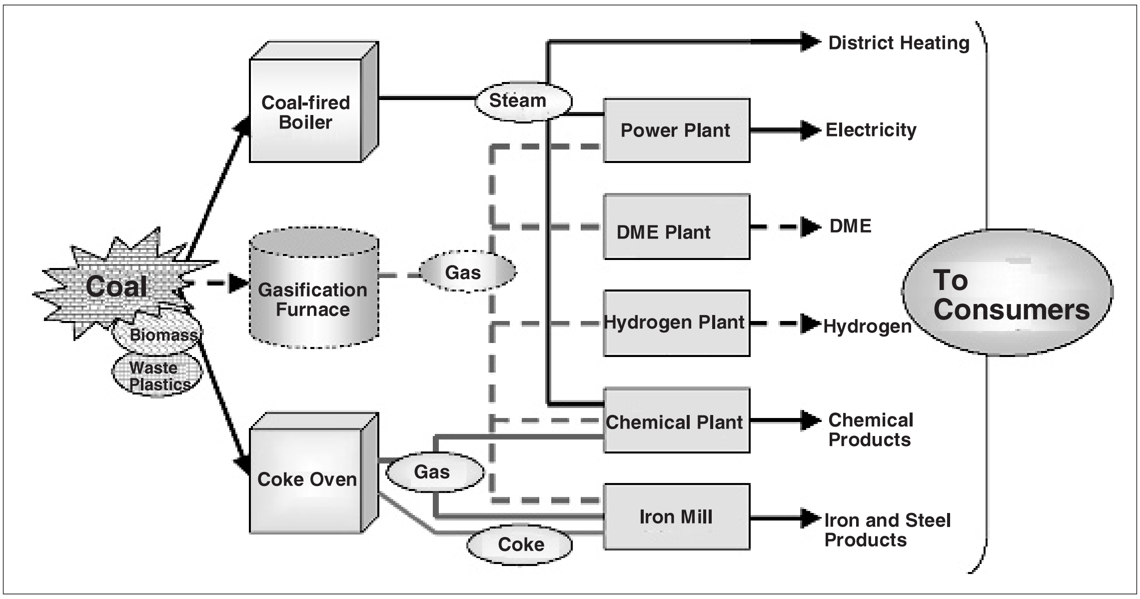
Source: References[8]

Figure 9 : Separation, recovery, isolation and sequestration of CO_2



Source: References[13]

Figure 10 : New energy and material production system based on coal gasification technology



Source: References[10]

are essential in curbing global warming over the medium and long term. Recovered CO_2 can be injected into oil wells to boost oil production (EOR: Enhanced Oil Recovery)[11].

At the same time, basic research is underway to inject recovered CO_2 into coal beds for carbon sequestration and recovery of a clean energy source: methane gas.

(3) Coal conversion technologies

Synthesis gas produced from coal is converted into high value-added materials and fuels such as chemical raw materials (methanol, ammonia, activated carbon, etc.), liquid fuels for automobiles, household fuels (dimethyl ether, etc. as substitutes for light oil, kerosene and LPG) and hydrogen. New energy and material production systems are expected to emerge from cooperation between various industries primarily in the field of coal gasification (see Figure 10). As for coal handling, development efforts are underway for CWM ("coal water mixture," where finely pulverized coal and water are mixed at a ratio of 7:3 to produce fluidized coal) and CCS (a "coal cartridge system," where finely pulverized coal is packed in cartridges for transportation purposes and coal ash is disposed of en masse). Both of these technologies are in the demonstration phase.

(4) Coal ash utilization technologies

It is also essential that coal ash produced by thermal power plants be utilized. Coal ash, for instance, is used for cement materials, roadbed materials and soil conditioners. Technologies that are expected to be in practical use include those for ultralight artificial aggregate production, fluidized bed boiler ash utilization, and activated fly ash production[13].

4 Research and development trends

Research and development trends in CCT in Japan, the U.S. and Europe can be summarized as follows:

4-1 Status in Japan

Table 1 shows an overview of the achievements of national coal utilization projects implemented so far[14], with reference to their categories, themes, development periods, outline, evaluation results and commercialization status. A total of some ¥360 billion has been invested in these projects.

In the field of thermal efficiency improvement, a number of technologies such as pressurized fluidized bed combustion combined cycle (PFBC) and ultra super critical pulverized coal-fired power generation have been commercialized. In particular, Japan is far ahead of the U.S. and Europe in expanding the capacity of power plants. Coal partial combustion technology was also established through a series of pilot projects, though the declining needs for this technology resulted in a shift to pressurized pulverized coal partial combustion technology that can be combined with IGCC.

Based on the iron-making technologies introduced from the U.S., an advanced process unique to Japan was developed, where a large quantity of powdered coal is blown into a blast furnace through the tuyere. This particular process is in use at all the blast furnaces in Japan. Currently, 130-140kg of coal is used to produce one ton of pig iron, one of the highest levels in the world.

Flue gas treatment technologies contributing to environmental improvement - (i) desulfurization and denitration systems for coal-fired boilers, (ii) a dry-type simultaneous desulfurization and denitration system using activated coke and (iii) a high-performance dust removal system - have all been commercialized in Japan, which leads the world in commercial applications of these systems. In 1991, for instance, SOx, NOx and particle emissions in Japan were reduced to only one-tenth the levels required by the standards in the U.S. and Europe. The most stringent emission standards in place are the ones adopted by the Hekinan thermal power plant of Chubu Electric Power: 25ppm for SOx, 15ppm for NOx and 5mg/Nm^3 for particles.

As for coal conversion, particularly coal gasification, the fluidized bed gasification process was originally being developed to produce low Btu gas for IGCC - which later gave way to the entrained bed gasification process to accommodate a variety of coal. In 1995, a trial project using a 200-ton/day pilot plant was completed for the latter process, while a new project for the construction and operation of a 250MW IGCC demonstration plant is underway. Although Japan lags behind the U.S and Europe in the field of coal gasification power generation, with little accumulated technology available, a project is in progress to test-run a 150-ton/day pilot plant for two-stage entrained bed gasification with the aim of commercializing a triple-cycle power generation system using a fuel cell, gas turbine and steam turbine. High-Btu gas production technologies such as hybrid gasification and hydrogasification have yet to be commercialized because of their poor cost effectiveness. With respect to coal liquefaction, pilot plants were set up for bituminous and brown coal in the framework of the Sunshine Project. Japan's level of technology in this area is on par with international standards, but coal liquefaction is nowhere near commercialization.

On the other hand, coal ash utilization technologies are in practice in the fields of civil engineering, construction and agriculture, being used for hardening agents, earthwork materials, Pozotech, artificial lightweight aggregates, etc.

An IGCC demonstration project (slated to launch test operations in 2008 and be adopted by the Misumi power plant of the Chugoku Electric Power in 2014 or later) and IGFC technological development are expected to boost Japan's CCT development. Also promising are hydrogen production from coal involving CO_2 recovery and a high-efficiency power generation system using hyper coal.

4-2 Status in the U.S.

Originally, CCT demonstration projects in the U.S. were designed to address the acid rain problem between the U.S. and Canada back in 1985. In an effort to commercialize CCT as early as in 2005 through test runs of demonstration plants, development efforts are underway in the following areas (Of 38 demonstration projects, 29 projects were completed before 2001, while a total of US$5.7 billion had been invested as of 1998):

- Advanced power generation technologies: PFBC, IGCC, A-PFBC, etc.
- Environmental improvement technologies: SOx/NOx reduction technologies
- Coal processing: coal conversion, liquid fuel production, etc.
- Industrial technologies: iron manufacturing, etc.

Early-stage programs in the 1980s focused on

Table 1 : Achievements of national coal utilization projects

Category		Theme	Development Period	Outline	Evaluation	Commercialization
(1) Improvement of Thermal Efficiency	Combustion	Pressurized Fluidized Bed Combustion Combined Cycle (PFBC)	1988s-1999	71MW-electricity demonstration project (Wakamatsu)	Commercial plants are operating in Tomatoh-atsuma (Hokkaido Electric Power), Karia (Kyushu Electric Power) and Osaki (Chubu Electric Power), producing a total of 670MW and with another plant in the pipeline. Suitable for medium-scale power plants.	○
		Ultra Super Critical Pulverized Coal-fired Power Generation (USC)		Steam conditions of steam turbines: 600/610°C, 25Mpa	Commercial plants are operating at eight power plants, producing a total of 7,100MW. Two more plants are in the pipeline (2,000MW in total). A net power generation efficiency of 41% has been achieved. Development efforts are underway in Europe, targeting 700°C or higher.	○
		Pressurized Circulating Fluidized Bed Boiler	1992-1994	A technical survey and trial design	On hold in the trial-design phase.	×
		Coal Partial Combustion Furnace	1984-1999	Shift from constant pressure to pressurization; introduction of a pressurized IGCC system (25 t/day at a pilot plant)	The technology has been developed through a pressurized pilot plant for applications for medium- to small-scale direct coal-fired combined cycle plants-which are on hold in a trial phase.	×
	Iron Manufacturing	Pulverized Coal Injection for Blast Furnace	-1976	Developed by each iron-manufacturing company	Already commercialized.	○
		Direct Iron Ore Smelting Reduction (DIOS)	1988-1995	500 t/day at a pilot plant	The technology has been developed for pilot plants, while a commercialization plan is underway to reduce CO_2 emissions.	×
	Industrial Furnace	Coal-based Metal Smelting System	1993-1997	1-5 t/day at a basic plant	The technology has been developed for basic plants, though a commercialization plan has been abandoned due to changes in the economic situation.	×
(2) Improvement of the Environment	Desulfurization	Activated Carbon Method	1975-1982	Desulfurization efficiency: 95%	Already commercialized.	○
	Denitration	Selective Catalytic Reduction Process	1979-1980	Denitration efficiency: 80%	Already commercialized.	○
	Desulfurization and Denitration	Activated Coke Method	1979-1981	Desulfurization efficiency: 97%, Denitration efficiency: 80%	Already commercialized.	○
	Dust Removal	High-temperature Dust Removal	1989-1995	Ceramic filter (less than 1 mg/Nm^3)	Adopted by Unit 3 of the Tomatoh-atsuma plant of Hokkaido Electric Power.	○
(2) Improvement of the Environment	Gasification	Entrained Flow Gasification	1991-1996	Production of low-Btu gas for IGCC (200 t/day at a pilot plant in Nakoso)	The technology has been developed for pilot plants, with a 250MW demonstration unit for IGCC scheduled to start operating in 2007.	○
		Hybrid Gasification	1974-1986	Production of high-Btu gas using coal and heavy oil (7,000 m^3/day at a pilot plant in Tokiwa)	The technology has been developed for pilot plants, but demonstration plants are not economically viable.	×
		Coal Gasification with Hydrogen Injection	1996-2000	Production of high-Btu gas with hydrogen injection	Elementary technologies have been developed, but the construction of pilot plants depends on future economic conditions.	×
	Liquefaction	Bituminous Coal Liquefaction	1974-1999	NEDOL method (150 t/day at a pilot plant)	The technology has been developed for pilot plants, but a plan for demonstration plants is on hold for economic reasons.	×
		Brown Coal Liquefaction	1981-1993	Joint development with Australia (50 t/day at a pilot plant)	The technology has been developed for pilot plants, while brown coal was replaced by bituminous coal for economic reasons.	×
	Fluidization	Coal Water Mixture (CWM)	1980-1995	Decalcified CWM for power generation and other industrial processes, distribution transit (from China to Japan)	The technology has been commercialized for both power and other industrial plants, though a fuel shift is currently tabled due to changes in the economic situation (at the Tokiwa joint thermal power plant).	○
		Low-grade Coal Water Mixture	1991-1995	Production of CWM from brown coal, based on the hot dewatering method	A feasibility study conducted in Indonesia suggested poor cost efficiency; commercialization depends on future economic conditions.	×
	Handling	Coal Cartridge System (CCS)	1982-1987 1990-1995	5 t/h, 25 t/h	A CCS center is operating in Chita City (200,000 t/y) for Nisshinbo Industries and Nichiha.	○
		Low-grade Coal Utilization	1977-1997	Dehydration and modification of brown coal	The technology has been developed for pilot plants; commercialization depends on future economic conditions.	×
(4) Coal Ash	Utilization Technology	Applications for Engineering and Construction Works	1980-	Hardened materials, earthwork materials, civil engineering materials (Pozotech), Artificial aggregate, etc.	Pozotech is already on the market, while full-scale demonstration projects are underway for artificial aggregates, fluidized bed ash solidification, etc.	○

Source: Author's compilation based on Reference [14] demonstrating SOx/NOx reduction technologies, followed by research on IGCC and other high-efficiency power generation technologies. CCT demonstration programs in the U.S. are unique in that they are designed for similar technologies, which together contribute to improving US competitiveness in this particular area. In addition, there have been extensive efforts in transferring US proprietary CCT to developing countries. President Bush announced in 2002 that a total of US$2 billion would be appropriated to a 10-year program dubbed the "Clean Coal Initiative."

