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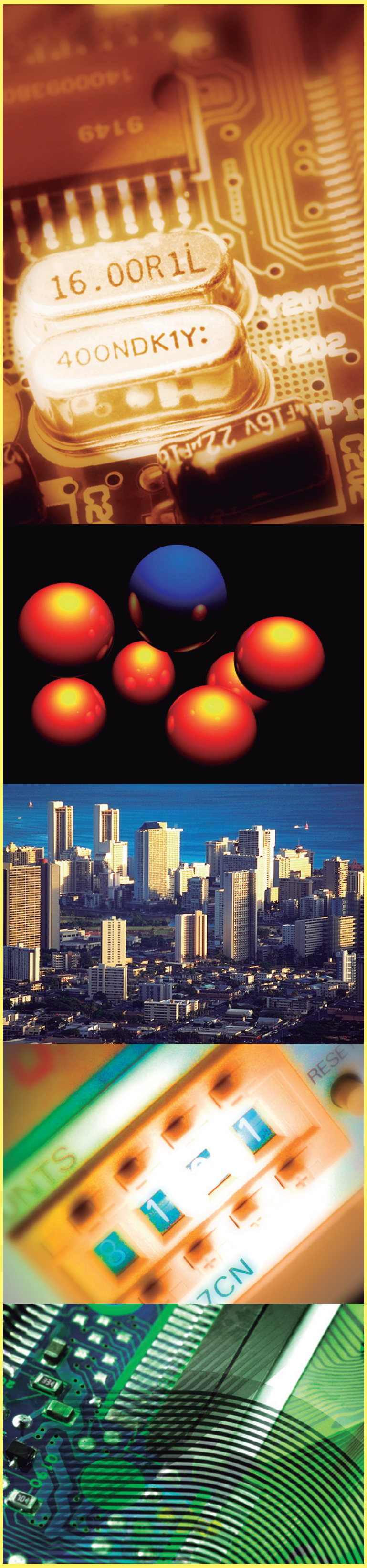

Foreword

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 2000 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.

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Executive Summary

Life Sciences

1 Science and Technology Policy for Promoting Research Cooperation between Mathematics and the Life Sciences in the United States

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Disciplines such as computer science, mathematics and information science have contributed significantly to the promotion of the Human Genome Project. The U.S. and European countries have begun to explore a variety of science and technology policies, based on the belief that cooperation between the life sciences and mathematics is indispensable for the future development of life science. Meanwhile, Japan lacks a science and technology policy to promote the integration of the life sciences and mathematics, and may fall behind other countries in the area of life science.

The total amount of U.S. federal funding for mathematics and computer science research is approximately 33 billion dollars. The funding for mathematics science research is 375 million dollars, corresponding to only one-tenth of that for life science, but has slowly been increasing over this decade. Half of the budget is funded by the National Science Foundation (NSF) and the rest by the Department of Defense (DOD), the National Institutes of Health (NIH) and the Department of Energy (DOE). NIH funds 63 million dollars (approximately 6.6 billion yen) of research, and supports interdisciplinary research involving life science and mathematics, etc.

In February 2003, a joint NSF and NIH symposium was held on "Accelerating Mathematical-Biological Linkages". The attendees agreed on (1) institutional actions including (i) expansion of the NSF-NIH linkage, foundation of a national institute responsible for research in interdisciplinary areas involving both mathematics and life science and (ii) establishment of a database integrating all kinds of data related to life science, such as genomics and proteomics, (2) education-oriented actions including (i) establishment of new programs for postdoctoral fellowships in interdisciplinary areas and (ii) hosting of workshops targeting deans of mathematics and life science departments aimed at creating curricula for interdisciplinary undergraduate education, and (3) researcher's actions, including the preparation of a list of the ten most challenging tasks in the mathematics-biology interdisciplinary area.

In the U.S., many universities have worked on the establishment of undergraduate curricula for educating "life scientists capable of mathematics". Meanwhile, Japan has no national policy or movement for promoting cooperation and integration between the life sciences and mathematics.

Progress in a new area cannot be achieved without recruiting a certain number of researchers in that area. In order to reach critical mass, it is necessary to establish a program targeting a large number of researchers or students. For the nationwide promotion of linkages between life science and mathematics, these actions are suggested: (i) establishment of divisions within governmental agencies to be responsible for promoting and supporting mathematics, (ii) enrichment of mathematics education for life science majors and (iii) creation of opportunities (research institutes) for cooperative research between life scientists and mathematicians.

(Original Japanese version: published in April 2005)

Information and Communication Technologies

2 Semantic Web Technologies for Service Description and Knowledge Processing

p.24

The amount of information available on the web has been growing explosively, and it is projected to reach 100 times today's size in the next few years. Technology that provides innovative services by combining these growing data sources is referred to as a "web service." The goal of a web service is to assimilate different description formats of information sources and to provide for each demanded service a description format adapted to it.

An increasing volume of information, however, is making it more difficult than ever to find the desired information. Conventional search engines that depend on statistical operations to rank search information are already having difficulty in returning satisfactory results. To address these problems, Tim Berners-Lee, the inventor of the Web, proposed in 1998 a new scheme for knowledge processing and called it the Semantic Web. The Semantic Web is technology that deals with "semantics," or meaning. It represents in the narrow sense the standard defined by W3C regarding the means of publishing documents for information sharing, and in the broad sense, a range of technologies that address ontology and other semantic aspects of published documents.

Semantic Web technologies could help build advanced information processing environments in which, for example, knowledge can be shared through the Internet. Current trends in web technologies are thus contributing to building environments for more sophisticated knowledge processing and more diverse service applications.

Today, at the frontiers of science and technology, an enormous amount of documents are produced and accumulated through research activities. In the area of new drug development, for example, researchers need to choose the target of experimental verification from a myriad of combinations of drug interactions based on their potential efficacy. Establishing Semantic Web technology will allow information to be structured so that information dispersed across different locations and organizations can be narrowed down semi-automatically. This method of information sharing under a common standard has the potential to dramatically improve the productivity of research and development in areas such as space exploration, bioinformatics, and nanotechnology.

To promote research on semantic and other web technologies, there should be a framework in which projects can be implemented with clearly defined missions that is adapted to interdisciplinary research.

(Original Japanese version: published in April 2005)

3 Developing Human Resources for International Standards

p.34

In international markets, mobile handsets based on Japanese standards are facing an uphill battle, and some Asian markets have even prohibited importation of certain Japanese home appliances. These facts highlight the increasing importance of applying international standards in order to secure competitive advantage in global markets. Meanwhile, many Japanese companies are finding that traditional on-the-job training (OJT) is no longer an effective tool for human resource development, making it more difficult for Japan to nurture human resources for international standards. This trend is not uncommon for other countries, thus, many countries are now launching programs to develop human resources in the field of international standards.

Japan clearly recognizes this need to develop such human resources, as demonstrated in the statements of "Intellectual Property Strategic Program 2004." The problem for Japan is that such recognition has not directly led to implementation of concrete human resource development programs. This is also true in respect of Japanese university education. While seven universities offer courses dedicated to standards, and 21 cover standards issues as part of other courses, there is no concerted effort on a national level, resulting in lack of consistency in education.

To address development of human resources for international standards in an integrated manner, Japan needs to discuss the fundamental problems in this area. There are five major problems: (1) lack of awareness of the growing importance of standards in globalization of the economy; (2) diverse skill sets (such as corporate strategy, finance, public relations, etc.) that are required personnel for standards; (3) absence of a relevant career path for standards personnel; (4) Japan's traditional low awareness of and support for the construction of cross-organizational frameworks and rules, especially for time-consuming strategic activities; and (5) a virtual lack of demand for highly specialized human resources because of traditional stance of merely adopting and conforming to established standards.

Human resource education in standards targets several different groups of people. Besides those directly involved in standards development, it needs to reach users of standards, government officials and academic experts who are concerned with the maintenance and establishment of standards, and corporate strategy makers who use standardization activities for business administration. Therefore, any discussion of such education requires identification of the respective needs of three affected groups: (1) Education for general users including young people, which targets the general public who use or will use standards in future, should be aimed at developing a basic understanding that standards are intellectual assets of human beings and that efforts must be continued into the future to establish and revise standards. (2) Those who are actually working with standards need to be trained to perform practical tasks, such as developing standards, documenting them, and putting them into practice. This type of education has traditionally been provided by companies through OJT, but most companies can no longer afford such activities. (3) Those involved in standards-related strategies should be educated to understand the current situations and future trends concerning standards, and in light of such understanding, to learn about available materials and methodologies with which to achieve desirable goals.

For Japan to effectively promote development of human resources specializing in international standards, we should look beyond direct extensions of current activities and seriously consider establishing a concrete, visible framework such as a "center for the development of standards experts" or a "standards strategy center." Ideally, this institution would undertake such functions as designing strategic human resource education curricula and collecting and disseminating relevant information. It would also pursue cooperation with industry and other related sectors, while promoting active utilization of properly trained and developed human resources.

(Original Japanese version: published in June 2005)

Energy

4 Status and Prospects for the Development of Synthetic Liquid Fuels

— Liquid Fuels Produced from Natural Gas and Biomass —

p.48

Forecasts made by the International Energy Agency (IEA), etc. suggest that the world’s oil demand will outpace supply by around 2015, due in large part to the growing markets in China and India, resulting in a surge in oil prices and disruptions in oil supply.

Specific measures should therefore be taken to diversify fuel sources in preparation for such a dire situation. The diversification of fuel sources improves compatibility among fuels, thereby increasing capacity to accommodate changes in energy supply. In particular, it is paramount that technologies be developed to convert natural gas, biomass and coal into relatively environmentally friendly liquid fuels.

This report addresses five promising liquid fuels that could substitute for oil - i.e., dimethyl ether (DME), gas-to-liquid fuel (GTL fuel), methanol, bioethanol and biodiesel fuel (BDF) - examining their characteristics and status of development from the viewpoints of their security of supply, environmental friendliness and cost effectiveness. It also sheds light on technologies for using synthetic liquid fuels in the power generation, transportation, industrial, and consumer sectors, presenting their status in Europe, North America, Asia and other parts of the world. In addition, challenges in developing and promoting liquid fuels are discussed, with the results described below as policy recommendations.

1. Promotional Measures

(1) Dimethyl ether (DME) should be promoted in consideration of its versatility and environmental friendliness. However, the use of DME as automotive fuel involves construction of basic infrastructures for handling, storage and supply. Likewise, promotion of bioethanol-blend gasoline requires dedicated oil refineries, tank facilities and filling stations - which are needed to prevent the fuel from absorbing moisture. A national initiative should therefore be launched to construct and improve these infrastructures.

(2) Synthetic liquid fuels such as DME, BDF and bioethanol can be produced from biomass resources. A preferential tax system should be adopted in order to increase the competitiveness of these biomass fuels in the domestic market. At the same time, they should be standardized to avoid safety and environmental hazards.

(3) Given the technological and market uncertainties involved, construction of

demonstration plants for DME and GTL fuel would pose too great a risk to the private sector if that sector were to shoulder the entire responsibility. A fixed-term public support system should therefore be put in place to encourage such construction.

2.Technology Development

(1) A pilot plant in Japan has succeeded in producing 7 barrels/day of GTL fuel, using homegrown technology. Industry and government should cooperate to enhance the international competitiveness of this fuel. Specifically, a demonstration plant (capable of producing several hundred barrels per day) should be set up, with the aim of accumulating a meaningful body of operational data by 2010. There is also a need to implement a large-scale demonstration project for domestic production, transportation and consumption of this type of fuel.

(2) In the initial stage of introducing DME, applications for commercial power generation (thermal power generation, etc.), as well as industrial applications (LPG alternatives), should be promoted. Meanwhile, in the medium- to long-term, research and development should be conducted to commercialize applications for automotive fuel.

(3) Feedstocks should be diversified to increase the supply of bioethanol and biodiesel. A medium- to long-term national initiative should therefore be put in place to develop technologies for converting domestic cellulose resources (non-food materials such as wood) into bioethanol, and to produce BDF from palm leaves and residues.

(Original Japanese version: published in May 2005)

Frontier

5 Trends in Space Transportation Systems in Various Countries

— Changes Arising from the Retirement of the Space Shuttle —

p.63

The Japan Aerospace Exploration Agency's (JAXA) H-IIA launch vehicle No. 7 was successfully launched on February 26, 2005, ending over a year of idleness for Japan's basic space transportation system since the launch failure of No. 6. In addition, more than two years after the in-flight break-up of the Space Shuttle, the space transportation system of the US National Aeronautics and Space Administration (NASA), another launch is finally approaching. During those two years, however, the USA changed its space policy, and the Space Shuttle is to be retired within 10 years due to its high costs.

This article will first discuss the movement toward retirement of the Space Shuttle. It will then look at post-Shuttle space transportation systems in terms of five broad categories: (1) manned space transportation systems, (2) transport of supplies to the International Space Station, (3) expendable launch vehicles, (4) deep space exploration beyond the Moon, and (5) reusable launch vehicles. Next, it will discuss projects currently in development or operation in various countries. Finally, the article will examine the appropriate policy for Japan on space transportation systems in light of this international competition on development.

Regarding manned space transportation systems: Following completion of the International Space Station (ISS) now under construction, NASA plans to carry out manned exploration of the Moon and Mars, and is attempting to develop the

Crew Exploration Vehicle (CEV). Russia plans to develop the new six-astronaut Kliper spacecraft. In Europe, France and Germany have begun competing in the development of manned spacecraft. China is also steadily expanding its own plans for manned space flight.

To address transport of supplies to the International Space Station, Japan's H-2 Transfer Vehicle (HTV) and Europe's Automated Transfer Vehicle (ATV) are in development. There is an increased likelihood that Japan will apply its own technology to help supply the ISS following retirement of the Space Shuttle. Japan plans to launch an HTV technical demonstration craft in 2008, while Europe is aiming to precede that with the first ATV launch in 2006.

Meanwhile, due to factors such as the longer life of commercial satellites, demand for satellite launches by expendable launch vehicles is expected to be low at only 20 to 30 per year. Major commercial launch corporations must compete for orders. The USA has developed two types of evolved expendable launch vehicles in the heavy class. The Atlas V has succeeded as a result of its performance goals having been lowered, while the Delta IV is yet to be completed. In addition, Sea Launch Co., with no land-based launch sites, is a new entry in the race. Although it started later, Sea Launch is gradually building a record of geostationary satellite launches. China is steadily developing its new launch vehicle, the Long March 5 series. In Japan, transfer of launch service of the H-IIA launch vehicle to the private sector will establish regular launch operation, while the necessary research for development of an augmented H-IIA that can launch larger satellites is also underway by JAXA.

In the field of deep space exploration, various countries have launched probes to the Moon, Mars, etc., while Japan's project for a Sample Return mission to an asteroid is in progress.

Space solar power systems (SSPS) are vast space structures developed to help address the energy crisis. In order to launch them efficiently, reusable launch vehicles with low transport costs must be realized. These types of systems have suffered a series of failures in various countries, but research and development is ongoing.

Based on development trends in various countries, this article makes three recommendations for how Japan should proceed with its space transportation systems: (1) implement use of the HTV, (2) maintain and develop technology for expendable launch vehicles, and (3) foster basic technologies through development of reusable launch vehicles. Development of Japan's H-2 Orbiting Plane (HOPE) has been suspended, but it should be used to foster basic technology through repeated small-scale demonstrations.

(Original Japanese version: published in June 2005)

Science and Technology Policy

6 The Current Status and Future Role of Senior Scientists in Universities
— Effective Use of the Senior Generation of Researchers —

p.77

Japanese have the world’s longest life expectancy and they have also remarkable for its low birth rate and aging population. Japan’s “dankai generation” (baby boomers) is now approaching retirement age. This is expected to have a major impact on Japanese research and development. However, it is also a problem that we share with other developed countries. In this article, we look at the measures being taken in various overseas societies, examine the contributions this generation of senior researchers can make to Japanese science and technology, and offer some proposals.

Large numbers of baby boomers will retire between 2007 and 2010. The significant economic impact of these impending retirements - the so-called “The year 2007 problem” - is now attracting attention. This generation is large and has a tremendous impact on Japan’s economy. The estimated loss to the national GDP will be ¥16 trillion.

At the same time, this generation is rich in experience and expertise, and remains vigorous and active. However, systems for utilizing the potential of those senior-generation researchers who possess both ambition and ability are still sadly lacking.

Based on the above perspective, we propose the following in order to enable ongoing utilization of senior researchers as valuable human resources:

(1) Activity in universities

Almost all Japanese universities have a mandatory retirement system based on age. Universities in North America allow researchers to continue working, regardless of age, as long as they are able to secure outside research funding. In addition, many American and Canadian professors in universities have established venture corporations. Systems such as these, which allow capable people to continue their research beyond notional retirement age, probably play an important role in enabling North America to maintain its technical prowess. Japan should also allow scientists able to obtain funding to continue their research at universities. A system that bases retirement on research results rather than on a mandatory age should also be implemented. And, senior scientists could be utilized in the remedial education that is carried out at many universities to address the varying academic levels of students. In fields less popular with students, such as nuclear power and electrical power, there is a serious danger that the retirement of senior personnel who have been continuously active in those fields, from postwar development to application, could result in technical expertise not being passed on. Utilization of senior scientists is an optimal requirement for ensuring continuity of knowledge and techniques in fields where the number of scientists is declining. Now is the time to build networks for technical succession.