In 2000, meanwhile, "Vision 21" was mapped out to pursue high-efficiency power generation towards 2015, with elementary research launched for 27 themes, of which 12 themes are concerned with CO_2 sequestration. Typical themes are as follows:

- Zero emission facilities designed to coproduce electricity, fuel and chemicals
- Ultra-low SOx/NOx emissions
- Reduction or sequestration of CO_2
- Modules designed to coproduce hydrogen, clean transportable fuels and chemical fuels

DOE came up with the "Coal and Power Program"to meet domestic energy demand, presenting three major themes - i.e., power generation systems, carbon sequestration and advanced clean fuels. Six national initiatives including "Clean Coal Initiative" and "Vision 21" are in progress to put the program into practice.

4-3 Status in Europe

In Europe, the EU laid out a framework program to strategically promote R&D efforts on an EC-wide basis, taking into account the common interest of the member countries. This program has been in place since 1984, with the fourth and the fifth phases implemented in 1994-1998 and 1999-2002, respectively; the sixth phase (2003-2006) is being implemented.

Development efforts related to CCT are in progress through the fifth-phase framework programs (energy-related programs such as "ENERGIE") as well as through the fourth-phase framework programs ("JOULE" and "THERMIE"). The former include the following activities:

- Demonstration of a 335MW IGCC plant of ELCOGAS (a continuous program in Puerto Llano, Spain): coal and petroleum coke are gasified in an entrained bed gasification furnace, into which limestone is charged to lower the melting point of ash.
- Demonstration of an advanced pulverized coal-fired power generation system (a continuous program in which 40 companies participate): a total of 40 companies including power companies and manufacturers will jointly develop metal materials to operate pulverized coal-fired boilers at temperatures above 700˚C.
- Demonstration of cogeneration through a 71MW PFBC power plant using brown coal (Cottbus, Germany): a PFBC boiler (12bar) produces both heat and electricity, using brown coal.
- Co-combustion of coal and biomass fuel (Austria): coal and biomass fuel are burned together in a pulverized coal-fired boiler to reduce CO_2 emissions (3-5% of coal is replaced with biomass fuel).

The sixth-phase program aims to develop (i) emission-free high-efficiency power generation systems, (ii) environmental measures such as CO_2 sequestration, and (iii) ecosystems, while emphasis is placed on measures to reduce CO_2 emissions, ensure energy security and promote renewable energy sources. At the same time, technologies for the use of biomass and other waste materials and for the co-combustion of coal and biomass fuel are being developed. Technology transfer to developing countries is also a priority issue. The EU has attached great importance to energy security ever since September 11, 2001, when the simultaneous terrorist attacks took place in the U.S. It is thus beginning to place a premium on the use of renewable energy sources and coal (including brown coal) produced in Europe to develop emission-free high-efficiency power generation systems.

4-4 Status in China

In its 10th Five-year Plan (2001-2005), the Chinese government is pushing ahead with science and technology research projects ("973 Plan," "863 Plan" and "2010 Target") in a bid to develop and promote energy-related technologies[15]. As for CCT, R&D is underway primarily in the fields of coal liquefaction, coal gasification, IGCC and eco-friendly coal utilization systems, all based on overseas technologies.

4-5 Comparison of competitiveness between Japan, the U.S. and Europe

Table 2 shows the competitiveness of CCT in Japan, the U.S. and Europe, based on the above-mentioned trends in CCT and Reference 11.

Although Japan is leading in combustion control, PFBC and the use of industrial coal for iron production - each of which contributes to improving thermal efficiency - it lags behind its Western counterparts in IGCC, with little accumulated technology available in this area.

In the field of environmental improvement, Japan has the world's most advanced technologies for desulfurization and denitration, while the U.S. and Europe have a competitive edge in commercial technologies for the isolation, recovery and sequestration of CO_2, as well as in coal gasification, fluidization and synthetic fuel production. DME production, however, is one of Japan's specialties. As for fuel production through indirect coal liquefaction, SASOL (South Africa) is a world leader - an advantage brought about by South Africa's historical background, where oil was inaccessible. The basis of direct coal liquefaction technology has been established in Japan, the U.S. and Europe through a series of pilot projects, but it is far from commercialization because of its poor cost effectiveness.

The U.S. and Europe place a premium on high-efficiency IGCC and the isolation, recovery and sequestration of CO_2, in which they have a competitive edge. Japan also needs to commercialize coal gasification technology and IGCC as part of a total system in order to dramatically improve the efficiency of coal-fired

Table 2 : Competitiveness of clean coal technologies in Japan, Europe and the U.S. (technological resources and operating cost)

Category		Japan	U.S.	Europe	Others
(1) Improvement of Thermal Efficiency	Ultra Super Critical Pulverized Coal-fired Power Generation	○			
	Pressurized Fluidized Bed Combustion Combined Cycle	○			
	Integrated Coal Gasification Combined Cycle		○	○	
	Use of Industrial Coal	○			
(2) Improvement of the Environment	Desulfurization	○			
	Denitration	○			
	Dust Collection	○	○	○	
	CO_2 Sequestration		○	○	
(3) Coal Modification	Gasification		○ Small Scale	○ Large Scale	
	Liquefaction	Suspended	Suspended	Suspended	
	Fluidization		○ CWM, Coal Water Mine		
	Synthetic Fuel	○ (DME Production)	○ (Alcohol and DME Production)		○ (Coal Indirect Liquefaction by SASOL- Republic of South Africa)
(4) Coal Basic Technology		○		○	

○ : Competitive, DME: Dimenthyl Ether

Soruce: Author's compilation based on References[10, 14] power generation. In addition it is essential that a power generation process recovering CO_2 and technologies for CO_2 sequestration be developed domestically.

5 Future challenges and recommendations on policies

5-1 Future challenges

Coal continues to be an important source of primary energy in Japan as well as in the rest of the world. As mentioned in Chapter 3 and 4, the following issues should be addressed to promote the eco-friendly use of coal[16].

(i)Energy efficiency improvement and CO_2 reduction to curb global warming

- Coal-based power generation systems with higher efficiency, and low-cost CO_2 reduction measures
- Mergers between industries to dramatically improve energy efficiency (focusing on coproduction of energy and chemical raw materials from coal)
- High-efficiency hydrogen production from coal, and low-cost CO_2 recovery and sequestration
- CO_2 reduction through the use of coal with biomass and other waste materials

(ii) Measures to reduce the environmental load caused by coal combustion

- Disposal and utilization of coal ash - a product of coal combustion
- Advanced, cost-effective flue gas treatment technologies for removing NOx, SOx and particles

(iii) International cooperation

- Technology transfer to Asian countries to contribute to conserving the regional environment
- Application of the Kyoto Mechanism*1, particularly the Clean Development Mechanism (CDM)*2

(iv)Measures to ensure the security of the coal supply

- Coalmine development and transportation infrastructure improvement in coal-producing countries[5]
- Information sharing between coal producers and consumers regarding the prospects for supply and demand
- Conversion and utilization of low-grade coal

5-2 Recommendations on policies

In view of the challenges mentioned above, the following are recommended to promote the development of eco-friendly coal utilization technology:

(1)Development, commercialization and cost-reduction of CCT, based on coal gasification

Eco-friendly CCT contributes to reducing the environmental load caused by coal combustion - the major challenge faced by coal. An adequate budget should thus be provided for the following initiatives, in which the government is expected to play a leading role:

(i) Develop a cost-effective power generation system by 2010, based on coal gasification technology, while improving its reliability and power generation efficiency. Promote coal ash utilization technology.

(ii) Further improve the power generation efficiency by 2015 through combined cycle power generation technology comprised of coal gasification power generation and fuel cells.

(iii) Reduce greenhouse gas emissions by 2020 through the separation, recovery and sequestration of CO_2.

Initiative (i) and (ii) should be conducted as a national project, based on a partnership between industry, government and academia. In particular, Initiative (ii) should incorporate an evaluation program with specific targets for achievements (period, performance and cost), while introducing a project that involves strict interim assessments of technological development in accordance with a roadmap for commercialization - a means to fill the gap between state-of-the-art coal gasification technology and commercial technologies.

In addition, it is essential that the coal product ion/transportation infrastructure be improved in coal-producing countries to ensure the security of the coal supply. In this context, the following approaches are recommended:

(2) Security of coal supply

It is necessary to further develop coalmines and improve the production/transportation infrastructure in coal producing countries by conducting extensive surveys of their status and mobilizing financial resources so that the main advantage of coal - low and stable prices - can be exploited over the medium and long term. In addition, the trade and investment climate in coal-producing countries should be improved through bilateral dialogue to facilitate financing.

On the other hand, a national initiative should be set up and promoted to develop technologies for converting Asia's low-grade coal into high-grade coal - a means to ease the shortage of high-grade coal, which constitutes the majority of coal consumed in Japan.

Japan is expected to play a leading role in organizing and managing the "Asia Coal Forum" (provisional name) in cooperation with APEC and ASEAN+3 (Japan, China and Korea) to share and exchange information regarding the prospects for the Asian coal market and CCT promotional measures.

It is also essential that human resources specializing in CCT be developed if eco-friendly coal-based power generation is to supply some 20% of primary energy over the next few decades. To this end, the following approaches are recommended:

(3) Medium- and long-term human resource development

Medium- and long-term support measures should be in place at universities or graduate schools (e.g., designation of one university per nine regions) to develop human resources in CCT: interdisciplinary educational programs. With regard to such programs designed for graduate schools, internship training should be provided by future employers (companies engaged in CCT) so that students can learn expertise in commercializing technological achievements. Universities and graduate schools are expected to foster human resources specializing in advanced CCT and coal science, who can present new ideas and understand their technical viability. Companies, meanwhile, should develop better OJT programs to further strengthen the international competitiveness of Japan's CCT resources.

6 Conclusion

While energy consumption in the world, particularly in Asia, is expected to increase further, cost competitiveness, the security of supply and environmental measures are decisive factors for the international energy market in selecting energy sources.

The advantages of coal, as history shows, lie in its cost competitiveness and widespread distribution. With concerns growing over global warming, however, it is increasingly important to reduce the relatively high environmental load caused by coal combustion - which translates into the growing need to develop eco-friendly CCT and take proactive measures to ensure the security of the coal supply. This article summarizes the situation of coal supply and demand, CCT and its development trends (in Japan, the U.S. and Europe), and challenges in utilizing coal in Japan.

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Notes

*1 The Kyoto Mechanism is a flexible approach adopted in the Kyoto Protocol to help "Annex I countries" (industrialized countries obliged to reduce their greenhouse gas emissions in compliance with the protocol) achieve their reduction targets for greenhouse gas emissions. This international cooperative framework is comprised of (1) Joint Implementation, (2) Clean Development Mechanism, and (3) International Emission Trading.

*2 The Clean Development Mechanism is a system in which "Annex I countries" jointly implement greenhouse gas reduction projects in newly industrializing or developing countries, thereby earning emission credits arising from those projects. Project investments by "Annex I countries" are expected to benefit host countries through technological transfer and the promotion of environmental conservation measures.

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8

Research Trends in Space Environment Observation and Fluctuation Monitoring

TERUHISA TSUJINO
General Unit

1 Introduction

The extent of human activities has evolved starting from self-sufficient small communities to nations, and further, to a global level. Today is an age where the development and utilization of space is gaining momentum. As this development proceeds, it has become increasingly clear that the extraterrestrial space environment such as solar activity, the magnetosphere of the earth, space objects, etc. is very much concerned with our existence and our activities on the surface of the earth.

This article introduces trends in recent research on space weather, space debris and Near Earth Asteroids (NEAs), which are typical objectives of observation to gain information on the space environment surrounding the earth. Based on these objectives, I also present some proposals for the guiding policies required for future space exploration.

2 Space weather

2-1 Space weather and its forecasting

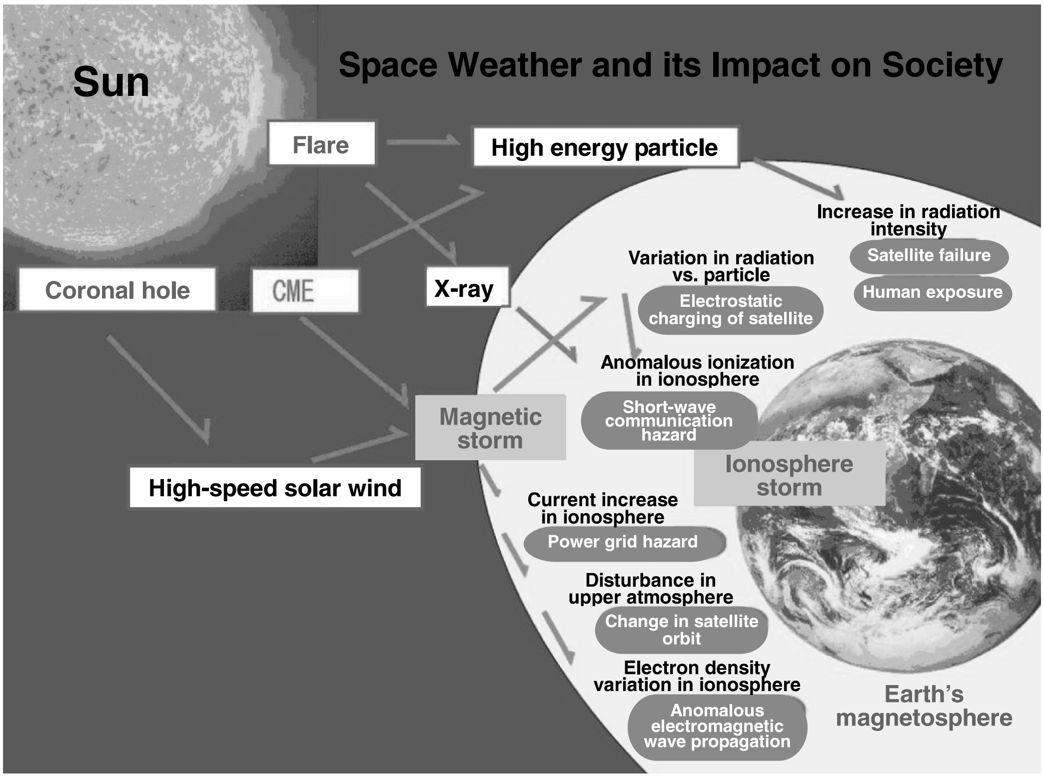
"Space weather" collectively represents fluctuation in environmental factors, including cosmic radiation and electromagnetic plasma that occur in space ranging from the electromagnetic sphere to the atmosphere. These factors naturally affect development activities in space, just as the wind and rain affect our lives on earth, hence the term "space weather."

Beginning October 23 of 2003, one of the largest sunspots ever known appeared on the surface of the sun, producing a series of enormous explosions (called "flares"), and the earth suffered serious geomagnetic storms. The National Oceanic and Atmospheric Administration (NOAA) issued warnings against the failure/malfunction of: commu nication/broadcasting systems, electronics devices, satellites, and systems using GPSs (global-positioning systems) such as car navigation systems. Solar wind shock waves reached the earth's magnetosphere interface at 15:25 (GMT) of October 24 and, about 15 minutes later, triggered the creation of one of the most extensive aurora in the polar regions. The observed magnetic field fluctuation during this period was as wide as 2,000 nT (nanoTesla). (The normal intensity of terrestrial magnetism in the polar regions is around 50,000 nT, and fluctuation caused by aurora is usually around 500 nT.)

The mechanism that produces these phenomena is generally understood to be the interaction between solar activity and the earth's magnetosphere as depicted in figure 1. We have gained a fairly good understanding of the mechanism that drives changes in space weather. In addition, the global deployment of ground observation equipments has enabled the accumulation of necessary data. These aspects have enabled us to some extent to forecast environmental fluctuation in space, or to give "space weather forecasting". Globally linked efforts for better forecasting have already begun.

One of the most important aspects of space weather forecasting is to secure satellite operation in orbit. The measures that have hitherto been implemented in Japan and other countries include: (i) activation of safe-mode satellite operation (shutdown of lower-priority

Figure 1 : Concept of Space Weather



devices, etc.); (ii) evacuation of astronauts to safer places in the spaceship; (iii) temporary postponement of launching; (iv) changing solar panel orientation; and (v) temporary shutdown of communication and observation tasks. More timely and appropriate measures will be enabled through improving accuracy of space weather forecasting and providing closely linked information systems.

2-2 Space weather observation

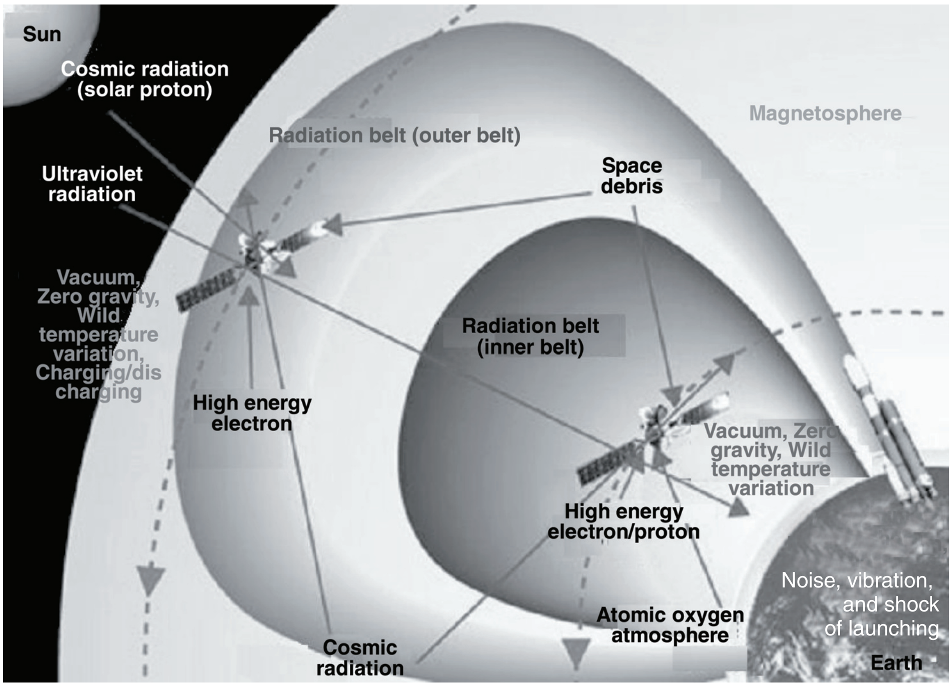
Explosions on the surface of the sun produce an enormous amount of high-energy charged particles, radiation, and gigantic plasma clouds into space, a portion of which are approaching the earth. Lives on the earth are protected from these threats by the atmosphere and the magnetic field produced by the earth (the earth's magnetism) since the earth itself is a huge magnet. The region of space surrounding the earth in which the earth's magnetism has strong influence is called "geospace" In particular, the area beginning from the transition area in which the neutral atmosphere gradually changes into ionized gas (altitude ≤80km) and further, into the magnetosphere filled with magnetic plasma (up to 70,000km), has a strong influence on human activity on the surface of the earth.

(1) Observation of space radiation environment

As shown in Figure 2, there is a radiation belt in the geospace region, consisting of an outer and an inner belt, and is called the "Van Allen Belt." The mechanism of the formation of and fluctuation in this belt requires systematic study including that on the underlying dynamics of the magnetosphere and the physics of particle acceleration. Space radiation, especially the abnormally intense radiation associated with explosions on the surface of the sun, can cause space ships to malfunction. Disabled space ships are destined to become space debris.

Various countries have launched satellites to measure the space radiation environment. The geostationary astronomic observation satellite, HIPPARCOS, launched by the European Space Agency (ESA) in 1989 after successfully entering transfer orbit, but failed to enter geostationary orbit due to apogee kick motor malfunction. This failure accidentally forced the satellite to pass through the Van Allen Belt at high frequency, bringing an unexpected wealth of information related to the space radiation environment. In Japan, the MDS-1 satellite was launched to intentionally remain in geostationary transfer

Figure 2 : Radiation Environment and Cosmic Ray Hazards in Space



Source:Provided by NICT

orbit to collect radiation-tolerance data on consumer electronic devices.

To gather information on the effects of fluctuation in the radiation environment of satellites, it is desirable for many satellites with different orbits to be installed with radiation-measuring equipment. The development of smaller and lighter sensors that can be mounted on various satellites for other missions and the launch of as many satellites as possible are effective methods of achieving this objective.

The major energy ranges for future investigation include the 0.01-20 MeV range for electrons and the 0.1-500 MeV range for protons.

(2) Observation of the magnetoplasma environment

The magnetoplasma atmosphere produces eddy currents in mid-latitude regions on the earth as well as three-dimensional currents flowing along the line of magnetic force. Fluctuation in these currents causes fluctuation in the earth's magnetism and, in high-latitude regions, gives rise to aurora. Thus, accumulating data on the global magnetism of the earth will provide, using proper inverse-transformation techniques, the possibility of forecasting fluctuation in the magnetoplasma environment in the ionosphere 100km above the earth's surface.

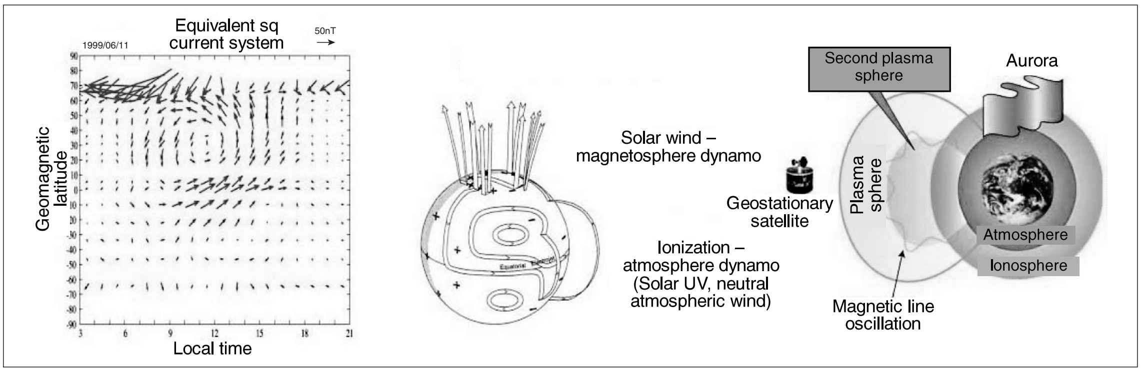
A project is in progress at Kyushu University in which MAGDAS (Magnetism Data Acquisition System) is being deployed at 54 observation points in Pacific Rim regions to transfer global magnetism data to the university for real-time analysis. The data are used to make imaging in the three-dimensional current system in the vicinity of geospace and to monitor the atmospheric plasma environment.

A pair of magnetism observation points is assigned to each location. The gradient method is used to measure plasma density parallel to the line of magnetism passing through the center of the two points.