(2) Activity in other organizations

Because industry-academia collaboration has been increasing in recent years, if senior researchers were to become free agents able to join TLOs and other organizations they would be well-placed to fill management roles in such areas as obtaining and managing patents, linking universities and corporations, and so on. Another proposal: Consider using public funds to establish responsible but low-risk, small, university-generated enterprises, such as research programs in rented laboratory space. If senior scientists can utilize their experience and work as managers in collaboration with younger scientists, significant mutual benefits could result.

Also seen in other academic societies are examples of organizations becoming engaged in such activities as providing intellectual services that utilize the experience of senior researchers, establishing NPOs through senior scientists at local universities, and working to develop local industry and universities. Seniors are active as volunteers to assist developing countries, in giving science lectures that welcome children, and in many other areas where their age is not seen as a handicap.

Developing systems that provide senior researchers with diverse choices will help to address some of the research resource issues arising out of a declining birth rate, an aging society, and decreasing interest in science.

(Original Japanese version: published in May 2005)

1

Science and Technology Policy for Promoting Research Cooperation between Mathematics and the Life Sciences in the United States

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1 Introduction

Mathematics has historically played an important role in the development of the life sciences. Especially in post-Mendelian genetics and molecular biology, mathematics and mathematicians have contributed to the development of various theories and models for analyzing and understanding the complexity of life and heredity[1,2].

A recent example of such a mathematician is Eric Lander (Director of the Broad Institute, MIT), a molecular biologist with an educational and research background in mathematics, who made a great contribution to the promotion of the Human Genome Project with his mathematical model for genetic analysis[3].

The U.S. and European countries have traditionally promoted interdisciplinary research or integrated research, and researchers themselves have actively participated in new research areas. For example, it was not geneticists who played the central role in advancing molecular biology; it was researchers with physics backgrounds, who were newcomers to the area of life science[4].

The significance of life science research has increased since the 1990s, based on the belief that progress in this area is a significant driver of the national economy. Consequently, many governments have allocated larger budgets to life science research and placed greater emphasis on policies for development of the field.

The Human Genome Project was not only the first large-scale project but also a turning point in the history of life science; the research style has been shifted from the conventional individual basis to a group basis. Moreover, the project has demonstrated that cooperation with other disciplines to form interdisciplinary or integrated areas can greatly advance life science itself. Since computer science, mathematics and information science contributed significantly to the promotion of the project, the U.S. and European countries have begun to explore a variety of science and technology policies based on the belief that cooperation between life science and these disciplines is necessary for the future development of life science. “Mathematics in Biology” was featured in Science (vol. 3030, No. 5659, 2004), the journal of the American Association for the Advancement of Science (AAAS) in Table 1.

This article surveyed recent developments in the U.S., such as federal support for mathematics research funding, efforts to promote research cooperation between life science and mathematics, and policies for educating life scientists for mathematical competence. The article also discusses measures for promoting research cooperation between life science and mathematics in Japan, which is a necessity for further development of life science in our country.

2 U.S. Budget for Mathematics Research

In order to clarify the current status of federal support for mathematics in the U.S., the dollar amounts of federal research budgets categorized by research field, and of mathematics research funds categorized by agency are presented below.

2-1 U.S. research budgets by research field

As shown in Figure 1, federal support for life science has increased dramatically, especially since 1998. This dramatic increase can be attributed to the 5-year plan for doubling the NIH budget that began in FY 1999. FY 2003 was the final year of the plan, and the budget increase then reached a plateau in FY 2004. Nevertheless, life science continues to enjoy a large share of the entire budget (28.6 billion dollars, approximately 3 trillion yen in FY 2003). By comparison, the Japanese research budget for life science in 2003 was 436.2 billion yen, which was about one-seventh of that in the U.S.

The U.S. research budget for engineering increased in FY 2001 and has remained constant since then. Meanwhile, the research budget for mathematics & computational science has been very low (3.3 billion dollars, approximately 350 billion yen in 2003), corresponding to only one-tenth of that for life science. However, the budget has slowly increased over this decade and is approaching the budget for environmental science[5].

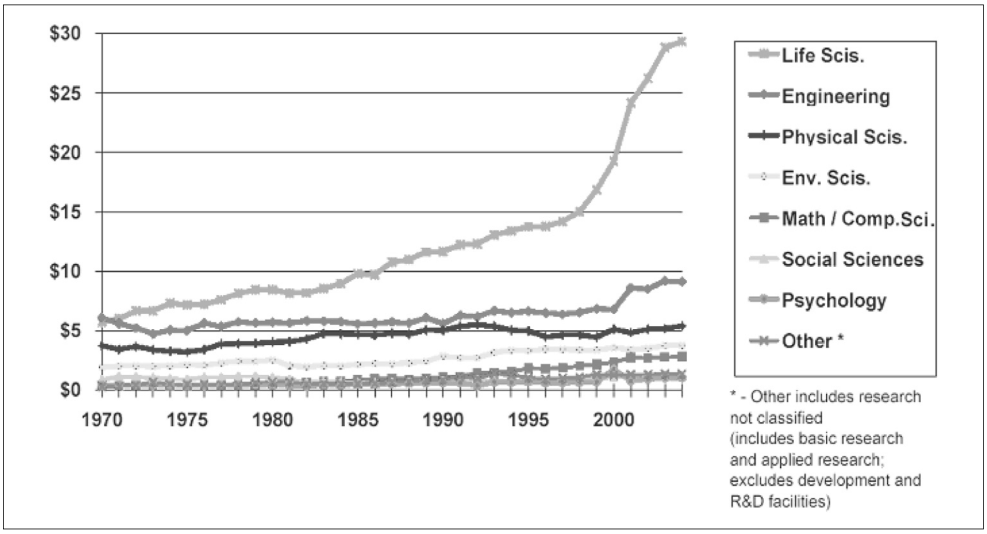
2-2 U.S. federal funding of mathematics research

Total U.S. federal funding of mathematics research is approximately 375 million dollars[6], half of which is funded by the National Science Foundation (NSF) and the rest by the Department of Defense (DOD), the National Institutes of Health (NIH) and the Department of Energy (DOE). In addition, the National Aeronautics and Space Administration (NASA), the Environmental

Table 1 : Science vol.303, No.5659, 2004

Mathematics in Biology
Biology by the numbers : Introduction to the current status and significance of mathematical approaches to biological issues
Life's patterns: No need to spell out? : Simulation of a vast array of biological structures
The new math of clinical trials : Mathematics for integrating past and current data from clinical trials
Making sense of a heart disease gone wild : Mathematics for integrating past and current data from clinical trials
Introductory science and mathematics education for 21st-century biologists : Need for mathematics education for 21st-century biologists
Uses and abuses of mathematics in biology : Recent involvement of mathematics in biology
Evolutionary dynamics of biological games : Analysis of biological evolution based on game theory
Inferring cellular networks using probabilistic graphical models : Analysis of genetic and metabolic pathway networks using mathematics

Figure 1 : Trends in federal research funding by research field ($ billion)



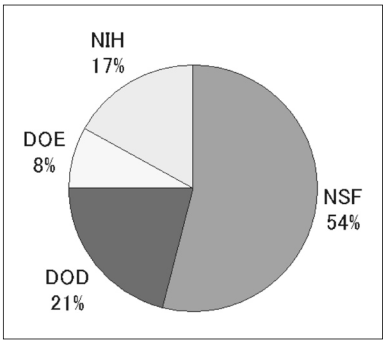
Source: AAAS website

Protection Agency (EPA) and the National Institute of Standards and Technology (NIST) of the Department of Commerce also provide some funding to mathematics research.

Interestingly, the NIH, the largest biomedical research organization in the U.S., has funded 63 million dollars (approximately 6.6 billion yen, 1 dollar = 105 yen).

These research funds are allocated to researchers through the National Institute of General Medical Sciences (NIGMS) and the National Institute for Biomedical Imaging and Bioengineering (NIBIB), both of which are research institutes at the NIH. The main target areas for research support by NIGMS are population biology, systems biology, macromolecular structures and bioinformatics, and those of the NIBIB are computer science, model development and bioinformatics[6].

Figure 2 : Federal funding of mathematics research by agency in FY 2005 (Total of all agencies: 374.5 million dollars)*



*From Message for FY 2005
Source: Prepared by STFC based on reference[6]

3 Efforts to Promote Research Cooperation between Mathematics and Life Science in the U.S.

In recent years, the significance of research cooperation between mathematics and life science has been argued in the U.S. Such argument has been triggered by the fact that the large government budget for life science research has not produced any recognizable social effect. For example, the number of patients with cancer or other lifestyle-related diseases has not decreased. Also, a complete cure for AIDS has not been developed. On a global scale, large-scale epidemics of emerging and reemerging infectious diseases have occurred. Despite progress in life science research, the number of newly developed drugs introduced into the market has actually decreased over this decade.

To improve on this situation, it was recognized that new blood was needed in the life sciences and that integration of the life sciences with other disciplines would achieve this.

Professor Cohen, of Rockefeller and Columbia Universities, expressed his optimism about research cooperation between mathematics and life science thus: “mathematics is biology’s next microscope, and biology is mathematics’ next physics”.

The following section introduces the actual efforts made by U.S. federal agencies for

Table 2 : U.S. federal agencies funding mathematics research (FY 2005)

Governmental agency	Department	Amount (million dollars)
NSF	Division of Mathematical Sciences (DMS)	202.3 (21.2 billion yen)
DOD	AFOSR: Air Force Office of Scientific Research ARO: Army Research Office DARPA: Defense Advanced Research Projects Agency NSA: National Security Agency ONR: Office of Naval Research	30.9 (3.2 billion yen) 10 (1.1 billion yen) 23 (2.4 billion yen) 3.5 (0.4 billion yen) 12.4 (1.3 billion yen)
DOE	Mathematical, Information, and Computational Sciences Division (MICS)	29.3 (3.1 billion yen)
NIH	NIGMS: National Institute of General Medical Sciences NIBIB: National Institute for Biomedical Imaging and Bioengineering	35 (3.7 billion yen) 28.1 (3 billion yen)

1 dollar = 105 yen

Source: Prepared by STFC based on references promoting research cooperation between mathematics and life science.

3-1 *Workshop sponsored by U.S. federal agencies*

On February 12 and 13, 2003, a joint NSF and NIH symposium on “Accelerating Mathematical-Biological Linkages” was held at the NIH. Attendees at the meeting discussed measures for accelerating research cooperation between mathematics and biology, and the research areas to be targeted.

The prescribed number of participants was 150, but more than 170 researchers, technicians and educators from areas related to life science and mathematics gathered at the meeting[7].

At the workshop, various discussions and suggestions were made on (1) institutional action, (2) education action and (3) researcher action.

(1) Institutional action

(i) Foundation of a national institute responsible for the expansion of NSF-NIH linkage (research funds etc.) and research in interdisciplinary areas between mathematics and life science.

(ii) Establishment of a database integrating all kinds of data related to life science, such as genomics and proteomics.

(iii) Establishment of standards to facilitate comparison of data or models published by different researchers.

(iv) Association among academic societies and educational institutions aimed at linking mathematics and life science.

(2) Education action

(i) Establishment of new programs for postdoctoral fellowships in interdisciplinary areas.

(ii) Hosting of workshops targeting deans of mathematics and life science departments for creating international curricula for interdisciplinary undergraduate education.

(iii) Establishment of positions for teachers in the interdisciplinary area between life science and mathematics.

(iv) Establishment of summer educational programs for high school students co-managed by mathematics and life science professionals.

(v) The preparation of teaching materials for elementary and junior high schools regarding the linkage between mathematics and life science.

(3) Researcher actions

(i) Preparation of a list of the ten most challenging tasks in the mathematics-biology interdisciplinary area.

(a) Establishment of models for systems at various levels, from cellular to human, and extending to the social environment.

(b) Modeling of complex metabolic and signaling pathways and interactive networks between biological substances.

(c) Integration of the probability theory for understanding uncertainty and risks.

(d) Further understanding of computer science - theories established from agent models or computer calculation.

(e) Understanding of data mining and simultaneous inference (requires a theory that goes beyond Bonferroni's method).

(f) Analysis of gene and protein structures using graph theory-based approaches.

(g) Modeling of brain functions.

(h) Development of computational science-based methods that allow the modeling of life processes with various spatial and temporal sizes.

(i) Establishment of ecological prediction methods.

(j) Analysis of the effect of data errors on the understanding of life science (the extent to which erroneous data may affect correct understanding of life science, e.g., missequencing)

(ii) Hosting of domestic meetings related to interdisciplinary areas between life science and mathematics.

(iii) Hosting of meetings and workshops on the education of researchers, providing opportunities for mathematicians to study life science and for life scientists to study mathematics.

(iv) Integration of databases and online journals to promote the publishing of papers in interdisciplinary areas between life science and mathematics.

3-2 Efforts made by funding agencies

(1) Research grants promoting interdisciplinary research between life science and mathematics

Based on the recognition that further research needs to be promoted in interdisciplinary areas between life science and mathematic, NSF and NIH jointly launched a research grant program beginning in 2002. To date, applications have been invited three times, i.e., once a year from 2002 to 2004. The next application deadline is June 30, 2005.

The program was originally titled "Joint DMS/NIGMS Initiative to Support Research in the Area of Mathematical Biology," but was changed to "Joint DMS/BIO/NIGMS Initiative to Support Research in the Area of Mathematical Biology" in 2004, due to the participation of the Directorate for Biological Sciences (BIO) of NSF.

The annual budget for the fund is 6.5 million dollars (680 million yen), of which NSF invests 2.5 million dollars (260 million yen) and NIGMS, acting under the NIH, invests 4 million dollars (420 million yen). The fund is allocated to twenty applicants per year, each receiving 100,000 to 400,000 dollars (10.5 million to 42 million yen) per year for 4-5 years.

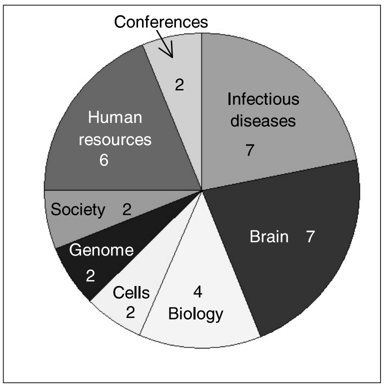
Six program directors (three each with doctors' degrees in life science and mathematics) invite questions from applicants, e.g., whether the suggested project fits the program[8].

(2) Analysis of subjects of life science-related research projects receiving NSF-funding for mathematics

As mentioned earlier, the NSF is responsible for more than half of the U.S. public funding that is invested in mathematics research. The NSF has designated mathematics as a priority area for the years 2000-2006 and aims at increasing the research budgets for mathematics.

In order to examine whether interdisciplinary areas between life science and mathematics have actually been created at the research level, this section analyzes the subjects of research projects adopted by NSF that are related to both mathematics and life science.

Figure 3 : Research areas of Mathematical Biology projects started from 2004



Source: Prepared by STFC

Award search was used to search the NSF grants. First, "*bio* and *math*" were used as keywords to search for standard grant research projects started after 2001. Standard grants are ordinary grants available to researchers on an individual basis. Of 1,000 research projects started after 2001, 417 (more than 40%) were retrieved using the above keywords, which included projects categorized as ecology, mathematical biology, systems biology & biodiversity, population dynamics, computational mathematics, applied mathematics, etc. This indicates that studies in interdisciplinary or integrated areas between various life science-related areas and mathematics are in progress.

In order to examine research projects for a particular interdisciplinary area between mathematics and life science, research projects in "mathematical biology" were analyzed.

Of the projects started from 2001, 51 were classified as mathematical biology, and more than half (32) were started in 2004.

By research subject, the most common subjects were infectious diseases and brain, particularly infection/ transmission models and neural networks. Projects concerning the development of educational programs for human resources in mathematics-biology interdisciplinary areas also had large shares (Figure 3). For reference, the titles of pure biology- and cell-related research projects are listed in Table 3.

Table 3 : List of titles of projects classified under pure biology- and cell-related research areas among Mathematical Biology projects adopted in 2004

Area	Title	Research institute
Cells	Two-dimensional cell motility model	Worcester Polytechnic Institute
	Dynamic regulation of the cell cycle by the proliferation control (RB) and death control (p53) oncogenes	Virginia Polytechnic Institute and State University
Biology	Dynamical systems in biology	Arizona State University
	Competitive coexistence and life cycle stages	University of Arizona
	Nonlinear dynamics of oscillator networks (Biological clock including the synchronous firing of cardiac pacemaker cells, etc.)	Cornell University
	Spatial Heterogeneity, nonlocal interactions and time delay in epidemiological and biological spread	University of Miami

Source: Prepared by STFC

4 Undergraduate Programs to Educate Life Scientists for Mathematical Competence

For the development of next-generation life scientists capable of using mathematics effectively, educational reforms have been promoted, mainly in undergraduate education.

4-1 Proposal for mathematics education in biology-related departments at universities

Professor Botstein (Department of Molecular Biology, Princeton University) et al. have proposed the need for mathematics education for 21st-century biologists[9]. Students majoring in biology (including those proceeding to medical schools) are generally required to take one or two semesters each of mathematics and physics and two to four semesters of chemistry, but most of the students are not enthusiastic about taking these courses. At the same time, faculty who teach these courses are not as enthusiastic about teaching the biology majors as they are about teaching physics, chemistry or engineering majors. Moreover, the time allocated for these courses differs greatly between curricula for biology majors and physics, chemistry or engineering majors.

Professor Botstein et al. quoted the words of Galileo, "the book of nature is written in the language of mathematics" to express their concern about biology majors being deprived of the natural science education essential for acquiring quantitative thinking, which is necessary for understanding complex systems involving life or organisms.

Professor Botstein has articulated the need for an integrated introductory curriculum (for the first and second years of undergraduate school) in which quantitative thinking for biology students is given significant emphasis. He suggests that, instead of teaching physics, chemistry and mathematics separately as in conventional curricula, they should introduce these disciplines systematically in context with the unsolved biological problems.

4-2 Mathematics education program for biology majors

Professor Gross, a Professor of Ecology and Evolutionary Biology and Mathematics at the University of Tennessee, and the President of The Society for Mathematical Biology, is committed to mathematics education for biology majors.

Professor Gross provides "Resources for Mathematics Education for Biology Students" at his website to enable free browsing and downloading of lectures given to biology students in various universities (some links may be broken).

Professor Gross himself provides an integrated lecture on mathematics and life science to biology majors at the University of Tennessee. For example, he asks his students to go outside and gather data on the size of leaves on trees. Then, he asks them questions such as "is the leaf width correlated with the length, does the relationship differ among species," or "what are the factors affecting leaf size, why do some trees have longer

Table 4 : Example of a mathematics lecture for biology students

University	Lecture title
Florida State University http://www.math.fsu.edu/~mesterto/biocalc.html	Biocalculus
Kennesaw State University http://science.kennesaw.edu/~mburke/modules/	Mathematical Modules in Biology and Chemistry
University of British Columbia (Canada) http://www.zoology.ubc.ca/~bio301/	Biomathematics
University of South Carolina http://www.math.sc.edu/~miller/411/411.html	Mathematical biology
North Shore Long Island Jewish Health System Bio-repository http://www.nslij-genetics.org/bioinfotraining/	On-line List of bioinformatics courses

links confirmed on April 11, 2005 Source: Prepared by STFC based on the above websites

leaves than others," and tells them to set up many hypotheses. Finally, students are asked to evaluate each of the hypotheses by analyzing the gathered data[10].

4-3 The "BIO 2010" report

As a part of the NIH program to reform undergraduate education, The National Research Council completed a report, "Bio 2010: Transforming Undergraduate Education for Future Research Biologists" in 2003[10]. The report was sponsored by the NIH and Howard Hughes Medical Institutes, both of which are known for providing significant funding to medical and biological research[9,10].

The report emphasizes that the future development of life science relies on research cooperation between life science and other disciplines, especially mathematics & computational science, chemistry, physics and engineering. It states that undergraduate curricula need to be revised to include education in interdisciplinary areas between such disciplines and the life sciences.

5 Status of the Linkage between Life Science and Mathematics in Japan

This chapter analyzes the current status of "research cooperation between life science and mathematics" and "education of life scientists for competence in mathematics" in Japan.

5-1 Views of life scientists on interdisciplinary integration

Are Japanese life scientists willing to cooperate with mathematics or any other scientific fields?

The attitudes of researchers toward interdisciplinary studies were surveyed in "FY 2003 Survey of the Actual State of Research Activities in Japan" conducted by the Research and Coordination Division, Science and Technology Policy Bureau of the Ministry of Education, Culture, Sports, Science and Technology[11].

The results showed that more than 60% of the researchers are interested in interdisciplinary studies (Figure 4). By discipline, the proportion of researchers who expressed interest was lower in life science compared to that in information & communication, environment, energy or material & nanotechnology.

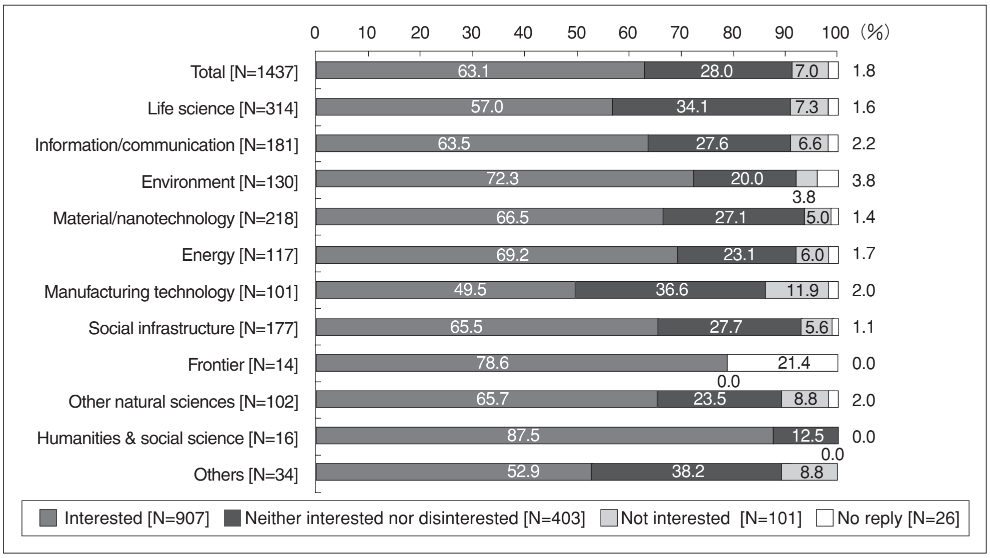
Those who had replied they were "interested" were further asked why they were interested. The most common answer was "because it is necessary to promote studies responding to social needs," and the second was "because it is necessary for the creation of new disciplines".

5-2 Is there any movement for promoting the integration of life science and mathematics?

In Japan, governmental agencies or funding agencies have not implemented any policy to promote the integration of life science and mathematics.

Among the projects that were allocated science

Figure 4 : Researchers' interest in the integration of humanities and science, and interdisciplinary research (by scientific field)



Source: Reference[11]

Table 5 : Projects categorized under life science-mathematics interdisciplinary research that received science and technology-related budgets in FY 2004

Project title	Governmental agency	Responsible organization
Cell/Biodynamics Simulation Project	Ministry of Education, Culture, Sports, Science and Technology	Keio University etc.
Institute for Bioinformatics Research and Development	Ministry of Education, Culture, Sports, Science and Technology	Japan Science and Technology Agency (JST)
Bioinformatics Infrastructure Development	Ministry of Economy, Trade and Industry	Japan Biological Informatics Consortium
Development of Analytical Methods for Intracellular Network Structures	Ministry of Economy, Trade and Industry	New Energy and Industrial Technology Development Organization (NEDO)

Source: Prepared by STFC

and technology-related budgets in FY 2004, four could be categorized as integrated research between life science and mathematics (Table 5). However, these projects focused mainly on bioinformatics and computer simulation, and none of them aimed at promoting the integration of life science and mathematics.

Moreover, among the research projects conducted under Exploratory Research for Advanced Technology (ERATO) of the JST, three could be categorized as integrated research between mathematics and life science: the "Kitano Symbiotic Systems Project (1998-2003)", a systems biology study concerning interpretation of each biological phenomenon as a system and its analysis by computational science, the "Aihara Complexity Modelling Project (2003-2008)", a study of the application of computation to complexity, including the establishment of dynamic data processing principles for a bioinformatics network, and the "Shimojo Implicit Brain Functions Project (2004-2009)", a brain science study concerning the learning mechanism. In addition, the Center for Developmental Biology at RIKEN has a research team working on "Systems Biology" under its Creative Research Promoting Program.

However, these projects are all based on the ideas of individual researchers. In the U.S., science and technology policies established by public organizations have promoted the integration of mathematics and life science, but Japan still lacks such a policy.

5-3 *Is there any movement to educate life scientists for mathematical competence?*

Japanese universities are not planning to initiate any undergraduate programs to provide life science majors with math abilities. However, there are some efforts to develop human resources specialized in bioinformatics, an interdisciplinary area between life science and information science.

The "University of Tokyo - Undergraduate Program for Bioinformatics and Systems Biology (UPBSB)" started in 2001, with the support of Special Coordination Funds for Promoting Science and Technology of the Ministry of Education, Culture, Sports, Science and Technology. This program aims at providing an undergraduate education appropriate for developing human resources in bioinformatics with strong support from faculty specialized in the information and life sciences. They consider that bioinformatics education requires a balance among (i) professional education in bioinformatics, (ii) basic education in information science and (iii) basic education in life science, which is reflected in the curriculum. Meanwhile, Special Coordination Funds for Promoting Science and Technology has also supported the Education and Research Organization for Genome Information Science to start the Bioinformatics Education Program from 2002 at Bioinformatics Center, Institute for Chemical Research, Kyoto University.

A research cluster devoted to "bioinformatics" at Keio University's Shonan Fujisawa Campus aims at clarifying life phenomena by simulating genes, genomes and cells in silico and works on research projects such as bioinformatics, the E-Cell Project and the E-Neuron Project.

6 Difference between Japan and the U.S. in Science and Technology Policies

This chapter explores the difference between Japan and the U.S. in science and technology policies related to cooperative research involving both the life sciences and mathematics, and discusses what we should do in the future.

6-1 Paths to accelerate research cooperation between life science and mathematics in U.S. and Japan

The U.S. and Japan are going in completely different directions to accelerate cooperative research between life science and mathematics. The U.S. aims at (i) educating life scientists to be competent in mathematics as well by changing the undergraduate curriculum and (ii) helping researchers expand their research areas by establishing programs that can provide knowledge of mathematics or life science to postdoctoral fellows or those who already have become life scientists or mathematicians, and attempts to (iii) attract researchers into new areas by funding research projects in interdisciplinary areas between mathematics and life science. These measures cover researchers from any field, so more and more researchers are likely to enter this new area in the future.

Meanwhile, Japan emphasizes the education of a limited number of elite researchers specialized in bioinformatics and systems biology, both of which are interdisciplinary areas positioned between life science and information science or computational science. In recent years, the importance of systems biology research has been emphasized worldwide[12]. Japan has taken the initiative in these areas but we may lose our preeminence at any moment. In the U.S., Harvard Medical School has founded the world's first department of systems biology, and the NIGMS of the NIH, which promotes the linkage between mathematics and life science, also supports systems biology. To date, the U.S. has more than ten public and private organizations serving as central bases of research programs related to systems biology[13]. Such a swift move by the U.S. can be attributed to its long history of science and technology policies promoting the linkage between mathematics and other research fields.

6-2 Research cooperation between life science and mathematics in Japan in the future

Considering these circumstances, it is necessary to change our direction from the education of a few elite researchers to the fostering of many capable researchers who can conduct research in new interdisciplinary areas between the life sciences and mathematics. These researchers are expected to play important roles not only in bioinformatics and systems biology but also in the creation and development of other new research areas based on mathematics.

Progress in a new area cannot be achieved without recruiting a certain number of researchers into that area. In order to ensure the critical mass, it is necessary to establish a program targeting a large number of researchers or students to develop life scientists capable of doing mathematics.

Japanese universities or academic societies are not very active in proposing research cooperation between life science and other disciplines. This may be due to the fact that life scientists in Japan have little interest in integration with other disciplines. Japanese mathematicians are also reluctant to cooperate with other disciplines or conduct studies in applied mathematics. Therefore, we must reform the attitudes of the researchers themselves. Such reform may be implemented through an accumulation of small, pilot projects responding to industry needs and requiring cooperation between mathematicians and life scientists for their success.

Moreover, the education of next-generation life scientists requires the enrichment of mathematics education for students at all levels from the elementary grades through high school, by means such as a cooperative education program between mathematics and the life sciences.

7 Conclusions and Suggestions

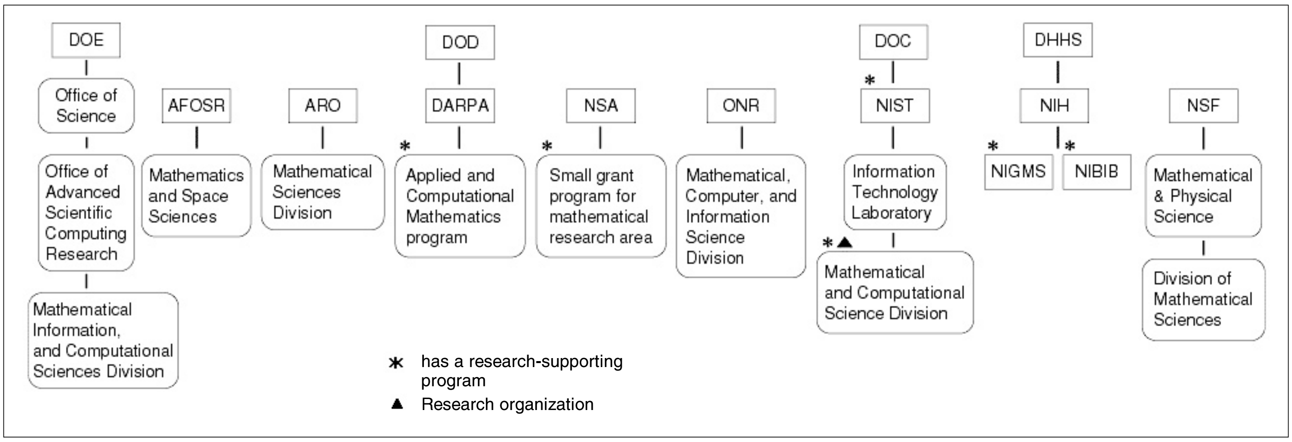
The following activities are suggested for promoting a linkage between life science and mathematics in Japan.

(1) Establishment of divisions responsible for promoting and supporting mathematics within governmental agencies

The U.S. government has many divisions that support research in mathematics, including the Division of Mathematical, Information, and Computational Sciences of DOE, Division of Mathematical Sciences of the NSF, the Mathematical and Computational Sciences Division of the Information Technology Laboratory of the NIST, the AFOSR (Air Force Office of Scientific Research), ARO (Army Research Office) and DARPA (Defense Advanced Research Projects Agency) (Figure 5). With the aim of supporting cooperative research between life science and mathematics, the U.S. government has established a cross-agency funding system represented by the linkage between the NIH and NSF, rather than the conventional vertically divided funding systems.

Meanwhile, the Japanese government has no division responsible for supporting mathematics research similar to those in the U.S., nor any system for planning science and technology policies related to mathematics. In order to develop interdisciplinary areas between mathematics and life science, divisions responsible for supporting mathematics must be established within governmental agencies. Additionally, we must increase competitive research funds supporting interdisciplinary areas between mathematics and life science, and take

Figure 5 : U.S. public organizations and divisions supporting mathematics-related research



Source: Prepared by STFC

measures to attract researchers to these new areas.

(2) Enrichment of mathematics education for life science majors

Mathematics education for life science majors is essential to promote linkage between life science and mathematics. In addition to conventional mathematics courses as part of the basic curriculum, multidisciplinary educational programs should be established, such as the analysis of life science issues using mathematics.

It is also important to establish opportunities for mathematics majors to acquire knowledge of life science.

If such educational programs cannot be established or implemented due to shortage of staff, overseas faculty can be recruited.

(3) Creation of opportunities (research institutes) for cooperative research between life scientists and mathematicians

New research areas cannot be created without an intense exchange of ideas among researchers from different disciplines. Therefore, we must provide life scientists and mathematicians with opportunities to conduct joint research.

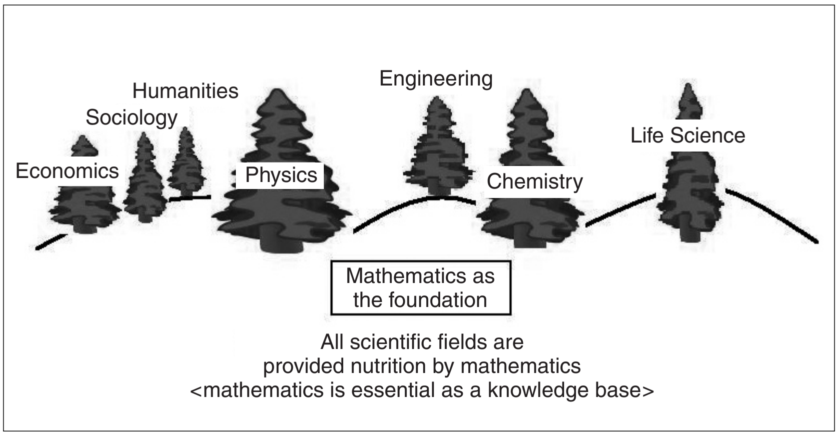
One effective approach could be to establish a research funding system for joint research that would allow mathematicians to participate at existing life science research institutes or life scientists at mathematics research institutes.