(3) Observation of the earth's magnetism

The earth's magnetism provides the earth with effective protection against the harsh environment of space. It changes not only in the short term, for example, on a daily or monthly basis, but also in very long term; we know that the direction of the earth's magnetism inverted around 700,000 years ago, and comparison with data of several hundred years ago reveals that the earth's magnetic pole has drifted. The coming millennium, beginning with the 21st century, will witness expanding human activity in space on the one hand, and the global weakening of the earth's magnetism on the other. There are a

Figure 3 : Magnetic Field Observation in Geospace from Geomagnetism Variation Data Using the MAGDAS System

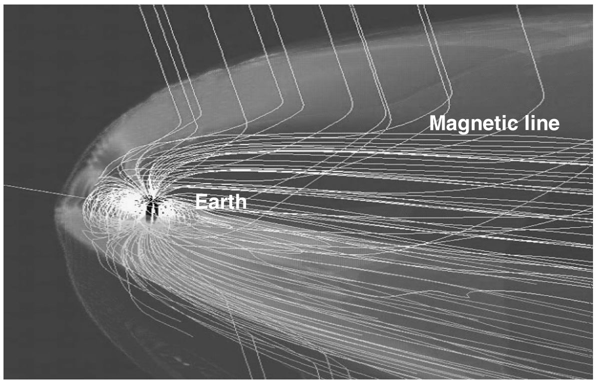


Left Equivalent current flow pattern in the ionosphere (100 km above the ground) estimated from collected magnetic field data.
Center Estimated global three-dimensional current system in geospace (Richmond, 1998)
Right Plasma density distribution in near space: estimated from magnetic line oscillation.

Source: Provided by Kyushu University

number of concerns about the latter, including: exposure of the human body to cosmic rays and charged particle flux from the sun, electric wave hindrance, satellite failure due to cosmic ray exposure, and power grid shorts in high-latitude regions. An anomalous decrease in the earth's magnetism has already been reported in Brazil, and adverse effects on the earth's environment and the earth's inhabitants due to the abnormally high intensity of cosmic ray fallout in these areas are appearing.

Figure 4 : Example of Magnetosphere-ionosphere Global Simulation



Source:Provided by NICT

2-3 Trends in numerical simulation

The ever-increasing performance of computers and their decreasing price have enabled the application of numerical simulations in various aspects of physical phenomena. In the area of space environment, numerical simulations have achieved to understand a systematic, global view of such phenomena as electromagnetic energy transport processes in response to the solar wind fluctuation taking place in a complex system including the ionosphere, and the dynamic characteristics of the linked system consisting of the magnetosphere and the ionosphere. This will be an essential tool for studying the complex system consisting of the magnetosphere and the ionosphere, which is required for space weather forecasting. Further refinement of programs and numerical simulation models are required.

In addition to magneto-ionosphere-linked models that simulate the motion of charged particles using fluid dynamics approximation, direct trajectory calculation for each charged particle on a global scale has also become a reality thanks to modern techniques of numerical calculation and huge computer power. Global simulation using this methodology has provided us with a mutually consistent understanding between magnetosphere-ionosphere perturbations, fluctuation in convection, and particle effects (See Figure 4).

2-4 Global trends for space weather forecasting

(1) International space weather observation project

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) has urged its member countries to cooperate in studies to minimize the adverse effects of cosmic radiation and charged particles from the sun. These studies include forecasting space environment fluctuation and evaluating its effect on the environment on the earth that supports human activity.

Beginning in 2004, SCOSTEP launched a new international observation study project called the Climate And Weather of the Sun-Earth System (CAWSES). Many countries including U.S.A., Russia, European countries and Japan are now preparing concerted research into space weather observation and forecasting.

In U.S.A., a space weather forecast simulation system will be developed starting in 2004. The five-year project sponsored by the National Science Foundation (NSF) will be led by Boston University[1].

Spaceship malfunctions are thought to be induced mainly by abnormal increases in radiation and re-creation of / fluctuation of the radiation belt. New theories, such as high-energy particle acceleration by ultra-low frequency waves (ULF), have been proposed for a consistent explanation of this phenomenon by the University of California (UCLA) and the British Antarctic Survey (BAS).

In Japan, tasks will be allocated to multiple research institutes according to the feature of the task and the organization, and each institute will bear the responsibility of providing observation data in that particular research area. The research institutes participating in the project include: National Institute of Information and Communications Technology (NICT)[2], Japan Aerospace eXploration Agency (JAXA)[3], Metrological Agency Magnetic Observatory[4], Tokyo University[5], Nagoya University[6], Kyoto University[7], and Kyushu University[8]. A systematic, closely linked observation research network will be constructed to effectively contribute to the global effort.

(2) Major observation systems in Japan

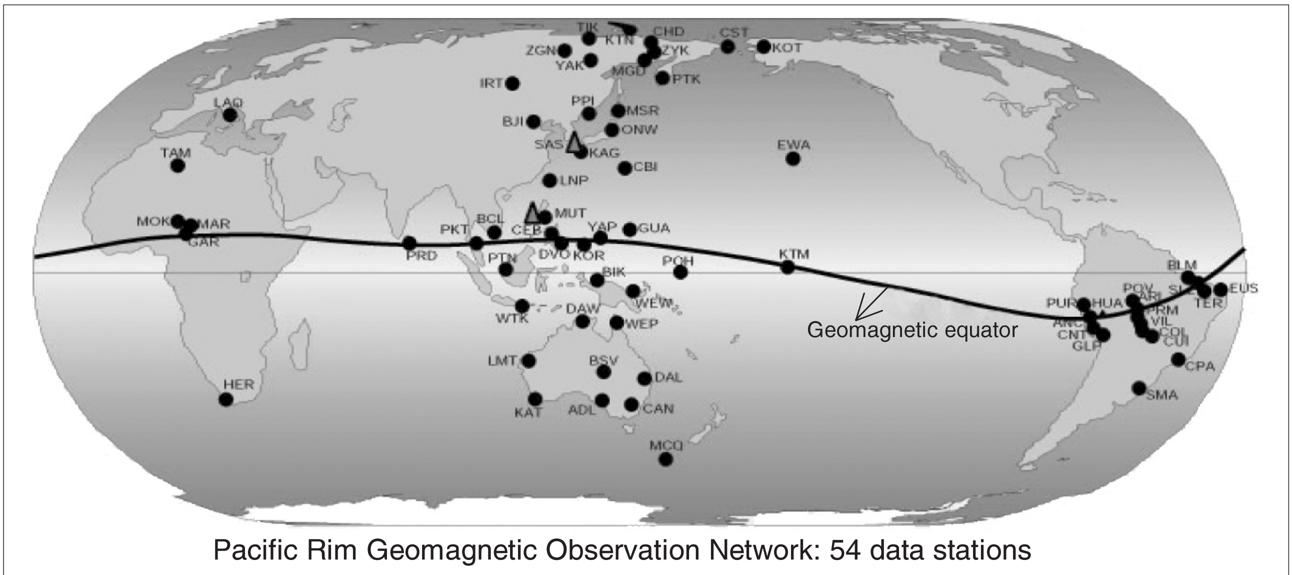
In Japan, Kyushu University led an international research project in collaboration with the Far Eastern area of Russia and developing countries in the equatorial region in the duration of 1991-2003 to construct the Pacific Rim geomagnetism observation network (see Figure 5).

Global networks such as this one are instrumental in enabling the three-dimensional imaging of current systems in geospace around the earth. Existing systems, however, cannot provide sufficient spacial resolution. To enhance system performance, the following challenges must be addressed:

i) A sufficient number of geomagnetism observation pairs and ionosphere observation radar networks must be installed to image the three-dimensional current system and to monitor the atmospheric plasma system. A high-capacity data-processing system is also required for the real-time analysis of these data.

ii) An imaging system to visualize the electromagnetic environment in geospace

Figure 5 : Pacific-rim Geomagnetism Observation Network



Source: Provided by Kyushu University

must be developed. It will continuously visualize the fluctuating three-dimensional current system, thus serving for the real-time monitoring of the electromagnetic environment in geospace. The remote sensing of high-energy plasma particle distribution in space near the surface of the earth, which is inaccessible from satellites, will also be covered by this system.

iii) A system capable of monitoring interactions between geospace and the ionosphere must be installed by comparing data obtained from the multiple point observation data of plasma density in the ionosphere. Exact-time information is essential to activate the system. Although GPS ground receiving stations have been distributed over a number of areas around the world, additional effort is still required to fill the still vacant areas.

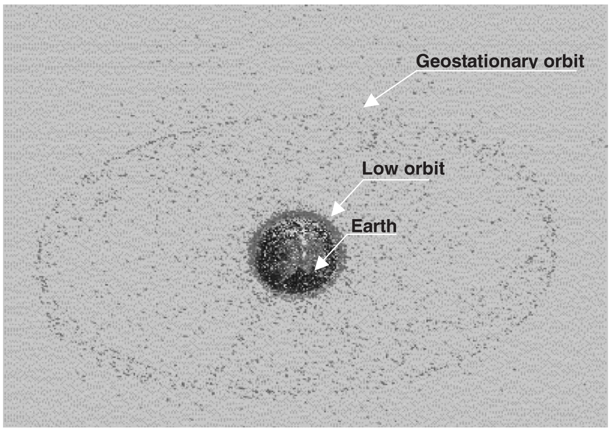
Advancement of “space weather” research will enable more accurate, real-time “space weather forecasting.” To achieve this, the well-organized combination of a number of factors are required including: the compilation of the past results of global electromagnetism research conducted in various countries over many years, the continual accumulation of observation data, and the introduction of innovative simulation techniques to handle complex systems.

3 Space debris

3-1 What are space debris?

Since the beginning of space exploitation activities, innumerable rockets and satellites launched into space, and the remains of upper stages of rockets and decommissioned satellites have finally become rubbish in space, or space debris. As shown in Figure 6, the distribution of space debris is concentrated in lower earth orbit, but it also extends into middle and geostationary orbit and even into its exterior. Low orbit satellites (altitude ≤1,000km) that have been abandoned due to unexpected accidents, or that have been decommissioned after completing their tasks, are still orbiting as space debris around the earth at a speed of about 7km per second.

Figure 6 : Distribution of Minute Space Debris



Source: Provided by Kyushu University

Collision with these pieces of debris seriously damages satellites and the international space station, and is also considered to constitute a grave threat to astronauts performing tasks outside the spaceship.

Space debris orbiting the earth at an altitude of higher than 1,000km has little chance of falling to the earth. Lower-orbit debris at an altitude of higher than 600km circles the earth for 20 years before it falls. Without implementing effective measures, continuing conventional space development plans will simply increase the amount of space debris. Promoting fundamental research into methods for the observation, mitigation, removal, and reduction of space debris is becoming increasingly urgent.

3-2 Threat of space debris

In recent years, examination conducted on recovered satellites and the windows of space shuttles after returning from missions has revealed numerous traces of collisions, indicating that space contamination by numerous pieces of minute pieces of space debris (sub-millimeters in diameter) is even worse than we previously estimated. Ground observation stations cannot detect these tiny pieces of debris. They are generally produced by the explosion of satellites in orbit at the last stage of rocket launch. Although very tiny, a piece of space debris orbiting at a speed of 7km/sec is capable of exerting an enormous impact (Collision with a 1-cm-diameter piece of space debris at low altitude is roughly equivalent to a collision between two cars running at 60km/hr). Collision with a satellite in operation could be fatal. A greater-than-1-mm-diameter piece of space debris is a threat to astronauts during extravehicular activities, and a piece of debris greater than 1cm could cause serious damage to an international space station.

The proliferation of space debris will be a serious hindrance to future space activities. How to avoid this problem is a major theme on the space development projects.

3-3 Observation of space debris

Large pieces of space debris (diameter >= 10 cm) in lower orbit can be tracked from ground radar stations and have been catalogued in a database. Their trajectories in orbit can be affected by external forces, or perturbation, such as air drag and gravitational pull from the sun and moon, and thus need constant tracking and data update in the trajectory database. Recently, size distribution information of relatively small pieces of space debris has been obtained from surface inspection conducted on several satellites recovered from lower orbits (See Figure 7). These satellites include LDEF (U.S.A), EURECA (Europe) and SFU (Japan).