In the U.S., there are many mathematics research institutes that meet international standards; these institutes are actively engaged in applied mathematics research, i.e., joint research between mathematics and life science or many other scientific fields. In the U.K., a research institute named CoMPLEX (Centre for Mathematics and Physics in the Life Sciences and Experimental Biology) was founded recently, where life scientists or medical researchers tackle the challenging tasks of life science or medicine in cooperation with mathematicians, physicists, computational scientists or engineers. This institute also serves as an educational institute and started a doctoral course in 2004.

Meanwhile, Japan has only one mathematics research institute meeting international standards, i.e., the Kyoto University Research Institute for Mathematical Sciences. However, the institute mainly focuses on pure mathematics research, so Japan actually has no research institute that focuses on applied mathematics or interdisciplinary areas involving mathematics and other disciplines. Thus, it is important to establish research institutes intended for applied mathematics, where interdisciplinary research between mathematics and life science or many other areas can be conducted for promoting the future development of science and technology in Japan.

Furthermore, the following activities are also important for the advancement of mathematics.

Figure 6 : Mathematics as the foundation



Source: Prepared by STFC

(4) Reinforcement of research cooperation between companies and universities

We must reinforce research cooperation between companies and universities and establish a system that encourages industrial issues to be effectively addressed by facilitating cooperation between mathematicians and company-employed researchers in other areas. This should promote the industrial application of mathematics and the creation of new research fields.

(5) Improvement of the public understanding of mathematics

We must establish a nationwide policy that brings students in all areas, and the public, to recognize the importance and significance of studying mathematics. Such a policy is essential to establishing a knowledge and industrial base for the application of mathematics to a wide variety of areas and its linkage and integration with other disciplines (Figure 6).

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2

Semantic Web Technologies for Service Description and Knowledge Processing

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1 Introduction

Web service refers to technology that combines multiple data sources accumulated on the web to provide users with desired information services. The Semantic Web, technology that deals with "semantics," represents in the narrow sense the standard defined by W3C regarding the means of publishing documents for information sharing, and in the broad sense, technology that addresses ontology and other semantic aspects of published documents. These technologies could help build advanced information processing environments in which, for example, knowledge can be shared through the Internet. Current trends in web technologies are thus contributing to building environments for more sophisticated knowledge processing and more diverse service applications.

Technologies in this area have been rapidly standardized recently and are becoming more important in industry. Among a range of structured technologies called web services, this report focuses on the Semantic Web and describes its trends. In some research fields in science and technology, there has been a growing need for knowledge processing, which is a goal of the Semantic Web and is a front-line constituent technology in this technological field. This technology is becoming increasingly significant, notably in bioinformatics, as a tool to derive future directions in research from a massive database of accumulated research results.

Chapter 2 describes trends in information distribution technology focusing on knowledge processing. In other words, it explains how recent advances in web technologies, which have enabled efficient information distribution, have been opening new possibilities in the sophistication of services in the business sector and the utilization of information in the academic research sphere.

Chapter 3 gives an overview, among other web service technologies, of the "ontology" -based Semantic Web technology intended for knowledge processing. This technology is currently being internationally standardized and is actively used for scientific and technological studies. Chapter 4, focusing on the research results presented at major international conferences in recent years on the Semantic Web, outlines research trends as well as how research activities should be promoted in this area. Concluding Remarks are given in Chapter 5.

2 Trends in web service technology

This chapter first outlines how web service technology has evolved, then provides specific examples that imply the ideal forms pursued by current Internet-based services. It then examines the benefits of web services.

2-1 The trend of providing services on the web

Technologies that handle the information available on the Internet have evolved through several steps. The first step was the widespread use of e-mail in the early 1990s and the emergence of the World Wide Web (WWW), through which electronic documents formatted in HTML (HyperText Markup Language) can be published. One characteristic of HTML documents is the ability to express hyperlinks, which act as entrances to other documents. However, this capability alone is insufficient for providing links between published documents.

To complement this, XML (eXtensible Markup Language) was born, allowing electronic information produced by any entity to use a common description format. In XML, the data items that represent the product name and the price in a document, for example, can be defined and identified so that different companies involved in merchandise distribution can share forms and other related documents electronically. Moreover, XML contributes to the structured collection and use of information. Structurally collected information can be easily modified for other purposes. These technological advances have made the collected information, or databases, applicable for diverse uses.

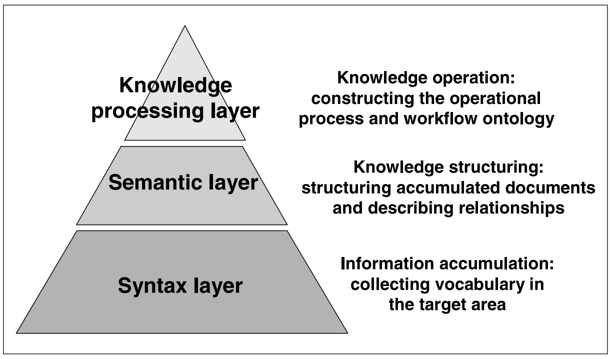
Along with development in sharing and structuring information, environments for document processing and information interoperation have been developed. The programming language called Java, for example, allows information accumulated in XML to be processed to display pages with dynamic movement and enables information to be input from remote places. In other words, these developments have enabled the ability to manipulate documents in various predefined formats in web pages and to provide access to large-scale databases of documented information.

2-2 *Providing ideal services*

These technologies help construct an integrated environment for operating electronically stored information and documents. In particular, the electronic commerce sector has actively introduced electronic information sharing to manage distribution processes. The services offered in this environment are essentially the content of information provided. This raises the question of what would be the ideal forms of service, or information, that the Internet could provide. This question is explored below, although it may seem to be a hypothetical issue.

Suppose that you are going to take several days off to travel. You are visiting a travel agency so that its agent can help you plan a vacation. The essential information in planning a trip is where and when to go. Next, limiting factors such as budget need to be considered. In addition, you may have preferences regarding airline company, seat type, and so forth. To have your travel agent create your travel itinerary and make the necessary arrangements, which are services you expect to receive, you have to supply such information to the agent.

Figure 1 : Conceptual model of knowledge processing in the Semantic Web



Source: Prepared by STFC

The most important element of a good travel agent is the ability to communicate actively with the customer. Naturally, the agent and the customer need to share language, vocabulary, and terms. This is a tacit assumption in human-human communication. The next important element is the ability to make a proposal based on the knowledge of the customer's preferences. This hopefully involves not only a one-way supply of information, such as giving recommendations, but services that meet the known customer needs, such as choosing services that accept discount coupons. Ideally, the agent remembers the personal preferences of the customer so that they are reflected in future travel planning. The agent should also be able to perform the necessary tasks autonomously even when the customer is not present, which means saving the customer waiting if it takes time to complete hotel and ticket booking arrangements.

In short, a good agent collects key information, chooses options according the customer's preferences, and conducts booking and other services with the consent of the customer. In conducting these tasks, the agent needs to share vocabulary with the provider of the information and the customer, and make decisions based on the acquired information.

The amount of information available on the Internet or the web has been growing explosively, and it will reach 100 times today's size in the next few years, according to a projection. There is no doubt that the number of "hits" for searches will become so massive that narrowing down search results will require enormous effort. If this becomes a reality, conventional search engines that depend on statistical operations to rank search information will be no longer able to return satisfactory results. This will raise the ironic problem of inability to find information even if there is plenty of useful information on the web.

The goal of web services is to assimilate different description formats of information sources and to provide a description format for each demanded service that is adapted to it. This allows the selection of services that meet customer needs from a massive information space. If this technology matures, the following web services will become available.

(i) An environment in which people who know little about information technology can easily input and output information
(ii) An Internet world that is accessible as a huge distributed knowledge database
(iii) Creation of new services by integrating data assets that have originally been constructed for different purposes

Web services with such characteristics are expected to contribute, among others, to narrowing the digital divide, addressing aging societies, supporting lifelong study, and controlling diverse information terminals and robots, consequently facilitating aids linked to people's daily lives.

2-3 An overview of Semantic Web technologies

Figure 1 shows a conceptual model of the technologies that help provide these advanced services. The structure can be divided into three tiers: from bottom to top, (i) the syntax layer, (ii) the semantic layer, and (iii) the knowledge processing layer. There are two points of note when hierarchically expressing a software structure. First, the top layer uses the function of the layer below it to implement its own expected function. Second, functions are defined independently among different layers. In other words, the function of the databases constructed using XML and other technologies is used to describe the semantic world, and this description then serves as the base of knowledge processing.

Knowledge processing-based services are conducted by building vocabulary structures called ontologies at the top knowledge processing layer and by describing services that define the relationship among the ontologies. In fact, this hierarchy can be divided into more detailed layers whose specifications have been set up as a standard technology. Chapter 3 further explains this detailed hierarchy known as the "layer cake."

2-4 Possibilities of web services in hot science and technology fields

Some researchers indicate that "service"-related science is essential today, particularly from the viewpoint of innovation policy. Focusing on service is especially important as a direction of development in information technology[1].

Let us take the foresight study conducted by the National Institute of Science and Technology Policy as an example. From all areas of scientific and technological research, it has selected 130 "hot science and technology areas," assumed to be noteworthy in the next 10 years. A closer examination of these areas reveals that, for many of them, the presence of web services and other large-scale information search tools are effective or even indispensable for technological achievements intended in the area.

This applies to the research area of "support for human intelligence," which was selected in the study from the information and communications field, and to "tailor-made medicine" and "biometric personal authentication" in the life science field. These technological areas would benefit from web services.

Similar emphasis on service in the evolution of information technology can be observed in the review results presented by experts in a recent European study on science and technology foresight[10]. This suggests that web services constitute a technological field in which discussion should not be limited to technological advances within the information technology sphere, but should concretely address the possibility of the fusion of web services with other fields and sectors.

3 Structure of Semantic Web technologies

The primary technological schemes for implementing web services are the Semantic Web and UDDI, the latter being explained later. This chapter first addresses the Semantic Web by describing ontology as its key concept, the language known as RDF, which is fundamental to knowledge processing, and the model of service provision. How the Semantic Web relates to UDDI is discussed at the end of the chapter.

3-1 Ontology-based linkage

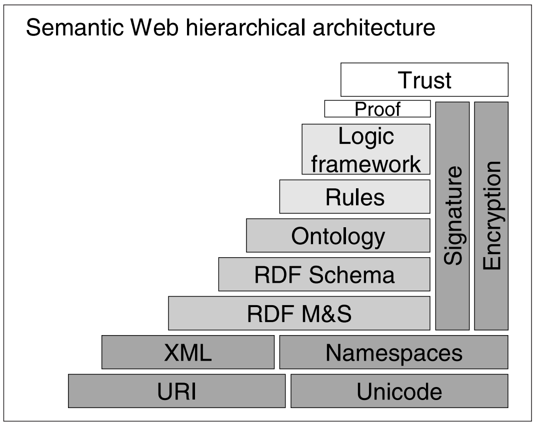
To allow researchers to perform as advanced information searches through a practical-sized database as that described in the example of the travel agent, the construction of ontology is the primary issue.

"Ontology" is a term used in the field of artificial intelligence to represent the structure of vocabulary. For instance, when someone runs a search for the term "Newtonian mechanics," the search engine is most likely to simply compare text data for matching. In contrast, ontology-based advanced searches refer, for example, to exploiting the relationship of "Newtonian mechanics" with "physics" or even with "relativity theory," which, like Newtonian mechanics, belongs to physics but is a different piece of knowledge in the area. Describing these relationships requires the accumulation of information according to a specific set of rules known as a logical expression. In summary, ontology-based knowledge processing means constructing systems that can answer diverse queries, using the accumulation of structures.

3-2 The layer cake

The previous section explained that structures are used in the Semantic Web to accumulate and apply information. The diagram in Figure

Figure 2 : Layer cake



Source: Prepared by STFC based on the reference[11]

2, known as the layer cake, defines the process of this structuring. The layers of this hierarchy have been specified one by one, starting from the bottom, and the specification process has so far been completed up to the fifth layer, the Ontology layer. This technological model has been discussed internationally by the World Wide Web Consortium (W3C), a standardization organization[11].

The information available on the web is usually in either text or graphic form and is categorized as "syntax"-level information. This type of information is expressed in syntax. HTML and XML are widely used syntaxes.

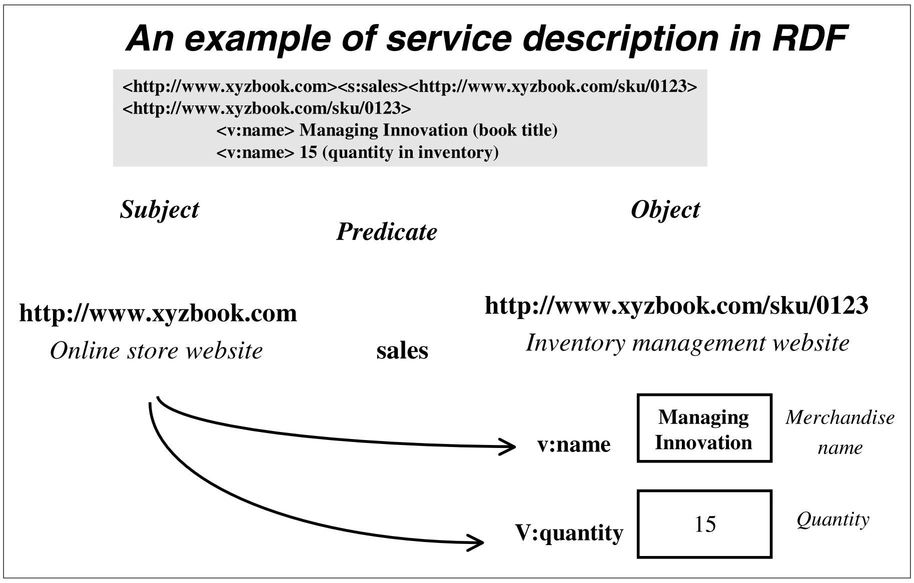
To deal with semantics, some layers are assigned to RDF, a notion explained below. These layers describe a knowledge structure built according to a specific set of rules.

On the top of these is the Ontology layer. In this layer, the target knowledge structures are formed as a vocabulary collected in RDF and as a set of rules to apply it. Genome and other application areas mentioned below are examples of ontologies constructed in this way and systems of using such ontologies.

3-3 Resource Definition Framework (RDF)

Let me briefly give an example of "knowledge description" here. Figure 3 shows a triple syntax called an RDF graph. RDF, an abbreviation for "Resource Definition Framework," is a concept adopted in defining knowledge structure. Knowledge fragments are expressed in a syntax consisting of three elements: the subject, the predicate, and the object. There are several

Figure 3 : Ontology construction logic



Source: Prepared by STFC

notation methods for this structure.

The example in the above chart refers to an online bookstore. The subject is a collection of books representing the merchandise displayed at the store, for instance. The predicate defines the rule: "sales" based on the "inventory" of the displayed merchandise. Hence, this diagram shows that the web page introduced by the predicate contains descriptions that serve as the object-the properties of the data on individual books-, such as the book title, "Managing Innovation,", and the number of copies in the inventory, "15 copies." The example assumes that the retailer and wholesaler maintain separate databases for merchandise control. The online store in this example uses Semantic Web technology to implement the service of "inventory inquiry."

3-4 Service provision models

Providing services through the web is not a two-fold process simply consisting of the information provider and its user. For example, there may be a business sector in which the provider of service-related information such as inventories of goods is not the business entity engaged in sales. In this case, for consumers to receive more advanced services, this information needs to be shared under specific rules. While inventory information may not be applicable for purposes other than sales, data on academic research, whose applications are not always specified in advance, could be used for a broader range of services.

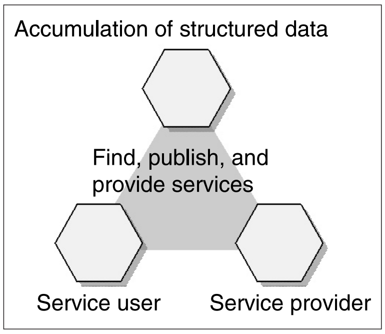
In short, in web services, the three parties - the data provider, the service provider, and the service user - can be independent entities. Therefore, service brokerage for selling certain services is feasible as a business. Figure 4 depicts the conceptual relationship among these entities.

Currently, technologists who promote electronic commerce assume that diverse services in business can be efficiently provided in such a structure. Similarly, in the academic research domain, it would be possible for computers to assist in deriving new academic findings from massive information databases constructed for different purposes in the same field.

3-5 Related technological schemes

For the Semantic Web, W3C has been setting international standards[11] and has published recommendations together with specifications for peripheral technologies. There is another standard developed by the OASIS Consortium, an organization established in 2000. It is called UDDI (Universal Description, Discovery and Integration)[9] and coexists with the Semantic Web standard scheme. The UDDI standard consists of UDDI Data Structure Reference, which is the main part and defines the structure of

Figure 4 : Conceptual model of service brokerage



Source: Prepared by STFC

the data to be stored in the database called the Business Registry, and UDDI Programmer's API, which is a programming interface for developing applications for using UDDI data. It is in this interface section that programmers develop software related to the content of the services intended. UDDI seeks to provide advanced web-based services in the electronic commerce area in particular. Note that under the UDDI standard, no ontology level is specified. This suggests that UDDI depends on descriptions in natural language concerning the semantics of services.

As with Semantic Web technologies, UDDI technologies assume that providing data is independent of the services based on that data, and that constructing services is feasible as a business. This perception is common across all web service technologies.

4 Research trends in the Semantic Web

This chapter describes research activities on Semantic Web technologies and on the application of such technologies to other fields of study, and examines research promotion possibilities in this area.

4-1 Theoretical research on the Semantic Web

In the following section, trends in theoretical research activities are briefly reviewed in connection with major topics. Next, as examples of attempts to extend these activities to applied research, some applied projects in the area of bioinformatics are examined. Ongoing research projects supported by public funds in Japan are then listed with short descriptions.

(1) Semantic integration

In the Semantic Web, more than one ontology can sometimes be created in the same field. This occurs, for example, when document databases developed over many years in different research institutes are to be integrated for interoperation. In this case, technologies for integrating multiple semantics, such as a technology for correlating different ontologies, will play an important role. This underlines the significance of research in these areas as correlation between ontologies and correlation between a global ontology and a local ontology. Studies in these areas are considered to be extensions of data integration research in the database sector of artificial intelligence.

(2) Description logic reasoning

To describe ontologies, logical expressions need to be configured. This process uses a syntax called predicate logic. Ontologies are written in OWL (Web Ontology Writing Language), whose standardization has been conducted by W3C. Describing a knowledge structure in predicate logic corresponds to constructing a set of elements that meet a certain condition, such as "If A, then B." The resulting set is the database fundamental to knowledge processing in the Semantic Web.

Knowledge processing based on predicate logic takes the form of generating answers from a collection of fragments of knowledge, such as "If A is true, then B is satisfied" and "If B, then C," to queries such as "Is Z true, if A holds?" This process is referred to as the reasoning mechanism. An important research direction in the Semantic Web is constructing ontology databases in the target knowledge areas, followed by effectively implementing the reasoning mechanism using OWL in each area.

(3) Finding, linking, and implementing services

The process of finding the necessary service in a network and receiving it corresponds to a user inputting keywords to search through a network for the desired service and executing the program. This can be regarded as an extension of typing keywords in an online search engine and finding the desired website. In this case, the requested service is expressed as a data sequence in certain structure. From this perspective, researchers are studying techniques to determine whether the description of a demanded service matches the description by the service provider as well as the efficiency of such techniques.

Some research projects are seeking to apply query schemes to practical applications and to benchmark such schemes. Others are attempting to dynamically combine services by using reasoning engines. This includes studies on algorisms to identify relations between metadata attached to services to describe the content of service. Some others adopt service condition comparisons and syntax comparisons in these studies.

4-2 Applied research project examples

(1) eScience

A group of researchers including Hendler, at the University of Maryland, U.S., is proposing a new direction in research by naming research that aims to solve problems in diverse scientific fields on grid computer systems "eScience." To avoid confusion, note that "eScience" addressed here is different from the project carried out in the U.K. on science and the computer[7].

Grid computing is the notion of connecting numerous general-purpose CPUs to perform computations in parallel. To predict the characteristics of a crystal, for example, a researcher needs to examine its chemical structure using existing databases. Grid computing is ideal for large-scale database searches and for relatively simple reasoning tasks based on the search results. This makes grid computing a promising candidate for the Semantic Web processing engine.

Meanwhile, databases of technical knowledge, although accumulated over time, have not necessarily been constructed in a unified manner. They vary in their data format and operational procedure. In other words, data size, computational complexity of service implementation, compatibility with other operations, and so forth differ from one database to another. This implies the need for interoperability. More specifically, this means constructing a platform through which services are provided to write the results of numeric simulations and other processing on the Semantic Web for common use.

The eScience project members have been trying to build a common information base by applying Semantic Web technologies to several existing databases on science and technology. To extract the knowledge that researchers want from fragments of existing information, it is necessary to define uniform semantics across various databases. The scientists involved in the project assume that this will enable services to support scientific and technological research efforts across a wide range of disciplines.

(2) Application examples in bioinformatics

Representative examples of application of the Semantic Web to bioinformatics are three Genome Ontology (GO) projects: myGrid, MBOY-Service, and Semantic-MBOY. These are systems to derive network structures of diverse reaction pathways (e.g. metabolic pathways) in the living body from data relationships.

It is assumed that in the living body there are reaction pathways for many different substances that are networked under complex control. In fact, researchers have so far identified around 17,000 rules associated with reaction. These reaction pathways are used to transfer signals. GO systems serve as tools to effectively retrieve pathways from the literature. They help find rules regarding the base pairs and proteins relevant to the target effect from millions of chemical reactions.

Common goals pursued in these research projects include automatic information service, providing structure messages and middleware for implementing this service, desirable forms of displaying information service results and of interfacing, measures to meet the different needs of individual users, and constructing complex ontologies.

(3) Research projects in Japan

Listed below are examples of Japanese projects seeking to construct ontologies in science and technology selected from the studies presented

Table 1 : Major Japanese research projects on the Semantic Web

Research content	Affiliation of researchers
Structuring the knowledge on nanomaterials technology	Osaka Univ. Institute of Scientific and Industrial Research
Support for developing and operating space systems	Japan Aerospace Exploration Agency, Osaka Univ.
Knowledge structuring in biology	National Institute of Advanced Industrial Science and Technology, Computational Biology Research Center
Drug function	RIKEN, Genomic Sciences Center

Source: Prepared by STFC

at the Japanese Society for Artificial Intelligence. Two of them are briefly described here.

The Institute of Scientific and Industrial Research (ISIR) of Osaka University has been working on constructing and using ontologies to structure the knowledge on nanomaterials technology. Nanotechnology research is related to a wide range of existing research areas. Aware of this, ISIR intends to develop a "conceptual" interface through which common notions across multiple fields are provided. Its current project specifically addresses knowledge structuring by analyzing patent information.

The Genomic Sciences Center, on the other hand, has been developing a knowledge base of reaction pathways that drugs have at the molecular level. The first step is to describe interactions between substances in RDF using the relationship between the three elements of "drug," "biomolecule," and "output from interactions." On the database that has accumulated their relations, drug interaction ontology is implemented. The basic rules regarding the combination of interactions are then defined to enable reasoning on the database. The result will be a tool that runs effective queries on drug-interaction relationships. With this tool, researchers will be able to infer reaction pathways from retrieved interactions and thereby discover new reaction pathways.

(4) The significance of Semantic Web research in bioinformatics

One study published in the domain of bioinformatics mentions the following as general findings from the research activities of authors for the application of the Semantic Web.

First, constructing ontologies regarding knowledge structures intrinsic to a field is extremely difficult. If database assets already exist, this difficulty increases because of the need to ensure compatibility with their data format. The authors point out that these factors make research in bioinformatics take a significant amount of time and human resources. They also note that an approach in which the users of the Semantic Web describe the services they want using a syntax of the Semantic Web so that they can find the appropriate services through the notation is a promising model applicable to many other fields. Bioinformatics is a representative field where pioneering studies are conducted on the Semantic Web. Adopting search tools that involve knowledge processing based on a large-scale database is likely to spread to other scientific disciplines in the future. Therefore, research techniques developed in bioinformatics could have a ripple effect on research on specialized databases in many fields.

4-3 How research should be promoted

Last November, the 3rd International Semantic Web Conference, 2004, or ISWC2004, the major international forum on research in Semantic Web technologies, was held in Hiroshima, Japan. Of the total participants of 450, over 300 came from overseas, creating an exceptionally cosmopolitan mood for an international conference in Japan. Among the papers presented, whose quality was generally high, that delivered by a researcher who appeared to be in his twenties was particularly impressive.

The keynote speech was made by Edward Feigenbaum, a professor at Stanford University, who is known as the father of artificial intelligence and the 1994 winner of the Turing Award. In his speech, he clearly expressed how Semantic Web research should be promoted. His strong message about this challenge was "Give me something that works!" As demonstrated in constructing and operating/managing ontologies, Semantic Web research applies the outcomes of advanced studies on artificial intelligence. Through this message, Feigenbaum probably intended to stress the importance of practical application in this research area, where language models and other theoretical studies are often the focus of attention. Not only did the professor underline the significance of real-world applications, he also added his hopes for the "spiral development of theory and practice."

If approaches to research promotion were split between the discipline type and the mission type, the former would refer to efforts voluntarily made within the framework of conventional activities in scientific societies, and the latter would indicate approaches that cross the existing boundaries of specialties that are conducted under top management control as projects progress. From this point of view, the spiral development mentioned by Feigenbaum requires mission-type projects to be set up.

One example of experiments aimed at demonstrating the effectiveness of the Semantic Web is the Semantic Web Challenge, an international contest of application systems[8]. This event, presented by a group of researchers and funded by several scientific societies, intends to better illustrate Semantic Web technologies to society and stimulate current research activities to higher goals.

In 2003, the first year of the contest, among the 10 projects that participated, the winner was CS AKTive Space, an application developed by the University of Southampton, U.K. It was a system designed for searching a database of British computer scientists. For the 2004 contest, 18 teams have submitted applications as of December. There has been only one attempt from Japan, "Semblog," which was submitted in 2003 by the National Institute of Informatics. More active participation of Japanese universities in such events is required.

Professor Feigenbaum also said that to develop research in the Semantic Web area, where connections with application fields are essential, drawing the "path" of research is important in formulating research plans. To explain the path, he cited robot soccer tournaments as an example. He pointed out that although this idea may have caused laughter among researchers at first, continued events year after year have produced a steady stream of research outcomes in the area of distributed artificial intellisgence. The professor compared this with an opposite example in which research on certain pattern recognition has led to an impasse. He stated that given today's improved processing capacity, pursuing recognition accuracy alone at the level of a fraction of a percent is meaningless as research.

Since the 1980's boom in artificial intelligence research, when large projects were launched and implemented, activity in Japanese academic communities in knowledge processing is assumed to remain relatively high. The problem, however, is that many research projects have followed the discipline model. For future promotion in the Semantic Web area, interdisciplinary research projects should be managed with clearly defined missions, as Feigenbaum's message suggests. In other words, it is essential to set up, beyond the spiral path, environments and goals that can bring meaningful achievements in both theory and application.

5 Conclusion

This article has focused on Semantic Web technologies because I consider that their inherent orientation toward service is important not only for future directions in information technology advancement but also as a research topic in many interdisciplinary fields of science and technology.

Currently, active discussions are held to implement Japan's Third Science and Technology Basic Plan. Information and communications technology is considered to continue to be a key field in the nation's science and technology policy. In interdisciplinary areas between this field and others, in particular, there are many technological development issues that have been recognized as critical.

To promote research in these interdisciplinary areas, mission-oriented management that emphasizes the "path" is essential, and this is the very type of management approach that Semantic Web research needs.

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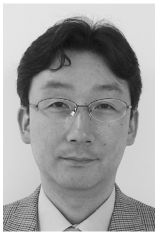

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3

Developing Human Resources for International Standards

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1 Introduction

Most people would have heard the term, "international standards*1." However, perception of what it actually means may vary from person to person. Some people may associate it with the form of mechanical parts, such as ISO screws. Others may connect it with ISO 9000, a management standard for quality control. Rather than targeting specific industrial products, ISO 9000 defines the quality assurance processes to be followed by an organization, whether private or public, in providing anything from products to services. There are other types of international standards, such as those covering document exchange formats for business transactions, and more recently, for ebXML and other electronic document exchange formats. Moreover, there are standards for materials[26]. In this report, all these standards are collectively referred to as international standards or simply standards*2.

This report does not directly cover curriculum standards such as JABEE (Japan Accreditation Board for Engineering Education). The first reason for this is that these standards have not been a topic of discussion in industrial standardization forums. The second reason is that curriculum standards for higher education like JABEE deserve to be examined in a separate report. That said, there still is a need for curriculum standards to incorporate education aimed at development of international standards experts, and an example of efforts in this direction in Canada is described in this report.

International standards have a 99-year history, dating the 1906 establishment of the International Electrotechnical Commission (IEC). Today, international standards are deemed so important that it is said, "whoever rules the standards rules the industry"[1]. Acknowledging that historical background, this report attempts to shed new light on the topic of developing international standards experts for the following three reasons:

The first reason is economic and industrial globalization. Today, companies around the world are producing goods and services with global markets in mind, which is raising their awareness and appreciation of international standards. They become critical factors governing the ability of manufacturers to secure competitive advantage in international markets [2, 25]. This is typified by the World Trade Organization (WTO) Agreement on Technical Barriers to Trade (TBT Agreement)[3], which reinforces the trend of international standards taking precedence over regional and national standards. In the mobile phone market, Japanese companies, which have long adhered to the PDC standard - a domestic format for digital wireless communications - are now facing an uphill battle in competing with overseas rivals. On the other hand, the Europe-originated GSM standard, a digital wireless communications format adopted by more than 100 countries, has proliferated across the world to create a market environment that favors European, North American and Asian companies. Moves toward compliance with the TBT Agreement among Asian countries have, in some extreme cases, led to import prohibitions against Japanese double-tub semi-automatic washing machines, which do not comply with the international standards[4, 26].

The second reason is a change in Japanese companies' in-house human resource development, more specifically the limitations inherent in traditional human resource development practices based on on-the-job training (OJT). The prevailing greater emphasis on specialized personnel and short-term profits finds many companies experiencing difficulties in training and developing standards specialists over the long term. The evolving role of standards puts new focus on human resource development. Economic and industrial globalization has brought new perspectives not only to corporate sales and procurement activities, but also to technological development. On one hand, establishment of international standards has allowed companies to expand the markets for their products and services worldwide and to gain greater benefits from mass production. Conversely, manufacturers are now required to take international standards into consideration from as early as the technological development stage. To echo much recent commentary on patents and other intellectual property, companies should not confine discussion of standardization issues to the development stages of individual products or components. Rather, they should effectively define their approach to standardization from a global viewpoint, as part of their overall corporate strategies, which include future visions and goals. Within such a framework, companies can then determine how their organizations will treat standards in individual R&D, sales and procurement projects[5].

The third reason is change in the social environment. As demonstrated by standards on accessibility, standards are beginning to assume new roles, e.g. acting as soft law*3 that complements the existing legal system, helps to avoid unnecessary friction between countries, and reduces social burdens. It was not until fairly recently that European countries, the U.S. and Japan began to focus on problems and remedies concerning human resource development in the field of standardization[6]. Shortages of human resources in this field are not limited to Japan, but are growing worldwide as standards take on new roles.

Standardization operates on various levels: corporate standards, industry standards, national standards, EU and other regional standards, and international standards such as ISO, ITU and IEC. This report focuses on international standards, in consideration of the need for globalization and Japan's rather poor capacity in this area. However, a discussion on the content of human resource education naturally extends to personnel involved in corporate standards because the question frequently arises: "How should internal standards be related to broader external standards?"

2 Overseas activities in development of human resources for standards

2-1 North American activities

(1) The United States

In the U.S., the development of industrial standards has been led by the private sector, which is said to be the major difference between U.S. standardization and that of other countries. This simply mirrors other U.S. policy-related activities, given that many U.S. policies have originated with proposals from the private sector and that Congress has played a leading role in deciding to adopt such policies. In other words, private-sector leadership is not specific to standardization activities. Rather, for the U.S., industrial standardization is an area where government involvement is fairly deep, as instanced by certain activities of the Department of Commerce (DOC) and the National Institute of Standards and Technology (NIST), as well as the Department of Defense's involvement in military specification (MIL). From a historical viewpoint, the diffusion of U.S. standards has been driven by government promotion and Pentagon military pressure to establish a war regime[7]. The DOC report entitled "Standards & Competitiveness - Coordinating for Results"[8], published in May 2004, describes four new policies and two long-term strategies to advance the Standards Initiative, a project led by Commerce Secretary Donald Evans since March 2003. One of the two long-term strategies is to expand inclusion of standards curricula at engineering and business schools. The other is to partner with colleges/universities on R&D aspects of new technologies and to influence standards at the earliest stages of development of new technologies. A typical example of such industrial standards-related activities at U.S.

universities can be seen in the Center for Global Standards Analysis, which was founded in 1999 at the Catholic University of America, Washington D.C. The Center offers educational courses to law students and engineering students, aiming at a fusion between the humanities and sciences. Employers of those who complete the courses include private-sector companies, standards development organizations, government agencies (including the U.S. Patent Office), and law offices[9].

However, the March 2004 report[10] issued by the Center shows that, among U.S. engineering universities, only three offer courses related to standardization: the Catholic University of America (mentioned above), the University of Colorado at Boulder (course discontinued in September 2004), and the University of Maryland. In business schools, no standards-related courses have been adopted so far, although some proposals were put forward in the past[11].