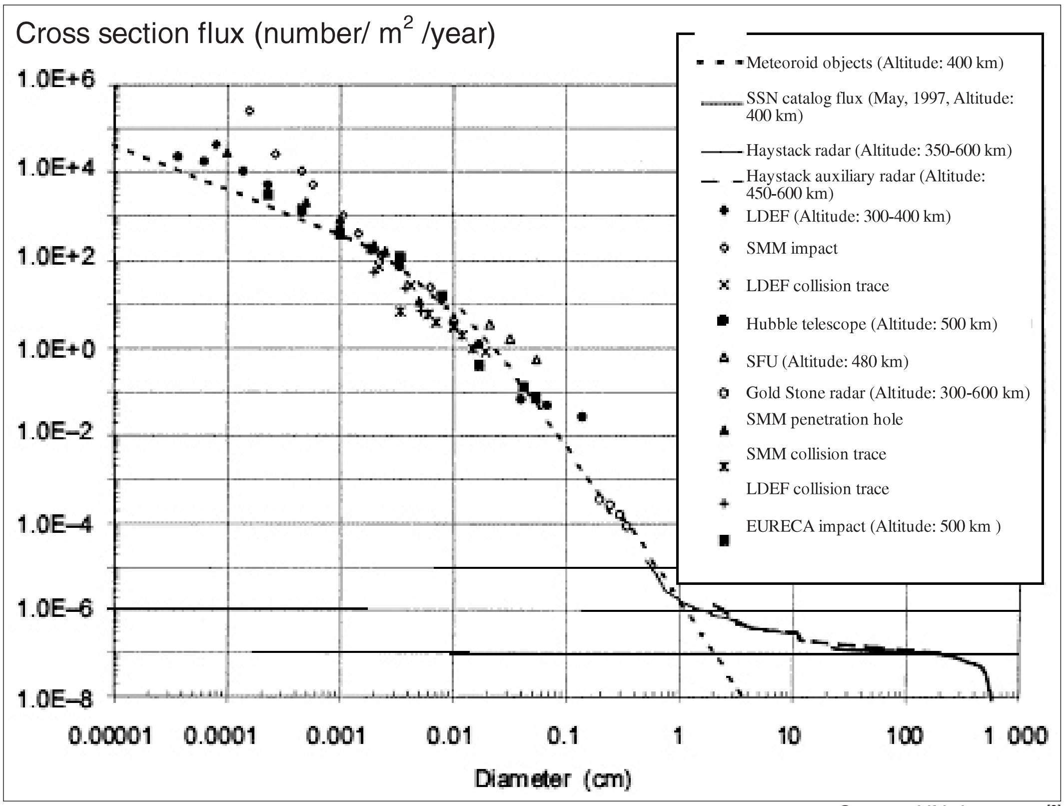
Observation data of medium-sized space debris, between several millimeters and several centimeters, and information on medium to high earth orbits are completely insufficient. The development of sophisticated observation technology is required to obtain the necessary information on these medium-sized objects, flying in medium and high earth orbits, to complete the space debris database.

In line with the need for international cooperation in space debris monitoring, the Inter-Agency Space Debris Coordination Committee (IADC), which was established in April 1993, urged its member countries in 1999 to implement space debris observation campaigns to collect information in the vicinity of geostationary orbits and lower earth orbits. In response to this, each country conducted a space debris survey using optical telescopes and ground radar facilities.

(1) Optical observation of Space debris

Using an optical telescope, relatively high earth orbit space debris can be monitored by reflected sunlight. Because of the nature of this method, observation can only be performed at night.

Figure 7 : Space Debris Flux Model



Source: UN document[9]

Table 1 : Optical Observation Facilities for Space Debris: Performance Comparison

Nation	Operating Organization	Primary mirror diameter (m)	View angle (degree)	Observable magnitude(star magnitude)
U.S.A.	NASA	3	0.3	21.5
Japan	JAXA/JSF	1	3	19.5
Swiss	Bern University	1	0.5	19.5
Russia	RSA	1	0.2	19
France	CNES	0.9	0.5	19
U.K.	Greenwich Observatory	0.4	0.6	18

Source: UN document[9]

Space debris circulating in lower earth orbit fly for most of the night in the shade of the earth and do not reflect sunlight at all, limiting the observable period to a few hours towards sunset and before dawn.

Space debris in the vicinity of geostationary orbit can be observed using the optical telescopes, except for a certain period around the vernal and autumnal equinox. The National Aeronautics and Space Administration (NASA) focuses on observing space debris of greater than 50 cm, and the European Space Agency (ESA), on space debris of greater than 20 cm. In Japan, a space debris survey being is conducted at the Bisei Spaceguard Center (Bisei Town, Okayama Prefecture). The system can catch space debris of greater than 50 cm, and efforts are being made to extend its capability to the 20-cm range.

Table 1 summarizes the comparison of telescopes used for space debris observation in major countries. The wider the view angle, the wider the space region that can be simultaneously observed. Although the telescope used in Japan has a smaller-diameter primary mirror compared to the telescope used in the U.S.A., it has a much wider view angle. In addition, the telescope at Bisei is used solely for space debris observation, enabling greater availability and better conditions than systems in other countries.

Considering the fact that no satellite has ever been recovered from geostationary and medium-to-high earth orbit, ground-based optical observation is very important.

The development and systematic operation of an enhanced optical telescope that enables the observation of smaller pieces of space debris is instrumental in enriching the information obtained using the optical method.

(2)Radar observation of Space debris

Using a ground radar station, space debris can be detected. The radar emits electromagnetic waves, and detects the waves reflected by space debris again on the ground. Due to the nature of this method, detection capability is limited compared to the optical method; the practical detection range is limited to about 1,000km.

NASA has started experimental observation to cover objects as small as 1cm using the military facility, Cobra Dane, located in the Aleutian Islands. Because of the limitation described above, the results obtained so far are limited mainly to larger debris (≥ 10cm). The system in Cobra Dane was originally installed to survey missile launches from the former Soviet Union, and is thus located in a high-latitude region (52.7, North Latitude). Because of this, the system cannot detect space debris with low orbital inclination.

ESA uses the radar that belongs to Forschungsgesellschaft für Angewandte Naturwissenschaften (FGAN), which can track pieces of debris as small as 2-3 mm in diameter. However, the effective view angle is severely limited because the radar is of a parabola format and cannot instantaneously scan a wide range of electromagnetic spectra.

In Japan, an experimental radar system for space debris observation started operation in April 2004 at Kamisaibara Spaceguard Center (Kamisaibara Village, Okayama Prefecture). (See the topics in the April 2004 issue.) This is the only radar system in Japan installed solely for space debris observation capable of continuous service. The system is experimental in nature, and one of its important missions is to gather operational/technical information for the future construction of a practical system capable of detecting small (≤ 10cm) pieces of space debris flying at relatively low altitudes. The realization of this unique observation facility is awaited worldwide.

Compared with the optical telescope method, which is accessible even by an amateur astronomer with a small-diameter telescope, the radar system requires huge system investment that can only be realized as a national-level project. The experience and results obtained from the Kamisaibara Spaceguard Center will accelerate the progress of the radar method in Japan, which has hitherto lacked systematic engagement. Based on these results, it is desired that an enhanced infrastructure comparable in performance to Cobra Dean and FGAN in low-latitude regions be constructed, enabling space debris observation that outperforms that of other countries.

(3) Space debris observation from Satellites

The use of satellites as instruments to observe space debris has not yet been realized. However, once it is put into practical use, satellites will provide a wealth of information, including the capability to measure tiny pieces of debris that are not accessible using the ground-based observation method. Several methods have been proposed for space-born measurement including PVDF, plasma, and the ion method. These methods are all devised for counting the number of collisions with tiny pieces of debris.

The satellite is equipped with wide solar panels to provide power to the on-board equipment. Geostationary satellites, for example, usually have a large solar panel exceeding $100\,m^2$, and collisions with tiny pieces of debris often take place on the surface of the solar panel. Taking advantage of this fact, solar panels can be used as collision detectors by installing an on-board surface inspection system (camera) to monitor the surface of the solar panel arrays.

Obtaining images with accurate collision imprints for analysis plays an important role in this method. A group in Kyushu University has already finished a conceptual design for an on-board surface inspection system, and implemented it as a prototype model consisting of a camera and image-processing system. The model was tested and has proved successful in searching for a collision imprint by scanning the surface using an on-board camera, and taking a close-up image of the imprint. This sequence is carried out automatically.

3-4 Mitigation of space debris

Even in the event of collision with a piece of space debris, the spaceship must continue its mission. Research on protection and damage control against space debris collision is also in progress. An example of this research is being implemented in the Japanese experimental module "Kibo" (meaning 'Hope'), to be incorporated in the front-end (traveling direction) of the international space station. The module is equipped with a bumper to absorb collision impact, and it prevents the penetration of debris smaller than 1cm.

For larger debris that the bumper cannot ddefend, the international space station will take evasive action (for example, change of altitude) by continuous calculation of the relative position between the space station and the debris.

3-5 Reduction and removal of space debris

The most fundamental approach to secure safe human activity in space in future should be to prevent space contamination from worsening, as well as the workaround method (e.g. evading collision) described in the previous section. The guiding principle for this should be to prevent generating space debris. The design and development of satellites and launch vehicles that do not generate space debris is of utmost importance.

Japan has taken the lead in adopting this principle among a number of countries and implemented debris-reducing measures for its upper stages of rockets and satellites, which are evaluated highly by other countries.

An example of this approach is incorporated in geostationary satellites; decommissioned satellites are programmed to move to higher orbit, preventing space debris being left in geostationary orbit, which is a valuable resource for future reuse. The method of space debris reduction has become one of the major themes in the '90s; Japan adopted this approach ten years before this on its own initiative.

Another advanced technology now being considered to reduce the amount of space debris includes the use of lasers to modify trajectories, finally forcing the debris to fall into the atmosphere. It seems, however, that it will take a long time before this method is applicable.

4 Near Earth Asteroids: NEAs

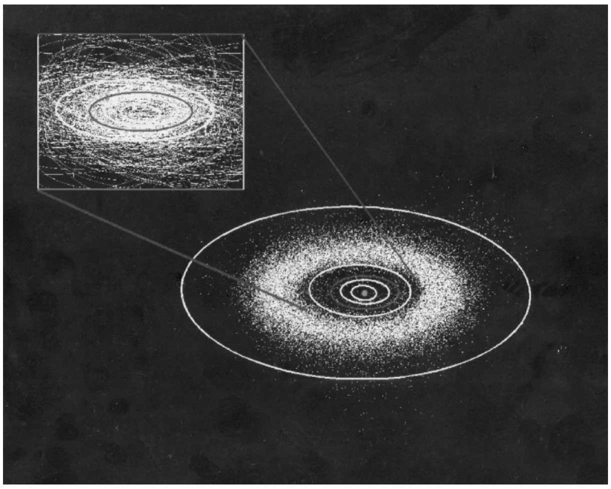
There is a belt of scattered asteroids (asteroid belt) between Mars and Jupiter. The first asteroid was discovered on the 1st of January, 1801, and there are many different theories concerning the origin of the asteroids; one theory says that they are small planets that could not grow to large planet at the infant stage, and another says that they are debris generated by the explosion of a planet. Until the end of the 19th century, some one hundred asteroids were found. The majority of them are circling around the sun in orbits confined between Mars and Jupiter. Some of them, however, are moving along the prolate ellipsoid that intersects the orbit of the earth, producing a non-zero probability of hitting the earth. These asteroids are specifically called Near Earth Asteroids (NEAs). The first NEA was found in 1898.

4-1 Disasters caused by NEA collision

On the morning on 30th of June, 1908, an asteroid with a diameter of 80 m rushed into the Tunguska region in Far East Russia. It exploded several kilometers above the ground, producing a huge hole directly below the explosion and razing all trees and vegetation from an area as wide as 80km×100km. If this scale of disaster took place in densely populated area such as Tokyo, several million or more than tens of millions of people would be killed instantly. The estimated probability of an asteroid hitting any one place on the surface of the earth is approximately once in 1000 years[10].

The collision probability of a larger asteroid is much smaller: once in one million years for an asteroid of 1-km diameter, and once in one hundred million years for an asteroid of 10-km diameter. These probability values, which are fairly reliable, can be calculated using the estimated value for asteroids whose orbits intersect the orbit of the earth.

Figure 8 : Asteroid Distribution in the Solar System: (Inside the orbit of Jupiter)



Many asteroids fly inside the orbit of the earth. The picture shown on upper left of the Chart is an expanded view inside the orbit of Mars, indicating the trajectories of asteroids that come close to the earth.

Source: Provided by the Japan Spaceguard Association

In 1980, Nobel prize laureate Luis Alvalez et al. made their theory public that the sudden, mysterious extinction of the dinosaur around 65,000,000 years ago was due to a collision of a 10-km-diameter asteroid. The crater created by the huge collision, which measures as much as 180km, was discovered in 1991[11].

The extent of the threat presented by the collision of steroids varies considerably, from the devastation of one small country to the destruction of human civilization, or even the annihilation of the human species. Although the probability of any asteroid hitting the earth is extremely low, we must keep in mind that collision will cause calamity beyond imagination.

4-2 NEA observation

(1) Trends in NEA observation

The development of new observation equipment by many astronomers in the 1960s has accelerated NEA research. Today, nearly one million asteroids have been found. Among them, there are nearly 3,000 NEAs.

The U.S.A. is most actively engaged in this field of study. In Japan, the Japan Spaceguard Association[12] (a non-profit organization) is playing a leading role in efforts to detect

Table 2 : Energy Released by Collision of Heavenly Bodies

Magnitude of energy released by collision with various sizes of heavenly bodies		
Asteroid (m)	Comet (m)	Energy released (Equivalent TNT explosive, Megaton)
10	6	0.024
I. Destruction of a nation-sized area		
60	36	20
80	48	50
150	90	340
II. Global destruction		
500	300	13,000
1,000	600	100,000
10,000	6,000	100,000,000
Atomic bomb dropped on Hiroshima		0.02
Nuclear winter		10,000

unknown Near Earth Asteroids[13,14]. If an NEA is found to be on a collision course with the earth, the measures to be taken will be enormous as described in the following section. However, no measure will be taken without steady, painstaking effort to discover and track asteroids that have a non-zero probability of hitting the earth and to calculate their orbits. The trajectories of these asteroids can be calculated with a fair degree of accuracy within the framework of Newtonian dynamics, enabling warnings to be issued at a sufficiently early stage.

(2) Necessity of continuous NEA observation

No NEA should remain undiscovered. Without discovery, there remains a possibility of an unknown asteroid suddenly appearing, causing calamity. To avoid this, a sufficient number of telescopes (several tens of telescopes) dedicated to NEA observation must be properly globally deployed.

By the same token, an NEA, once discovered, must not be lost from our view; the deployment of telescopes to track them constantly is also necessary, enabling regular updates of trajectory information. Currently, this tracking observation depends largely on the volunteer efforts of many amateur astronomers.

As the number of the newly discovered asteroids increases, it is not too early to seriously consider establishing a systematic tracking observation network involving professional astronomers.

4-3 NEA collision prevention

In the unlikely event of an NEA being found on a collision course with the earth, disaster prevention measures must be taken. As summarized in Table 2, the collision will release a much higher order of magnitude of energy (104-108) than the atomic bomb dropped on Hiroshima. There is no way of completely preventing disaster. In fact, very small asteroids with diameters of less than 10m hit the earth at a frequency of roughly once a month. However, these tiny asteroids do not cause major disaster because, thanks to the atmosphere surrounding us, they usually decay their speed before hitting the earth. For larger asteroids (whose diameter is greater than several tens of meters), measures to evade collision must be devised[15].

As mentioned above, the trajectories of asteroids can be fairly accurately calculated using Newtonian dynamics, enabling us to forecast when the collision will take place. Let us assume that the projected collision time, for example, is 30years from now. In this case, if we can modify the speed of the asteroid by 1cm/s to correct its direction now, it will pass by the earth at a distance greater than earth's diameter 30years hence. To give an appropriate pull in the correct direction, the physical parameters of the NEA such as mass distribution, composition, shape (powder or aggregate), must be known, necessitating launching a space probe to gather information. The technology required for NEA exploration is complex, but several countries such as U.S.A. and Japan have already launched space probes as an experimental approach in the vicinity of specified asteroids. Although significant expansion of these projects is required to actually send a space probe to an NEA, it will be well within the reach of our technology. The priority at present is to discover all dangerous asteroids to reduce the probability of unexpected collision even if infinitesimally small[16].

4-4 Observation network required in future

The only one systematic NEA observation effort in Japan is undertaken by the Japan Spaceguard Association using the telescope installed at the Bisei Spaceguard Center. In U.S.A., five groups are actively engaged in NEA observation under the auspices of NASA, and they have already detected more than 600 NEAs with diameters greater than 1km, NASA's primary objective (The total estimated number in this category is between 1,000 and 2,000).

For Japan to make an effective contribution in this area of research, a number of Bisei-type observatories must be added to our arsenal. The steps to be taken for this are as follows:

i) The construction of several optical telescopes whose performance is equal to or better than that installed at the Bisei Spaceguard Center (diameter: 1 m) for the efficient detection of larger NEAs (diameter ≥ 1km). These should be put into operation without delay.

ii) The deployment of a number of smaller telescopes for the continuous tracking of detected NEAs. The number of NEAs whose orbits have been defined is constantly increasing.

iii) The addition of a larger telescope with a greater-than-4-m aperture is highly desirable for probing NEAs with diameters of greater than 100 m.

5 Conclusion

5-1 Crisis management for the human species

We live surrounded by many potential threats including natural disasters such as earthquakes and floods, man-made disasters such as accidents and terrorism, and the food/energy crisis. The first step in crisis management is to be aware that the unthinkable may suddenly happen, destroying the bases of our lives.

(1) Space weather

With the advance of space exploitation and utilization technologies, the fruits of space development (including GPSs, satellite broadcasting, and weather observation) are already ingrained our daily lives. Satellites on their missions are constantly sending meaningful information to the ground. It is therefore essential that we, from the viewpoint of crisis management, consider what will happen if signal waves from satellites suddenly stop arriving. Abrupt changes in space weather can hinder the proper operation of our space equipment; we have had numerous instances of this happen. Continuous, steady effort is required to safeguard the proper operation of these systems, and enhancing these activities will bring us better space weather forecasting, enabling the operators of this space equipment to prepare for disorders more appropriately.

The development and maintenance of various systems are required for more accurate space weather observation (see the main text for details), and national-level engagement and support for this purpose is required.

(2) Space debris

Measures to reduce and remove space debris are essential to maintain the proper operation of existing and future space crafts, and the countries that have launched space crafts should be mainly responsible for performing these activities. As a major space-developing country, Japan should further enhance its role in international cooperation for space debris observation because it has the qualified technologies and facilities to bear this burden.

(3) Near Earth Asteroids

The probability of collision of a Near Earth Asteroid within a few years seems extremely low. Nonetheless, from the viewpoint of crisis management of rare but serious disasters that have hitherto been more or less disregarded, establishing systems for evaluation and early warning systems is essential.

5-2 Systematic support for steady observation research

The effect of fluctuation in the space environment on human activity on the ground is yet to be fully understood. Currently, overall research and operation are split and allocated to a number of research institutes in Japan according to their special interests and strengths, including volunteer efforts.

National Universities sharing this burden need large expenditure for the development and maintenance of equipments, as well as the allocation of researchers and costs for daily observation. These observation efforts have been more or less of a volunteering nature by researchers, and could hinder continuous, systematic research. Conducting daily observation by dedicated personnel should be seriously considered.

Surveying and observing the space environment that surrounds the earth is being conducted through international cooperation. To properly share the burden as a major member of this collective endeavor, establishing a systematic operation system supported by the nation is required, as well as the efforts of first-line researchers.

5-3 Current standing of Japan

Among a number of countries, U.S.A. is head and shoulders above other countries both at the level of technology and the volume of equipments and facilities. Many research efforts now being conducted in Japan are also well acknowledged in the world; these include the Circum-pan Pacific Magnetometer Network (Kyushu University), measures to reduce and protect against space debris, and the operation of a wide-field large telescope (Bisei Spaceguard Center), to name only a few. Unfortunately, the community of those supporting the endeavor is not well known among the general public. Educational campaigns by key figures and proper support for volunteer activities seem effective ways of facilitating the role Japan plays in international collaboration for space environment observation and fluctuation monitoring.

6 Conclusion

Space is connected to life on the earth, and it has much to do with our lives by providing an essential environment. However, it is also important to be aware that space is sometimes dangerous. To conclude, I would like to stress, for the security of human activity on the earth, the importance of supporting research efforts and to raise the interest of the general public, especially the younger generation, to observe and monitor changes in space.

Acknowledgements

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Glossary (with full spelling)

- *BAS* British Antarctic Survey
- *CAWSES* Climate and Weather of the Sun-Earth System
- *CME* Coronal Mass Ejection
- *CNES* Center National d'Etudes Spatiales

- •*ESA* European Space Agency
- •*EURECA* European Retrievable Career (European unmanned recoverable free flyer)
- •*FGAN* Forschungsgesellshaft fur Angewandte Naturwissenschaften
- •*GPS* Global Positioning System
- •*IADC* Inter-Agency space Debris Coordination committee
- •*JAXA* Japan Aerospace eXploration Agency
- •*JSF* Japan Space Forum
- •*LDEF* Long Duration Exposure Facility (Equipment for long-term exposure)
- •*MAGDAS* MAGnetic Data Acquisition System
- •*MSD-1* Mission Demonstration test Sattellite-1
- •*NASA* National Aeronautics and Space Administration
- •*NEA* Near Earth Asteroids
- •*NICT* National Institute of Information and Communications Technology
- •*NOAA* National Oceanic and Atmospheric Administration
- •*NPO* NonProfit Organization
- •*NSF* National Science Foundation
- •*PVDF* Polyvinylidene Fluoride (Piezoelectric plastics)
- •*RSA* Russian Space Agency
- •*SCOSTEP* The Scientific Committee On Solar-TErrestrial Physics
- •*SEES* Space Environments Effects System
- •*SFU* Space Free Flyer Unit
- •*SMM* Shuttle Mir Mission
- •*Sq* geomagnetic solar quiet daily variation field
- •*SSN* Space Surveillance Network
- •*TNT* TriNitroToluene
- •*UCLA* University of California, Los Angeles
- •*ULF* Ultra Low Frequency

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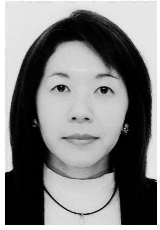
9

The Current Argument between Scientists and Government for Science and Technology Policy in U.S.



KUNIKO URASHIMA
Environment and Energy Research Unit

1 Introduction

Science and technology are important keys if Japan is to be able to overcome the various problems it faces and open up new visions for the future. In other words, Japan must promote science and technology and appropriately surmount the issues it faces by actively developing the comprehensive policies shown in the Science and Technology Basic Plan along with concrete measures based on those policies. Not only in science and technology, but throughout society, Japan must stimulate the formation of a base for scientific, rational, and independent judgment on social issues. For example, it is necessary to understand the mechanisms by which disease and disasters occur and their influence spreads and to prepare countermeasures. Science and technology provide means to do so. At the same time, science and technology also have negative aspects, and we must remember to carry out appropriate measures in response to those aspects[1]. "Regulatory science" is often used for scientific research regarding such risks.

In 1987, Dr. Uchiyama (Emeritus Director General of the National Institute of Health Sciences) advocated regulatory science mainly for pharmaceuticals and foods as "a science that works out methods to more accurately understand the origins and facts surrounding the substances and phenomena that surround us. It then predicts and evaluates effectiveness (advantages) and safety (disadvantages) and contributes to national health through government administration"[2].

In Europe and USA, the term was first used in a 1972 paper by the physicist Alvin Weinberg. He used it to refer to those problems that modern society can use science to address but that cannot be solved by science alone. In other words, he used it to refer to the science that handles issues such as the establishment of safety standards and other safety regulations. However, he mentioned only indicating the problem[3]. Subsequently, in her 1987 paper entitled "Contested Boundaries in Policy-Relevant Science," Sheila Jasanoff of the United States attempted to analyze the scientific bases of policies carried out by US regulatory agencies from a social constructionist perspective*1. According to this article, regulatory agencies sometimes determine policy based on science in which cause and effect relationships are not necessarily clear. In other words, the paper made it clear that even statements that at first glance appear to be scientific are not always entirely so. Political and economic agendas may also be involved, and the boundaries between politics and science in regulatory science are always in motion[4]. In particular, such regulatory science is widely used on issues that cannot be resolved by science alone, such as climate change and renewable energy, embryonic stem cell research, and education (e.g., evolution).