(2) Canada

In Canada, the Canadian Standards Association (CSA) and the Standards Council of Canada (SCC) have been spearheading promotion of human resource education as an important part of the Canadian Standards Strategy (CSS). In January 2004, CSA and SCC proposed to the Policies and Procedures Committee of the Canadian Engineering Accreditation Board (CEAB) a study on undergraduate curricula related to standardization. The accepted proposal consists of three parts: (1) requirements for the inclusion of standardization issues in engineering curricula, (2) access to standards-related information, and (3) involvement of university instructors in activities related to standardization. Furthermore, the updated edition of the Canadian Standards Strategy for 2005-2008 considers establishment of a Canadian Center for Standardization Research[12]. It names as higher priority institutions the University of Western Ontario, the University of Ontario, Queens University, and the University of Waterloo. CSA has also been offering educational programs to its members independently since 1998. As of August 2004, more than 1,300 members had participated in the programs.

2-2 European activities

The Enterprise and Industry DG of the European Commission regards standardization activities as a key policy. History shows that activities for standardization across national boundaries, including those in commerce, originated in Europe. The issue of how to set a common standard across different languages and systems was first addressed in Europe and then spread to other parts of the world, such as North and South America, Asia, and Africa.

The European Commission's Enterprise and Industry DG also emphasizes building an academic network. It provides a Web page dedicated to this network[13], and lists 20 European universities that offer courses related to standardization (see Table 1). The aim of this academic network is: (1) to promote awareness of standardization at university level, (2) to develop closer cooperation between universities and other institutions, (3) to enhance information exchange, and (4) to enhance knowledge dissemination and exchange of ideas.

In addition to the above, an academic society called the European Academy for Standardization (EURAS), which is headquartered in Hamburg, was established in 1993[14]. Moreover, there is an initiative called the Asia Link Project[19], which aims to develop a curriculum on standardization through collaboration between European and Asian universities, as mentioned in the next section.

2-3 Asian activities

In developing Asian countries, industrial standards are recognized as a pillar of national industrial policy. The Second Northeast Asian (China-Korea-Japan) Standardization Cooperation Seminar, held in Beijing in 2003, named as the sixth article of its trilateral memorandum of cooperation a plan for human resource development for standardization[15]. From January 2004, a joint research with European universities started that is described later. In the Third Seminar, held in Tokyo in December 2004, South Korea verbally reported its activities: “In 2004, seminars on standardization was conducted at 11 science and technological universities. For

2005, 30 universities have applied. The seminar targets sophomore to senior students. Since there is no professor specializing in standardization, a team comprising standardization professionals from companies and research institutes gives lectures. We are also planning a standardization education program for high-school students. It will include standardization education for high-school teachers during school holidays." The memorandum of cooperation signed at the end of the seminar states in "Article 3. Standardization Education Plan": "In recognition of the proposal made by China on this issue and the examples of education at science and technological universities presented by South Korea, the three countries have reconfirmed that they shall continue exchange of general and project-specific information and reference materials and mutual corporation in developing standardization experts. The China Association for Standardization shall continue to work as the secretariat [16]." In South

Table 1 : European universities with courses related to standardizations

Country	University	Aim (education/ research)	Type (humanities / sciences)
Germany	Technical University of Aachen, Computer Science Dept., Informatik IV	Research	Sciences
	Dresden University of Technology, Department of Economics	Partial education, research	Humanities
	University Erlangen-Nürnberg Faculty of Law and Technics	Research	Combination
	J.W. Goethe University Chair of Economics, esp. Information Systems	Special education, research	Humanities
	Universität der Bundeswehr Hamburg Department of Standardization and Technical Drawing	Special education, research	Sciences
	University of Hamburg, Institute of SocioEconomics (IAW)	Special education, research	Humanities
	Fraunhofer Institute, Systems and Innovation Research	Research	Humanities
Greece	Aristotel University of Thessaloniki, Union of Hellenic Scientists for Protypation and Standardization	Partial education, research	Sciences
Lithuania	Kaunas University of Technology, Economics and Management Faculty	Partial education, research	Humanities
	Klaipeda University, Marine Technology Faculty	Partial education	Sciences
Malta	University of Malta, Faculty of Mechanical and Electrical Engineering	Partial education, research	Sciences
Sweden	Stockholm School of Economics, Center for Organisational Research (SCORE)	Research	Humanities
Netherlands	Delft University of Technology, Faculty of Technology, Policy and Management	Special education, research	MoT
	TNO Institute for Strategy, Technology and Policy Studies, Information and Communication Technology Policy	Research	Humanities
	Eindhoven University of Technology, Faculty of Technology Management	Special education, research	MoT
	Erasmus University of Rotterdam Management of Technology and Innovation	Special education, research	MoT
UK	University of Sussex, Science and Technology Policy Research	Research	MoT
	University of Edinburgh Research Centre for Social Sciences/Technology Studies Unit	Research	Humanities
	Queen Mary Intellectual Property Research Institute, Centre for Commercial Law Studies, Queen Mary, University of London	Partial education	Humanities
	University of Manchester, Manchester Business School	Partial education, research	Humanities

"Partial education" indicates that standards are taught as part of specialized education. "Special education" indicates that there is a course dedicated to standardization education.

Source: Prepared by STFC, based on information available on the Web[13]

Korea, the Private Sector Standards Team of the Korean Standard Association is promoting standards-related education. For 2005, the team not only established standards-related courses at the 33 universities listed in Table 2, but also published a common text book entitled “Future Society and Standards” for use in the courses. Graduate courses are now being planned[17]. These activities in South Korea are drawing the attention of European and North American countries[18].

Furthermore, there is another international initiative called the Asia Link Project[19], which intends to develop a curriculum for standardization education by 2006 through collaboration between universities in Europe (Hel mut-Schmidt-University, University of the Federal Armed Forces - Hamburg, and Erasmus University

Table 2 : South Korean universities offering standards-related education

University	Involvement (sciences/school-wide)
KOREA University	Sciences
Catholic university of DAEGU	Sciences
DAEBUL University	School-wide
PAICHAI University	School-wide
SILLA University	School-wide
YONSEI University	Sciences
WONKWANG University	Sciences
CHUNG-ANG University	Sciences
HANSHIN University	Sciences
HANYANG University	Sciences
Catholic Sangji College	Sciences
KANGWON National University	Sciences
KUNKUK University	Sciences
Gyeongju University	School-wide
Kyung Hee University	School-wide
KWANGWOON University	Sciences
FAR EAST University	Sciences
Kumoh National Institute of Technology	Sciences
NAMSEOUL University	Sciences
Dongduk Women’s University	School-wide
DONG-EUI University	School-wide
Seokyeong University	School-wide
SEOUL National University of Technology	Sciences
SEOUL Women’s University	Sciences
Sungkyunkwan University	School-wide
SoonChunHyang University	Sciences
Ajou University	Sciences
Youngsan university	Sciences
Chonbuk National University	School-wide
JEONJU University	School-wide
Chungju National University	Sciences
Korea Maritime University	Sciences
HONGIK University	Sciences

Source: Reference[17]

Rotterdam), China (China JiLiang University), Indonesia (Institute of Technology Bandung), Sri Lanka (University of Moratuwa), and Vietnam (National Economics University) started in 2004. Now that the outline of the curriculum has been defined, the project is about to proceed to discussion of the teaching materials. With a goal of completion of the curriculum by 2006, various organizations are participating in this project, including EU standardization organizations (CEN, CENELEC, and ETSI), standardization officials of the participating countries, and the ISO Secretariat[20].

3 Current Japanese efforts to develop human resources for standards

In Japan, there is also growing awareness of the significance of developing human resources in the field of standardization. For example, "Intellectual Property Strategic Program 2004"[21], which was announced by the Intellectual Property Policy Headquarters in May 27, 2004, points out the need to develop human resources for standardization as follows.

In "Chapter 3 Exploitation", "Section 2 Support for International Standardization Activities" states,

"(1) Reinforcing Strategic International Standardization Activities

3) Creating a favorable environment for the development of human resources specializing in standardization

In FY 2004, the Government of Japan will continue to establish environments to promote the development of human resources specializing in standardization at universities and other educational institutions. In this regard, the GOJ will encourage universities in particular to take voluntary measures to provide educational programs regarding standardization in courses for the development of human resources specializing in standardization that will directly lead to business, existing courses for the development of intellectual property experts, and Management of Technology (MOT) courses.

(Council for Science and Technology Policy, Ministry of Public Management, Home Affairs, Posts and Telecommunications, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Economy, Trade and Industry, and other ministries and agencies concerned)."

Our problem in Japan is that such awareness has not directly led to a concrete human resource development program. For instance, no further discussion has been conducted on what the ministries and agencies concerned should actually do to achieve the above goal and how to evaluate the results. As in the activities under the above-mentioned trilateral memorandum, Japan's initiatives lack concrete measures, compared with China and South Korea's ongoing efforts, which are producing outcomes. In this regard, Japan's efforts could be viewed as less substantial.

In fact, Japan does not even compile statistics on the current state of standards-related education at Japanese universities. For this reason, we collected relevant information on our own initiative, by conducting a questionnaire survey using the experts' network of the Science and Technology Foresight Center, as well as the Internet and other resources. The results are shown in Table 3. Major findings are as follows: standards-related courses (1) are currently offered at Jissen Women's University, Chiba University, Tokyo University of Agriculture and Technology, Toyo University, Nara Institute of Science and Technology, Kinki University, and Japan Advanced Institute of Science and Technology, (2) were formerly offered at Waseda University and Hiroshima University, and (3) will be offered at Ochanomizu University and Yamagata University. There are many other universities that teach industrial standardization issues as components of various courses whose focus is not standardization.

If the number of universities in Table 3 alone is taken into account, Japan is placed between the U.S. and Europe. In reality, however, Japan neither has a center for standardization like the U.S. nor provides widely recognized educational courses as in Europe. Some courses were even cancelled after a few years of teaching. Overall, Japanese activities for standardization education lack consistency and coordination.

Table 3 : Standards-related education at Japanese universities

University	Status	Faculty or Course Name
Azabu University		School of Veterinary Medicine, College of Environmental Health
Osaka University		Common course, “Chemistry of new substances”
Ochanomizu University	planned	
Kanazawa Institute of Technology		Technological theory
Kwansei Gakuin University		Graduate School of Policy Studies “Technology transfer”
Kibi International University		Department of Intellectual Property Management, School of Policy Management,
Kinki University	ongoing	Department of Information and Systems Engineering, International standardization policy
Kyushu University		School of Agriculture, Soil and food analysis methods; Graduate School of Medical Sciences “Protection of intellectual property”
Kobe University		Courses related to marine pollution prevention under international treaties and to the ship officer’s certificate system at the Faculty of Maritime Sciences
University of Shizuoka Graduate School		Business administration
Shizuoka University		Faculty of Information, Computer networks
Shizuoka Institute of Science and Technology		“Electronic Components Engineering”
Jissen Women's University	ongoing	Department of Food and Health Sciences, Faculty of Human Life Sciences, Japanese and international standards concerning food
Chiba University	ongoing	International exchange courses, International standards
Tokai University		School of Engineering, Patent strategy
University of Tokyo		Faculty of Engineering (safety assessment), Food science on “JAS” at the Faculty of Agriculture
Tokyo University of Marine Science and Technology		Department of Logistics and Information Engineering, Faculty of Marine Technology, “Intermodal transport,” “Inventory management,” “Logistics information systems design”; Department of Food Science and Technology, Faculty of Marine Science, JAS; under consideration in the “Food logistics safety control professionals’ training course”
Tokyo Institute of Technology		Department of Advanced Applied Electronics, Science and technology studies; Department of Electrical/Electronic Engineering, Technology management studies
Tokyo University of Agriculture and Technology	ongoing	Graduate school, Master’s course program, “Industrial technology standards,” “Standardization strategy”
Tokyo University of Science		Master of Intellectual Property course, Graduate School of Management of Science and Technology
Toyo University	ongoing	Graduate School of Business Administration
Nagaoka University of Technology		Mechanical safety engineering
Nagoya Institute of Technology		‘Nagare (Fluid-reltaed)’ field
Nagoya University		Graduate School of Environmental Studies
Nara Institute of Science and Technology	ongoing	Interdisciplinary studies
Nihon University		Biochemical resources studies
Hitotsubashi University		Graduate School of Commerce and Management, Faculty of Commerce and Management, Graduate School of Law
Hiroshima University	discontinued	
Japan Advanced Institute of Science and Technology	ongoing	Technological standardization
Waseda University	discontinued	Business administration, Competition strategy
Yamagata University	planned	
Yokohama National University		Division of Electrical and Computer Engineering, School of Engineering, “Electrical code and facilities management”

Blanks in the status column indicate that standardization issues are covered in lectures in the faculty or course listed.

Source: Prepared by STFC

4 Problems concerning the development of human resources specializing in standards

Five critical issues need to be discussed in relation to the development of human resources specializing in standards.

The first problem is a lack of awareness of a changing role of standardization. As described in “1. Introduction,” this change is the reason that human resource development in the field of standardization is attracting attention. Public understanding is necessary for the changing role of standards, together with the factors behind such change: (1) economic globalization has expanded markets for products and services beyond our shores, raising the need to take standards into consideration even at the development stage of technologies; (2) standardization activities towards global market becomes an indispensable part of organizational comprehensive strategies for the future; and (3) in society, standards are used as soft law to complement the current legal system[22].

The second issue is the kinds of capabilities that standardization experts should possess. For example, in the past, people involved in standardization of programming languages were specialists in compiler technology and were expected to review specifications of language standards in order to reflect them in the design of their companies' compilers. However, today’s professionals in programming language standardization need to work from the early stage of the programming language design, to estimate the expected profits from potentially expanded markets as a result of standardization, and to manage the cost of standardization, taking into account of the expected applications and operating/development environments. They should also be able to identify organizations and companies that would be willing to offer cooperation in the standardization process, and they should know how to deal with related intellectual property. For management standards such as those involved in Corporate Social Responsibility (CSR), standardization experts should have extensive knowledge in fields ranging from business strategy through finance to public relations. Even experts in technical standards should be capable of handling a fairly extensive range of issues, as shown in the programming language example. They are expected to be capable of not only discussing technical issues but also solving legal and administrative problems, and even conducting negotiations in a foreign language. Demand for human resources with outstanding capabilities in such diverse areas is probably not limited to standardization, but can exist in any field. One challenge is to determine which of these capabilities are fundamental to human resources specializing in standardization.

The third issue is related to career paths, which are inherent in human resource development. In Japan, there is a tendency for standardization personnel not to be assigned important roles in organizations, even in industries where standards are emphasized. This situation is not likely to improve in the near future because it is a result of companies’ past and ongoing treatment of standardization personnel combined with these employees’ past and current positioning. This concern essentially arises out of the first problem that refers to what roles organizations (companies and countries) should assign to standards and how seriously they should address the issue of treatment of standardization experts.

This brings us to the fourth problem: Japan’s traditional lack of awareness of and support for activities for constructing large cross-organizational frameworks and rules for time-consuming strategic activities such as international standards[23]. This also suggests a lack of career path for human resources dedicated to such activities, as mentioned under the third problem above. There are extreme opinions that attribute all these shortcomings to Japanese characteristics, but such reasoning will never lead to solutions. Adopting and utilizing a long-term strategic viewpoint is just as crucial for standardization as it is for other fields.

The fifth issue is the approach to standards in individual organizations. One option is to simply adopt and conform to established standards, as most Japanese organizations have done over the years. Those multinational Japanese companies that need to apply international standards can recruit standardization personnel from Europe or in North America, have no need to hire experts within Japan. Meanwhile, for companies operating only within Japan, there is no direct imperative to observe international standards and thus no need for human resources in this domain. In such circumstances, human resource development for international standards would not be required in the first place. Let us discuss this issue more specifically. In a case where a company is developing a highly original technology, it does not have to be concerned about whether the technology will be accepted by others (although the company must certainly make the technology widely acceptable for profits). By contrast, standards are not worth developing unless they are accepted and applied by majority. This suggests that standards development involves different types of difficulties from those faced in developing original technologies. It also implies that prominent figures in standards development are rare, because standards are formulated by teams rather than by individuals. The cost of developing human resources specializing in standards varies widely, depending on whether the personnel are trained to become leaders or followers, depending on the organization's approach to international standards.

Solutions to the above five problems differ from country to country. For example, the third (career path) problem is very difficult to solve for Japan because it relates to Japanese-style organization and human resource management. On the other hand, in Western countries, where professionals exist in diverse fields, standards specialists and consultants are readily accepted. Human resource development is, ultimately, a long-term project for any country, there is no point in searching for a quick remedy. Given today's rapidly changing circumstances, it would be waste of time to try and build a quick consensus on the very best way to lay the cornerstone of a nation for next hundred years. One possible and realistic solution is to have different people make different efforts to develop next-generation human resources based on their own particular ideas. This report proposes some possible actions that Japan can take to support human resource development in the field of standards. The next chapter focuses on educational curricula, development of which is already being discussed in China and other countries that aim to actively develop standards specialists.