In this article, I will describe some recent cases where regulatory science is disputed by scientists and policymakers in the United States.

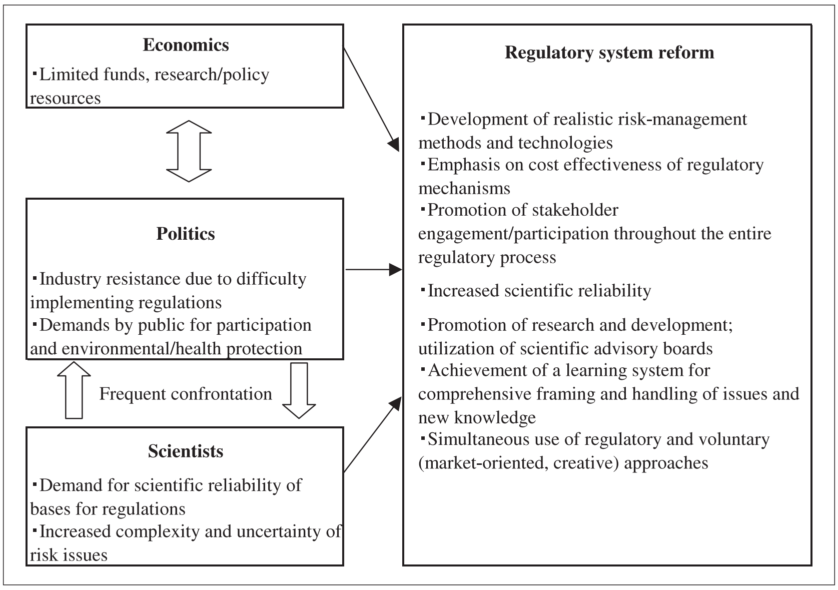
2 The regulatory system and the proposed draft peer review new standards by OMB in U.S.

2-1 The regulatory system and organizations for in setting regulations

In general, regulatory systems are debated against the background shown in Figure 1[5].

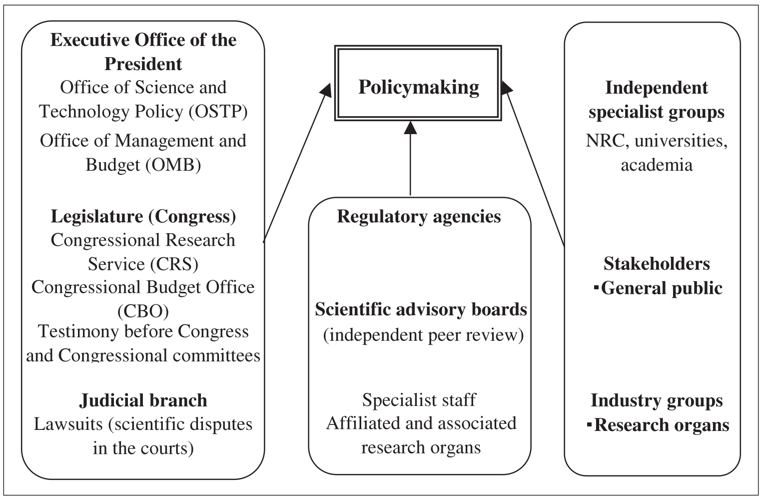
In 1993, the United States Congress enacted the Government Performance and Results Act of 1993 (GPRA). Under that law, for all programs they intend to carry out, all US Federal Government agencies are required to establish purposes, goals to be achieved, and indicator measurements, and to explain their results. In other words, the GPRA required that policies that should be implemented under the limited budget available be prioritized and their results be clarified. In the United States, enactment of the GPRA has meant the adoption of full-fledged administrative review within the Federal Government. In each agency, policymaking, work methods, and results are systematically evaluated[6]. Organizations currently involved in US regulatory policy are shown in Figure 2.

Figure 1 : Overview of regulatory system



Created based on reference materials of the Second Meeting of the Subcommittee on Management of Genetically-Modified Organisms, Ministry of Economy, Trade and Industry, November 21, 2001.

Figure 2 : Organizations involved with regulatory policy in the US



Created based on reference materials of the Second Meeting of the Subcommittee on Management of Genetically-Modified Organisms, Ministry of Economy, Trade and Industry, November 21, 2001.

2-2 The proposed draft peer review new standards by OMB

In August 2003, the Office of Management and Budget (OMB) in White House released its proposed "draft peer review standards for regulatory science[7]." The standards are intended to improve the quality, purposes, realism, and fairness of peer review when public funds are invested in research related to regulations carried out by the Federal Government. To be implemented by the OMB along with the Office of Science and Technology Policy (OSTP), the standards are positioned as new guidance for the distribution of important scientific knowledge. They would be applied to all scientific/technical research related to regulatory policy. For environmental and health warnings and all other research that will influence government regulations, the standards would introduce thorough peer review by neutral scientists in the same field. In particular, in the case of information significant to regulations, the proposed standards would require peer reviewers unconnected with the government agency having jurisdiction. In addition, specialists who receive funding from the government agency concerned and who have performed multiple peer reviews in recent years for that agency or one peer review on the same specific matter in recent years would not be eligible to be peer reviewers.

2-3 Current status of "peer review" of research and development support in the United States

Ordinarily, US government agencies (DARPA, NSF, DOE, NASA, etc.) utilize two selection methods, "peer review" and "program management," in their R&D support programs. Peer review utilizes repeated evaluations of drafts by "peer reviewers" from the US and abroad. It is typically used in the support of basic research. Peer review could be called the basic principle for the selection of R&D programs in the United States. It is said that 30 percent of government research and development support programs utilize it[8]. In the US, the making fair examination by numerous specialists such as outside peer reviewers, program managers are decided acceptance of research, however the weakness is that review takes a great deal of time and money. Meanwhile, the role of program managers in R&D support is to utilize the results of examination by outside peer reviewers as data to be examined when deciding to accept or reject research based on its content, and to report the results as a recommendation to the top who will be making the decision.

3 Criticism of the OMB proposal

3-1 Criticism of the OMB's new peer review system by scientists

After publication of the OMB proposal, the Union of Concerned Scientists (UCS) received many objections and complaints from scientists, so it began a investigation of policymaking in scientific fields by the Bush Administration.

A history of the point of issues is shown in Figure 3.

In response to the OMB proposal, in February 2004, UCS published a 37-page report entitled "Scientific Integrity in Policymaking[9]" that was signed by 60 scientists, including 20 Nobel laureates, a former Presidential Science Advisor, and former directors of the National Science Foundation and the National Institute of Standards and Technology. At the same time, the UCS published a statement declaring that the Bush Administration has distorted scientific fact for its own convenience in policymaking concerning the environment, health, biomedical research, and nuclear weapons[10], and it opposed the OMB proposal as being biased towards the Administration and problematic in many ways. The report and the statement pointed to the following points as problematic.

- The Bush Administration has pushed some of the many government advisory panels towards dissolution and it appoints only scientists who have same opinion with advisory committees in Administration.
- In many Federal Government agencies, the current Administration appears to have suppressed or distorted inconvenient scientific knowledge, and it effects to

Figure 3 : History of the issues

Aug-2003
The Office of Management and Budget (OMB) publicly announces its draft proposal on the adoption of peer review.
↓
Dec-2003
Members of Congress and Science Committee members submit opinions that the proposed peer review system by OMB is inappropriate.
↓
Feb-2004
Over 60 scientist members of the UCS state that the Administration distorts scientific facts in policymaking on the environment, medical care, etc.
↓
Mar-2004
The UCS submits a report with the same content as its statement, and opposes the OMB proposal.
↓
Apr-2004
The Administration (presidential science advisor John H. Marburger III) rebuts the criticism.
↓
Jul-2004
The UCS issues a statement criticizing the attitude of the current administration for refusing to implement an improved proposal in response which submitted in February.
↓
Aug-2004
Over 4,000 scientist members of the UCS sign a statement criticizing the attitude of the Bush Administration.

particular impact on public health, public safety, and welfare.

- The Administration appears to have taken actions to control expert scientific advisory panels in order to avoid publication of reports that may contradict its policies.
- The OMB gives no examples of failure in formulating regulations or decision making based on scientific information.

In addition, the report asserts that the scope and scale of the manipulation and suppression of science are unprecedented. Furthermore, the scientists criticize the policies being advanced by the Administration under the name "Restoring the Integrity of Science[11]" as likely having a negative effect on health and the environment[12]. Moreover, they mention that the trends seen in recent policy shake the foundations of science, and the situation must be addressed quickly.

They also point out where the Administration interprets the term "peer review," widely used among scientists, for its own convenience. Generally, scientific publications are peer reviewed by scientists in the same research field, and only papers that have passed through the review process are published. Through the review process, specialists in the research field examine the papers for novelty, and many papers are rejected for publication because of insufficient novelty or other reasons. Under the OMB proposal, however, it is feared that the White House version of "peer review" will mean review only by review panels comprising reviewers who are friendly to the Administration and its corporate supporters. Because leading specialists in a field would only be able to engage in peer review only once every few years under the policy, it would be difficult to carry out proper peer review. In public comments[13] on the proposal, scientists have stated that peer review itself would become meaningless.

3-2 Suggestions in the UCS statement regarding the OMB proposal

The UCS report concretely and explicitly notes examples of policies that are problematic to science, scientists, and social welfare. The report cites cases where scientists in the Environmental Protection Agency, Food and Drug Administration, Department of Health and Human Services, Department of Agriculture, Department of the Interior, and Department of Defense were subject to undue pressure on subjects such as climate change, mercury discharge amounts, public health issues related to reproduction, lead poisoning in fetuses and children, workplace safety, and nuclear weapons. The report states that new regulations and laws are needed to address the situation. It goes on the say that the President, Congress, scientists, and the public must do the following in order to restore scientific integrity in policymaking in the Federal Government.

- The President should eliminate the danger of expert science advisory panels becoming unfair.
- Congress should hold hearings on the matters indicated in the report to halt this dangerous trend. Panels should be composed of non-stakeholders with a high degree of expertise. Anyone should be able to access the scientific information of the government, and an advisory organ like the Office of Technology Assessment should be established.
- Through academic societies and other groups, scientists must work to become more deeply involved in the issue. They must appeal directly to Members of Congress and use the media to make the point that misuse of science can lead to serious problems[14].

3-3 Opinions of other groups on the OMB proposal

Members of Congress and the Science Committee in Federal Government also pointed out problems with the OMB proposal in December 2003. A written opinion[15] was submitted stating that the adoption of the peer review system would be unrealistic and ill advised because it mandates peer review of matters that do not require it. For example, proposal peer review under the OMB would be required before Federal Reserve Board Chairman Alan Greenspan could set interest rates and before weather forecasts, including urgent hurricane warnings, could be issued.

According to the American Public Health Association, it could not understand why the OMB would offer such a proposal in the absence of evidence that the current system does not work or of a single example in which failure to peer review led to a flawed Federal Government regulation[16]. In addition, Public Citizen[17] points out that requiring peer review would delay the process of issuing warnings to the public on matters that endanger health, possibly causing unimaginably large problems. Public Citizen also noted the problem of the OMB publication not giving even one example of a failure of regulation formulation or of decision making that was based on scientific data[18].