5 Discussion on desirable education for different groups of people

5-1 The need of education tailored to different groups of people

Human resource education on standards targets several different groups of people. Besides those directly involved in standards development, it needs to reach users of standards (including the general public), government officials and academic experts who are concerned with the maintenance and establishment of standards, and corporate strategy makers who use standardization activities for business administration. To effectively educate all these groups, a program would need to address a wide range of issues: technologies related to the creation and distribution of documented standards, technologies related to the standards development process (e.g. how to organize conferences), research and development in diverse technological fields, the handling of intellectual property, related laws and systems, and even the treatment of standards in business administration. In reality, however, educational programs should be divided according to the nature of each group. One approach to grouping is simply to classify target personnel into either management or technology, in the same way as university student bodies are divided between humanities and science majors. However, this report adopts the following classification: (1) general users, (2) those who actually work with standards, and (3) those who strategically address standards. There are three reasons for this proposed classification. First, considering that Japan particularly lacks human resources to deal with standards-related strategy, as compared with the situations in European, North American, and other Asian countries, education of such personnel should be distinguished from that of other groups. Second, the traditional division between the humanities and sciences is not effective for these kinds of strategic issues. Third, as described earlier, Japan's traditional training programs, which use OJT to educate standards-related personnel, are limited in their ability to address today's needs.

5-2 General education

General education is essential for laying the foundations in any field. The primary target of general education on standards is ordinary people who use standards, but it also includes young people who will be concerned with standards in the future.

The only country that is active in addressing general education on standards is South Korea, which plans to introduce such a course into high school education from 2006. However, many other countries are expected to follow suit in due course. The goal of general education should not be limited to teaching common knowledge of standards, but should also extend to enhancing the basic understanding that standards are intellectual assets of human beings, and that both efforts are necessary to revise existing standards and to establish new standards.

5-3 Practical education on standards

Practical education on standards aims to develop expertise in conducting standards-related tasks in workplaces, e.g. establishing standards, documenting them, and putting them into practice. As already discussed, such education has traditionally been provided by companies through OJT. However, most of today's companies can no longer afford standards-related OJT. Moreover, in order to adapt to a business environment shaped by intensifying global competition, professionally educated human resources are essential to effective performance of standards-related tasks.

Those who have received practical education on standards can mainly contribute to areas such as R&D and product development. Some may even find roles in both practical and strategic activities, since some of the practical tasks are relevant to standards-related strategy.

The core of practical expertise is international negotiation skills, which translate into how strictly one adheres to systems and procedures and how strictly one can induce others to adhere to them. Basic negotiation skills consist of:

- Logical thinking and presentation capability
- Ability to handle formalities in negotiations
- Technical English skills and English communication skills for conferences and negotiations
- Skills necessary for persuading concerned parties of the merits of one's argument

For establishment of actual standards, the following elements are needed:

- Understanding of management practices specific to standardization organizations
- Understanding of sector-specific standardization organizations
- Ability to build competitive and cooperative relationships with competitors and related companies through the standard development process
- In Japan, understanding of the terminology and procedures involved in formulating JIS standards, and knowledge of tools used to develop JIS standards.

5-4 Education for thosewho strategically address standards

The target of this education can be divided into two types: those who have experience in standards-related activities, and those who have experience in strategy-related jobs. (Educating those who have never been engaged in either area would be impractical.) Once educated to strategically address standards, they can contribute, on a broader basis, to national and regional standards-related strategy and measures, industries' and trade organizations' standards-related strategies, and businesses administration in which standards-oriented strategy is needed. On the more practical side in private sectors, they can assume roles in formulating standards-related strategy within the framework of intellectual property strategy, or as part of product development.

Besides the general elements of education, such as establishing goals, developing implementation measures and evaluating the results, strategic education on standards should include the following: understanding of both the current situation and future trends in standardization; materials and methodologies for formulating remedies with which to achieve a desirable state, in light of both the current situation and future trends; and skill acquisition for using such materials and methodologies. Except for certain elements, such as the acquisition of technical skills and conformity assessment, the education discussed here involves highly social activities, which make experimentation impossible during the learning process. Case studies on strategies will play a critical role in this process.

Education on the current state and future trends should cover standards development organizations, national strategies related to standards, standards acting as legislation (including soft law and hard law), standards in global markets, standards' relationship with intellectual property strategy and product development strategy, the cost and benefits of establishing standards, and the risks and benefits of independent (internal) standards.

Whatever the target group, the most important consideration for Japan in offering education on standards-related strategy is to strengthen the fundamental awareness that standards are something that should be proactively developed and revised, rather than something that is provided by others. Without this perception, we will be confined to merely deciding which standards to choose and when to adopt them.

6 Conclusion

Strategy on standards is as essential to science and technology promotion as strategy on patents, from the viewpoint of managing intellectual assets from the moment of genesis in scientific and technological activities. Today, standards have taken on much greater importance in relation to change not only in the globalization-driven market environment, but also in legal systems. Based on this awareness, this report has described the current state of human resource education on international standards around the world and in Japan, and has highlighted problems and issues. Moreover, the report has discussed what kind of human resource education is desirable for three different target groups: the general public, those who actually work with standards, and those who strategically address standards.

In addition to standards themselves, the issues relating to human resources involved in standards need to be addressed strategically. History suggests that traditional standards-related activities in Japan have focused mainly on individual issues, causing us to lag behind even other Asian countries when it comes to making strategic efforts. Newly industrialized Asian countries, typified by South Korea, are focusing on the strategic value of standards and reinforcing government-led human resource development. Among Western countries, the U.S. has been slow to develop standards specialists at universities and, as in Japan, corporate human resource development through OJT is waning there. However, these drawbacks have been offset by standardization efforts led by active consortiums, or forums and nonprofit organizations, and a proliferation of independent consultants.

In Japan, human resource development for standards is promoted under programs such as Intellectual Property Strategic Program 2004, and courses on standards are offered at universities, as shown in Table 3. However, there are still no clear answers to the questions of who should spearhead efforts for human resource education at a national level and what kinds of activities are ongoing, and the problem of standards-related course content varying widely between universities. In short, in Japan, consciousness of problems concerning standards has not led to implementation of substantial human resource development programs. As a result, Japan continues to face such conventional problems as shortages of experts in standards-related strategy and failure to train and develop successors to experienced standards personnel.

An effective solution to these problems would be the establishment of a concrete, visible framework such as a “center for the development of standards experts.” A name like “standards strategy center" may be more appropriate if such an institute were to be geared to the development of professionals in standards-related strategy, which Japan will need toward the future. This institute could undertake such functions as:

- Designing educational programs for strategic human resource development
- Collecting information on what kinds of education are offered to which groups of people
- Constructing a database of practices concerning standards
- Developing a career path for standards experts
- Actively disseminating the above information.

To overcome the above challenges and promote active utilization of human resources, the institute should collaborate with industry and other related sectors. It should also facilitate active utilization of properly trained and developed human resources.

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Glossary

*1 international standard(s)

This term is usually translated into Japanese as "kokusai hyojun" or sometimes "kokusai kikaku." International standards are those set by international standards development organizations, typically ISO, IEC, and ITU. While ITU is a subordinate body of the United Nations, ISO and IEC are nongovernmental, nonprofit organizations. Standards development organizations, with their members representing countries and regions around the world and procedures to build international consensus, develop de jure standards. De facto standards or consortium standards (also known as forum standards) are those that have been developed without such formal international procedures and therefore are distinguished from de jure standards, even though they may be widely adopted internationally. Consortium standards sometimes appear into de jure standards as a result of specific (mostly short-cut or fast track) procedures established by international standards development organizations.

*2 standard

This term is translated as "hyojun" in Japanese, when "standard" specifically refers to a set of criteria defined by a country or organization rather than expressing its general meaning of model, measure, or norm. "Standard" is sometimes translated as "kikaku" (e.g. Heibonsha's World Encyclopedia). Some dictionaries list "hyojun kikaku" as the translation (e.g. Progressive English-Japanese Dictionary). In general, standards are set by consensus of the parties concerned. The standards development process starts with selection of those parties and includes a procedure for building a consensus among them. Some standards are widely adopted without such procedures; these are called "de facto standards."

*3 soft law

In the absence of a formal Japanese equivalent, this English term is used to describe a set of rules (code) that is not legally enforced by the national government but is observed on a voluntary basis. In fact, companies and individuals are expected to follow these rules, and compliance with them can bring benefits while noncompliance can result in economic disadvantages and social criticism. Examples of soft law are standards, codes of conduct, and self-imposed controls. They are called "soft laws" as a contrast to "hard laws," which are legally binding rules whose violation can result in punishment or administrative disposition[22]. Soft laws are also referred to as "voluntary codes.[24]" Note that some hard laws, including the Road Trucking Vehicle Law, Building Standard Law, Electrical Appliance and Material Safety Law, and Food Sanitation Law, adopt standards, suggesting that standards are not always merely soft laws.

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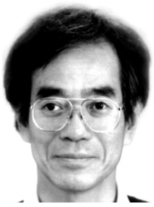

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4

Status and Prospects for the Development of Synthetic Liquid Fuels
— Liquid Fuels Produced from Natural Gas and Biomass —

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1 Introduction

The latest forecasts suggest that oil will continue to be a major source of energy, with demand expected to increase at an average annual rate of 1.9% until 2020[1]. With the markets in China and India growing dramatically, the world's demand for petroleum products including LPG (Liquefied Petroleum Gas) is likely to outpace supply between 2010 and 2020, which will probably result in a surge in oil prices and disruptions in supply[2]. To prepare for such a tight oil market and help alleviate global warming and air pollution, it is therefore paramount that technologies be developed to convert natural gas, biomass and coal - each of which is more abundant than oil - into relatively environmentally friendly liquid fuels.

In some European countries, government initiatives are underway to produce environmentally friendly liquid fuels from natural gas, biomass and coal. These programs are designed to reduce greenhouse gas emissions, tighten regulations on vehicle emissions and improve fuel economy. Capitalizing on abundant biomass resources, the U.S. and Brazil are producing and promoting liquid fuels as a means to ensure energy security and promote domestic agriculture. South Africa, meanwhile, is converting natural gas and coal into liquid fuels for domestic consumption and exports to Europe and the U.S.

Likewise, efforts are underway in Japan to develop technologies to convert natural gas, coal and biomass into synthetic liquid fuels in accordance with the "Energy Basic Plan" (a plan announced in October 2003 that sets out priority technologies for oil, natural gas and coal) and the "Biomass Nippon Strategy" (a strategy announced in December 2002 that sets out key technologies for high-efficiency energy conversion). However, several problems have yet to be solved, e.g., high production costs, and a lack of fuel standards and demonstration projects for the infrastructures needed. The diversification of fuel sources improves compatibility among fuels and reduces geopolitical risks associated with energy supply. Such an approach is critical in diversifying primary energy supply sources and reducing the environmental burden associated with commercial fuels.

This report addresses five promising liquid fuels that could substitute for oil - i.e., dimethyl ether (DME), gas-to-liquid fuel (GTL fuel), methanol, bioethanol and biodiesel fuel (BDF) - examining the status of their development, consumption and challenges. Chapter 2 reviews the characteristics and development status of synthetic fuels, focusing on its security of supply, cost-effectiveness and environmental friendliness. Chapter 3 outlines technologies for using synthetic liquid fuels, focusing on the power generation, transportation, industrial, and consumer sectors. Chapter 4 describes the status in Europe, North America, Asia and other parts of the world. Chapter 5 summarizes challenges in developing and introducing synthetic liquid fuels. And, Chapter 6 presents policy recommendations for diversifying Japan's fuel mix.

2 Status of synthetic liquid fuels

This chapter discusses medium- to long-term trends in fuel demand, expected needs for oil alternatives, and the characteristics and development status of new types of synthetic liquid fuels.

2-1 Trends in fuel demand

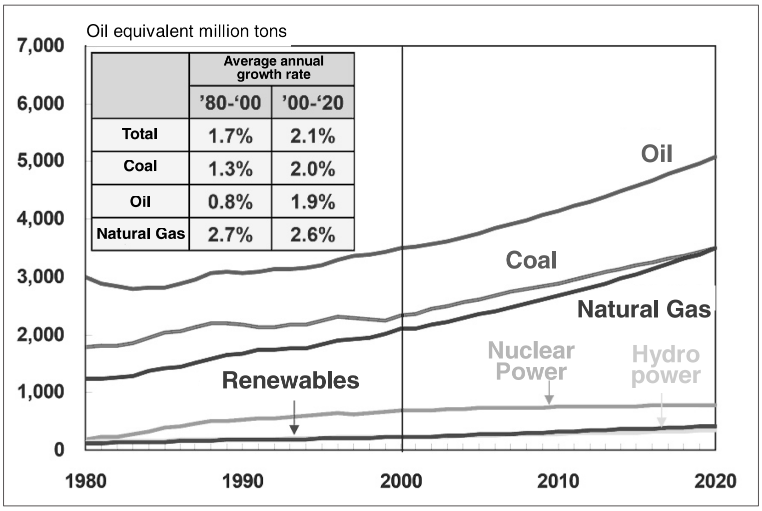
As shown in Figure 1, the world's fuel (primary energy) consumption is likely to increase at an average annual rate of 2.1% until 2020, far outpacing the average of 1.7% between 1980 and 2000. Oil continues to be a major source of energy, with consumption expected to increase by 1.9% annually until 2020[1].

2-2 Needs for oil alternatives

According to the "BP Statistical Review of World Energy (2003)", the world's proven oil reserves can sustain oil production for 41 years at current consumption rates. However, forecasts made by IEA, OECD, oil majors, etc. suggest that oil demand will outstrip supply by around 2015 due to growing demand in China and India, resulting in a surge in oil prices. As shown in Figure 2, the point of time when demand begins to outstrip supply (coupled with a decrease in supply and a surge in prices) is referred to as the "Roll-Over Point"[2]. A surge in oil prices and disruptions to supply are expected to take place.

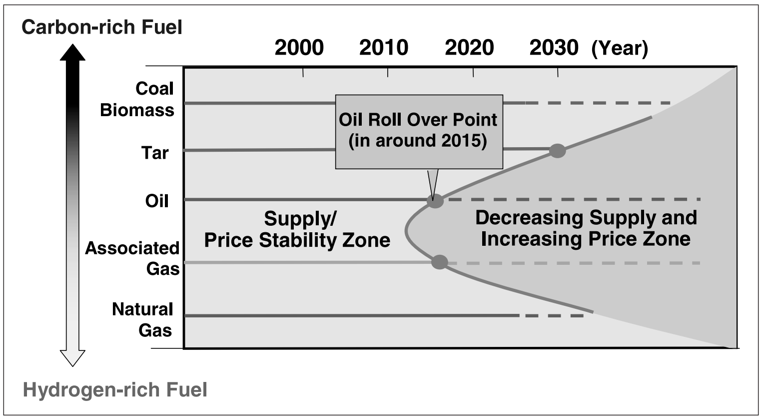
It is therefore paramount that technologies be developed for converting natural gas, biomass and coal - each of which is more plentiful than oil - into liquid fuels.