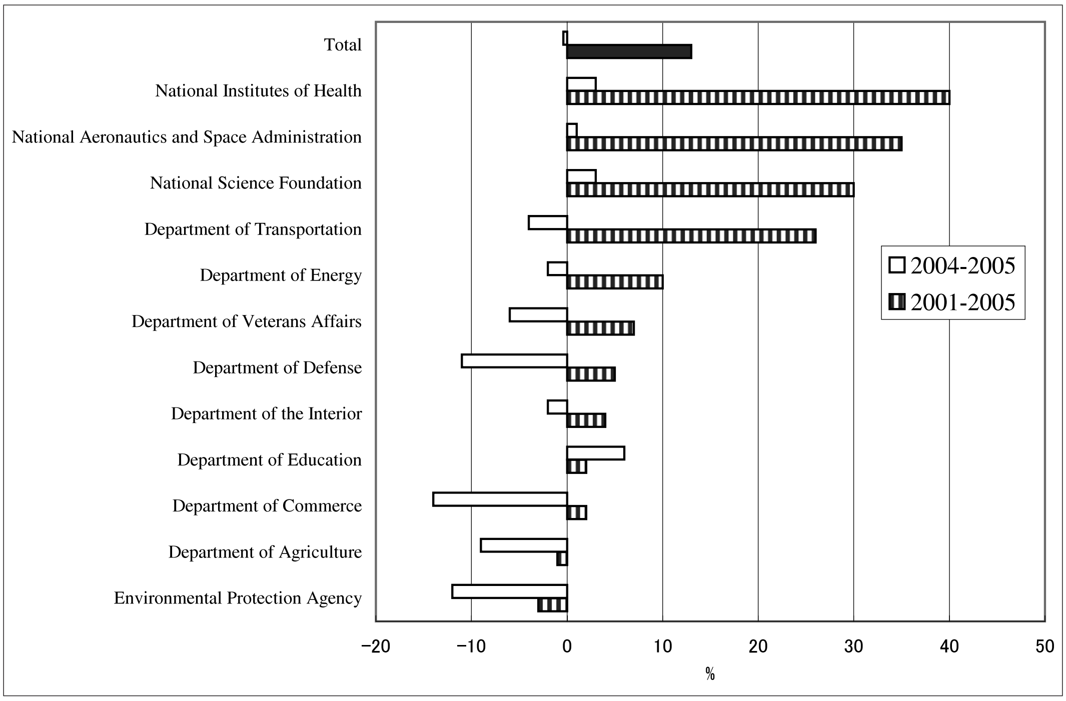
3-4 Criticism of environmental policy

Scientists and the protection of the environmental groups continue to point to Administration action on policies related to the environment in particular as problematic. Environmental issues are deeply connected to regulatory science, therefore scientists involved strongly oppose the OMB proposal.

Even though environmental issues extend across many fields, since the current Administration took office the budget and number of projects of the Environmental Protection Agency (EPA), which had fluctuated for several years, have declined relative to other agencies[19]. The transitions of science and technology budget in government are shown in Figure 4[20]. As can be understood from the chart, although the science and technology budget as a whole increased 30 percent from 2001 through 2005, the budget for the environment decreased.

In addition, a number of opinions are being offered on environmental policy, not just on problems with the peer review system mentioned above. For example, in August 2003, around the same time the OMB proposal was released, the Natural Resources Defense Council (NRDC) reported that the EPA is attempting to loosen Clean Air Act regulations, leading to an increase in the amount of pollutants emitted by older coal-fired power plants and oil refineries. The EPA's policy is that when, for example, a coal-fired power plant replaces boilers or other equipment, the plant would not have to install pollution control equipment to meet current standards if the cost of the pollution control equipment is less than 20 percent of the entire cost[21]. Not only pollutants such as NOx, SOx, and soot emitted by coal-fired power plants aggravate asthma, chronic bronchitis, pneumonia, and so on, research showing a major causal relationship with cancer has also been published, so scientists point out that such loosening of regulations is a serious problem for the citizens.

Figure 4 : Federal Government budget for science and technology



4 The response to by the administration for the UCS statement

In reply to the UCS statement, Presidential Science Advisor John H. Marburger responded that the current Administration in fact strongly supports science[22]. As evidence, he mentioned that the budget in NIH has been increasing as well as the National Science, so that the overall science and technology budget has increased compared with before as shown in Figure 4. The budget increases $91 billion for fiscal 2005 ($132 billion) compared with the 2001. This is the highest level in 37 years.

Other points made in the response include the following. A program on climate change has been in place since 2001. The emission of greenhouse gases especially CO_2 is a problem since the Industrial Revolution started and is a major issue in every country, as well as the US government is addressing solutions. With the purpose of reducing worldwide greenhouse gases, the Administration is spending about $4 billion on understanding the mechanisms of greenhouse gases and their effects on human beings and for research and development in clean energy technologies. The President created the US Climate Change Science Program (CCSP) to respond and receive comments and stakeholders including a two-stage independent review of the plan, set a standard for government-led research programs.

In addition, the OMB has for the first time hired toxicologists, environmental engineers, and public health scientists to review regulations and help agencies strengthen their scientific peer review process.

In this way, the Administration is using concrete examples to voice its objections to the UCS assertions. However, scientists are dissatisfied with other issues in addition to those noted by the UCS.

5 Recent trends

5-1 Issues with mercury regulations

In March 2004, an article reporting that the environmental policy in Bush Administration leans towards the energy industry appeared in the New York Times[23]. In April, seven Members of Congress including Democratic Senator Hillary Clinton sent the EPA Administrator a request for an investigation regarding improprieties in guidelines on mercury emission regulations, a current matter of concern. There are approximately 1,100 coal-fired power plants in U.S. and the exhaust gas from burning coal includes mercury, which are estimated 48 tons/year. It's a 40 percent of annual mercury emissions. The mercury mixes with rain and falls to the ground, where it flows into rivers, lakes, and oceans, and accumulates in fish and shellfish. Recently there is concern that mercury may enter the body directly through respiration and have a particular impact on fetuses in the womb. The request for an investigation demanded clarification of the allegation that during the process of formulating regulations on mercury emissions, the Bush Administration deliberately removed wording from a National Academy of Sciences study in its proposal in order to minimize health concerns[24]. In response to the letter, the EPA Administrator stated the following.

- The current Administration is the first to decide a schedule for reducing mercury emissions.
- The 90-percent reduction of mercury emissions is only a draft proposal.
- It is impossible to immediately install mercury removal equipment throughout the United States.

The Congressional Research Service also published reports[25-27]. The Clear Skies Initiative*2 and the mercury regulations proposed by EPA for power plants are also criticized as requiring lighter reductions of mercury emissions from the energy industry than it does from other industries[28-29].

5-2 A new statement from the UCS

In July 2004, many more UCS member scientists, over 4,000, including 48 Nobel laureates, signed a statement criticizing the attitude towards scientific advice in the Bush Administration[30]. The statement was issued to criticize the Administration for not adequately examining[31] the report submitted in February 2004. The report added the following to the points previously made.

A project on the environmental impact of mines changed direction to a focus on rationalizing coal mining, leading to impacts on fish and wildlife. Furthermore, salmon are facing extinction, and this will have a major impact on wildlife that depends on them for food. Policy countermeasures are urgently needed.

As seen in the case of the "Star Wars" initiative, there have been cases in the past of scientists individually or in groups objecting to particular Federal Government policies. However, for so many scientists[32] to criticize a president's science policy as a whole is unprecedented. In November 2003, even Richard L. Garwin[33], who received a National Medal of Science for his "valuable scientific advice on important questions of national security," signed the statement. In addition, some scientists with ties to the current Administration are among the signatories[34].

Scientists point out that addressing issues such as reproductive medicine, pharmaceutical regulation, and the environment from a political rather than a scientific point of view will damage trust between the Administration and scientists. However, the opinion in Administration is that there are research fields such as embryonic stem cell research in which not only scientific views but also moral issues are important, so not everything can be handled uniformly by government.

6 Conclusion

Since 2001, research and development funding has increased in the Department of Defense, NASA, and the Department of Homeland Security in particular. It is noteworthy that they are all defense-related, and among many the agencies that is where the upward trend continues. On the other hand, the number of articles published in the United States in science and technology has been stagnant or declining for the past several years[35], while they have doubled in Europe, China, Taiwan, South Korea, and Japan over the past 10 years, and the number of Nobel laureates from outside the United States is also increasing. Currently the US is restricting visas in comparison to the past, when it gathered numerous scientists from around the world.

Since the Republican administration took office, budgets for environmental fields have continued on a downwards trend compared with the previous administration. Recently, however, the Senate has reduced the cuts to the R&D budget in EPA[36]. It seems that the action of the scientists may have had some impact.

Those scientists organized themselves and put their pride as scientists ahead of party support and, in the form of the statements, objected to Administration policy. How the Administration will respond and how things will develop are the points worth watching now. We should always pay attention to the actions of scientists in science and technology fields in various foreign countries. The organization of scientists to point out problems to the government may happen in Japan in the future. It may be demanded or become necessary.

It is desirable that complex issues such as the environment or embryonic stem cell research be resolved through debate based on scientific judgment and rational premises, with risk considered even if some uncertainty must be permitted. And the most important thing is that scientists, government, and the citizens share information, exchange opinions, and attempt to understand one another.

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Note and Glossary

*1 A perspective that does not assume the existence of objective and absolute reality, but instead contends that reality is constructed by society.

*2 Clear Skies Initiative
A plan that sets caps for SO_2, NOx and mercury emissions by power plants and sets a goal of 70 percent cutting from 2000 levels.

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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.

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The following are major activities:

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— 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).

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

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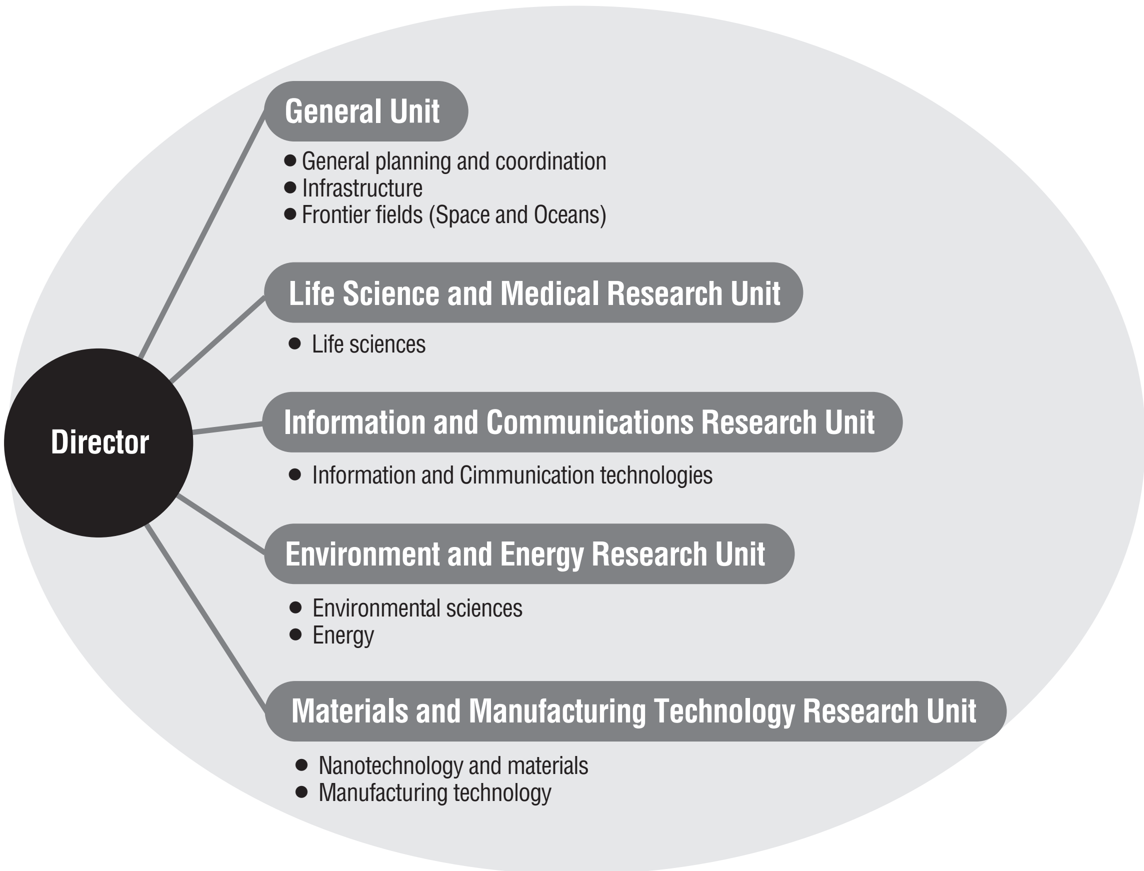

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