Figure 1 : Trends in world fuel demand



Source: Reference [1]

Figure 2 : Fuel supply-demand inversion curve



Source: Reference [2]

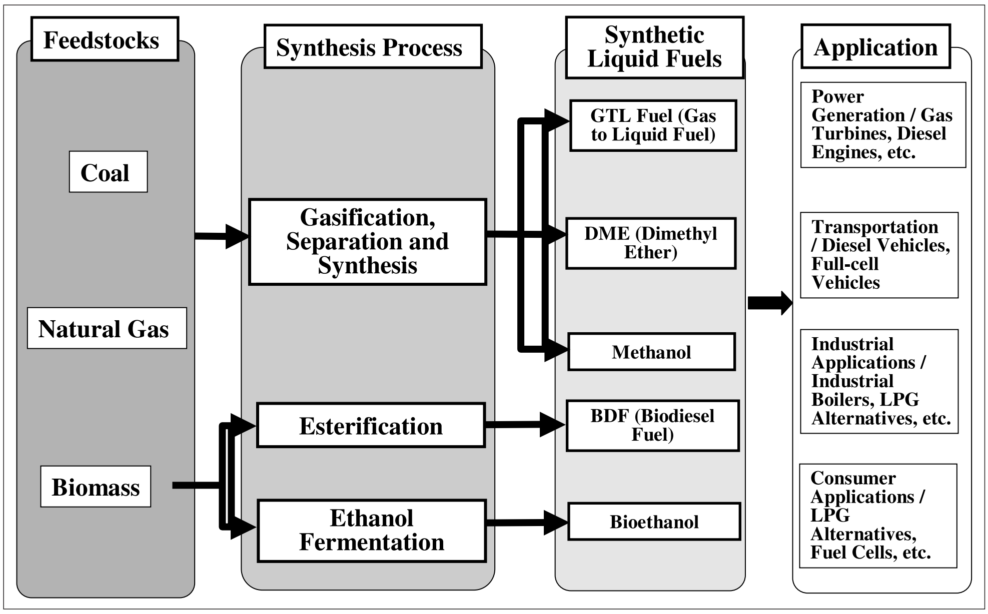
2-3 Characteristics and development status

Promising alternatives to oil include: (1) dimethyl ether (DME), (2) gas-to-liquid fuel (GTL fuel), (3) methanol, (4) bioethanol, and (5) biodiesel fuel (BDF). Figure 3 shows the processes of converting natural gas, biomass and coal into liquid fuels. Table 1 summarizes the advantages, disadvantages and handling characteristics of each oil alternative, their overall characteristics (production technology, supply stability, cost-effectiveness and environmental friendliness) and development status, all of which are described below:

(1) Dimethyl ether (DME)

Dimethyl ether (DME) is a clean fuel produced from a variety of resources such as natural gas, biomass and coal. It is a sulfur-free, highly ignitable and non-toxic gas at atmospheric temperatures and pressures, and can be readily liquefied through direct and indirect liquefaction processes*1. However, its calorific value and lubricity are lower than those of conventional light oil. Domestic consumption is estimated at 10,000 tons a year, mainly for use as a propellant. About 150,000 tons is consumed annually, worldwide. As for prospects for its future supply, projects led by Japanese companies (see Table 2)

Figure 3 : Synthesis process of liquid fuels and their applications



Source: Prepared by STFC based on references [3, 4, 5]

Table 1 : Characteristics of synthetic liquid fuels

Synthetic Liquid Fuels	Advantage	Disadvantage	Handling
DME	Ignitable, combustible and environmentally friendly	Adaptation needed for equipment, low in lubricity	Pressurized and liquefied for transportation and storage
GTL Fuel	Ignitable, combustible and can be distributed through existing facilities	Pegged to oil prices, low in lubricity	Can be handled like kerosene and light oil
Methanol	Stays in the liquid phase under normal temperature and pressure conditions	Toxic, low in calorific value	Can be handled like kerosene and light oil
Bioethanol	Carbon-neutral, renewable, environmentally friendly	Competes against food, highly water-absorptive, corrosive, degradable, low in calorific value	Measures needed to prevent water absorption
BDF	Carbon-neutral, renewable and can be distributed through existing facilities	Competes against food, component fluctuations low in calorific value	Can be handled like diesel fuel

Source: Prepared by STFC based on references [2, 6]

Table 2 : Commercialization plan for DME production (Excerpts)

Developer	Technology	Commercialization Plan
DME International (led by JFE)	Direct synthesis (slurry bed reactor), 250 degrees Celsius, 4-8 atm	37,000 t/y (planning phase), 910,000 t/y (market research phase)
Japan DME (led by Mitsubishi Gas Chemical)	Indirect synthesis (methanol dehydration)	1,830,000 t/y (planning phase), Australia
The Mitsui & Co. Group	Indirect synthesis	2,500,000 t/y (planning phase), Iran, etc.
Topsoe (Denmark)	Direct synthesis (fixed bed reactor)	Benchmark tests underway
Lu Tian Chemical Group Co., Ltd. (China)	Indirect synthesis (methanol dehydration)	50,000 t/y (commercialized), 1,000,000 t/y (planning phase)

Source: Prepared by STFC based on reference [5] and http://www.meti.go.jp/committee/summary/0002068/0001.html

are expected to produce a total of 4.7-6.4 million tons a year, using natural gas as a feedstock. However, this amount accounts for a mere 20% of domestic LPG consumption, which stood at 19 million tons in 2002 (equivalent to some 30 million tons of DME on a calorie basis); there is a long way to go before DME will substitute for LPG[6]. In the medium- to long-term, demand for DME could increase in response to growing demand for power generation fuels in certain parts of the world, particularly Asia.

The standard import price of DME for commercial power generation is set at ¥1.5-2.0 per 1,000 kcal, which is cheaper than light oil and LPG, or on a par with liquefied natural gas (about ¥2.0 per 1,000 kcal; an average of the actual costs over the past three years). However, the cost of DME may exceed that of LPG because of the need to build receiving terminals and renovate users' facilities, together with higher distribution/storage costs attributable to the low calorific value of DME. The production cost of DME should be reduced further.

On the environmental front, production of DME generates more carbon dioxide per unit calorie than do LPG and LNG, although the combustion gases of these fuels appear to contain a similar percentage of carbon dioxide*2. However, taking combustion efficiency into account, DME has an advantage over oil for power generation purposes, and is more efficient than diesel fuel and LPG for use in diesel vehicles. Moreover, unlike diesel fuel, it does not produce particulate matter, and hence can contribute to reducing air pollution caused by vehicle emissions.

(2) Gas-to-liquid fuel

Gas-to-liquid fuel is a highly ignitable synthetic hydrocarbon containing no sulfur or aromatics; it is produced from natural gas and coal, with light oil, kerosene, naphtha, etc. as byproducts. GTL light oil is expected to substitute for light oil as it can be distributed via existing light oil infrastructures. GTL fuel production is composed primarily of three processes: synthesis gas production, Fischer-Tropsch synthesis*3, and hydrocracking. The bulk of GTL fuel is produced by foreign oil majors*4 and various production technologies are in the pipeline, some of which are close to commercialization. In Japan, Japan Oil, Gas and Metals National Corporation (JOGMEC) set up a pilot plant (7 barrels/day) in September 2003 in cooperation with Chiyoda Corporation and Nippon Steel Corporation, while other projects have yet to take shape.

The world's total production currently stands at 147,000 barrels/day (Shell, Sasol, etc.), which is likely to increase when projects in the Middle East, etc. are completed in a few years' time. The dependence on Middle Eastern products may not decrease in the short term as they are produced from low-cost feedstocks. However, in the long term small- to medium-sized oil fields in Southeast Asia will likely start producing GTL fuel.

The supply price of GTL light oil is estimated a ¥10/liter higher than conventional light oil if low-cost Middle Eastern natural gas is imported. However, further cost reductions could be possible through economies of scale.

GTL light oil, when burned, releases less CO_2

than conventional light oil, but its production involves high emission levels, resulting in more CO_2 emissions overall. However, lower emissions of NOx and particulate matter may contribute to reducing vehicle emissions.

(3) Methanol

Methanol is produced through catalytic methanol synthesis, a process that converts synthesis gas into methanol. Demand for methanol as a chemical feedstock, remains strong. Methanol, when burned, does not produce SOx and particulate matter, but it is not in widespread use in Japan for liquid fuel because of its toxicity and low calorific value. About 700,000 tons of methanol (blended with gasoline) is consumed annually, worldwide (particularly in Brazil, the U.S. and EU). Although some 200 methanol-powered vehicles are on the road in the Kanto and other areas, the government's "Eco 2000 Initiative", which was designed to set up 2,000 methanol stations across the country by 2000, has yet to be accomplished.

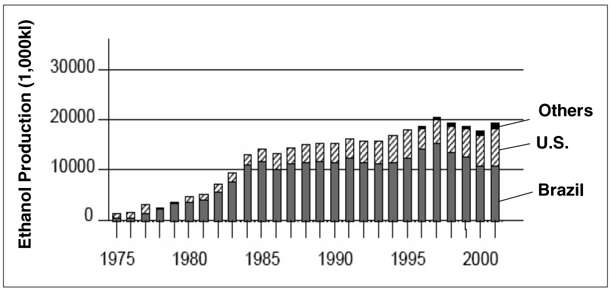
Because of its poor cost competitiveness and regulatory constraints, the chances are slim that methanol will be used widely as automotive fuel. However, it holds promise as a fuel for fuel cells for mobile information devices and motorcycles as it can readily be reformed [7]. Research is now underway to develop direct methanol fuel cells for mobile information devices.

(4) Bioethanol

Bioethanol is produced from energy crops such as sugar cane and corn through biochemical conversion. It is one of the renewable energy sources that do not increase the atmospheric CO_2 concentration (i.e., it is carbon-neutral), while it has some drawbacks such as corrosiveness to metals and rubber, and degradation due to moisture absorption.

Standards have been in place in Japan since August 2003 for the ethanol-gasoline blend ratio; up to 3% of the total. While use of this type of blended fuel has yet to become widespread in Japan, some 1.8 million kiloliters/year of ethanol

Figure 4 : Ethanol production in Brazil, the U.S. and others



Source: Prepared by STFC based on reference [6]

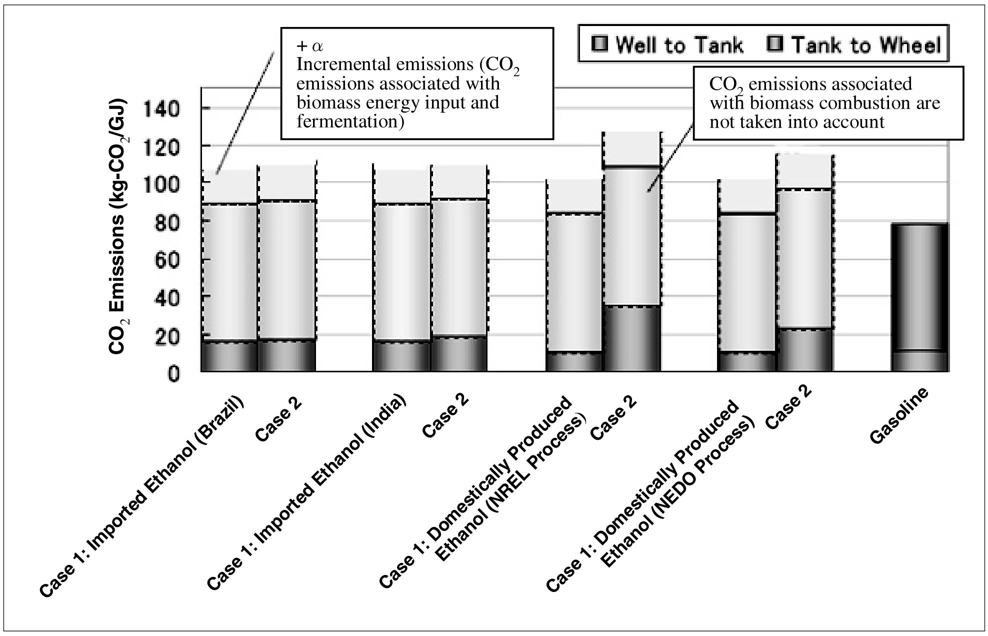
will be needed if three percent of gasoline is to be replaced with it (hereinafter referred to as "E3"). As is obvious from Figure 4 (Ethanol Production in Brazil and the U.S.), Brazil will most likely be the only country to have surplus export capacity for bioethanol. Domestic production of bioethanol is not commercially viable since its raw materials (sugar, starch, etc.) are used primarily for food production. Its current import price is somewhere between ¥40 and ¥50 per liter as against a wholesale gasoline price of ¥27 per liter. Moreover, bioethanol prices are susceptible to fluctuations in the raw materials market. For these reasons, arrangements such as long-term contracts with exporting countries are needed to ensure the supply of bioethanol at stable prices - a prerequisite to converting all gasoline into E3.

From the viewpoint of LCA (Life Cycle Assessment), as shown in Figure 5, CO_2 emissions of ethanol are estimated at 13-45% of those of gasoline since the emissions associated with biomass combustion are not taken into account[6]. However, gasoline, when blended with oxygen-containing organic compounds such as ethanol, produces various effects, both positive and negative: its combustion gases contain less carbon monoxide and hydrocarbon, but more NOx, aldehyde and fuel evaporation emissions. The ethanol-gasoline blend ratio is thus capped at 3% in Japan.

(5) Biodiesel fuel (BDF)

Biodiesel fuel (BDF) is comprised of fatty acid methyl esters, which are produced from fats

Figure 5 : Life cycle assessment of ethanol for its CO_2 emissions



"Well to tank" refers to CO_2 emissions associated with production (mining), transportation, and production (refinement); "tank to wheel" refers to those associated with combustion. Case 1 uses average values for variables such as feedstock yields and waste material occurrence density; Case 2 assumes that feedstock yields and waste material occurrence density are 15 and 50% lower, respectively, than the averages. The NREL and NEDO processes (homegrown ethanol production technologies) are both ethanol fermentation processes using wood biomass, research on which is underway at NREL (National Renewable Energy Laboratory) and NEDO (New Energy Development Organization). Assumptions for the calculation are based on the targets. LCA of gasoline represents accurate figures based on actual data on operating plants; that of biofuels involves scores of assumptions, showing rough figures. Of the figures discussed above, fossil fuel consumption outside Japan (including marine transportation fuel) is not included in Japan's greenhouse gas emission inventory. "Incremental emissions" in the chart cannot be quantified.

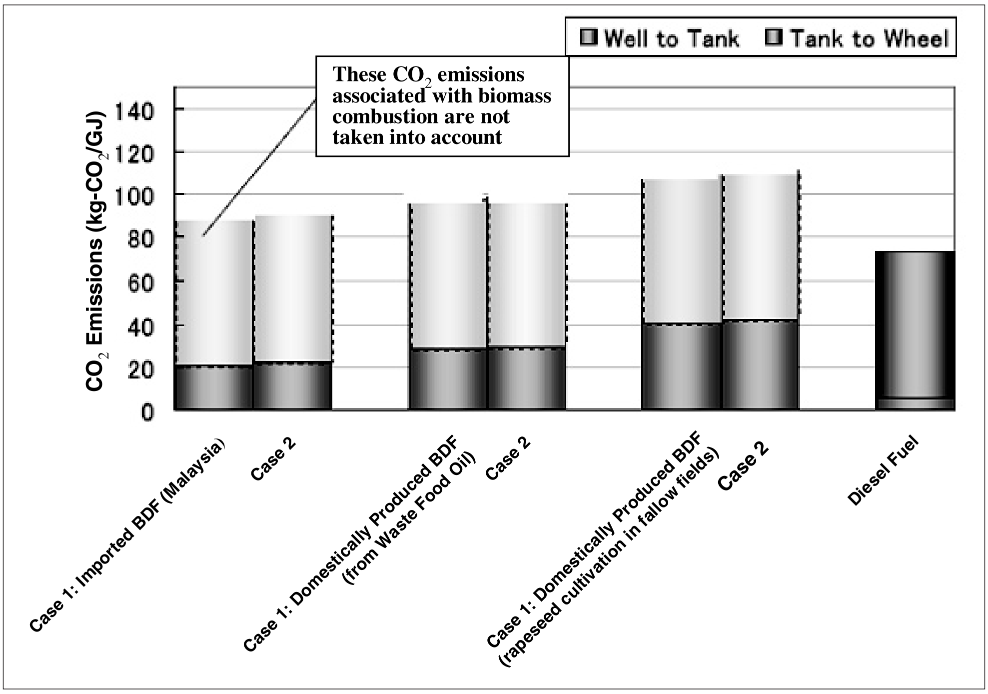
Source: Prepared by STFC based on reference [8]

and oils of biomass origin (palm oil, rapeseed oil, etc.) through thermochemical conversion (methyl esterification reaction). It is used, either undiluted or blended with light oil, as automotive fuel. Some municipalities in Japan have fleets of BDF-powered official vehicles.

In consideration of the export capacity of each raw material exporting country, palm oil produced in Southeast Asia is most promising as a feedstock for BDF, though its import price is estimated at ¥38-91 per liter as against a wholesale light oil price of ¥30 per liter[6]. Its cost, when produced domestically from waste food oil, is still high, hovering between ¥72-87 per liter.

From the viewpoint of LCA (Life Cycle Assessment), as shown in Figure 6, CO_2 emissions of BDF are estimated at 28-57% of those of light oil since the emissions associated with biomass combustion are not taken into account[6]. BDF has another advantage: CO_2 emissions associated with the combustion of imported BDF are not counted as Japan's emissions. As for the effects of "light oil blended with BDF" on vehicle emissions, an experiment conducted by the Ministry of the Environment in 2002 showed that the fuel produces more carbon monoxide and NOx than light oil; particulate matter such as soot decreases, while unburned components of light oil and lubricant increase. Further research should be conducted to analyze how the various properties of BDF affect fuel tanks, engines and emissions.

Figure 6 : Life cycle assessment of BDF for its CO_2 emissions



"Well to tank" refers to CO_2 emissions associated with production (mining), transportation and production (refinement); "tank to wheel" refers to those associated with combustion. Case 1 uses average values for variables such as feedstock yields; Case 2 assumes that feedstock yields and waste material occurrence density are 15 and 50% lower, respectively, than the averages. LCA of diesel fuel represents accurate figures based on actual data on operating plants; that of biofuels involves scores of assumptions, showing rough figures. Of the figures discussed above, fossil fuel consumption outside Japan (including marine transportation fuel) is not included in Japan's greenhouse gas emission inventory. The combustion of BDF produces CO_2, the amount of which cannot be quantified as BDF varies in its composition. Source: Prepared by STFC based on reference [8]

3 Technologies to use synthetic liquid fuels

This chapter outlines technologies for using synthetic liquid fuels, focusing on the power generation, transportation, industrial, and consumer sectors. Table 3 shows applications for each fuel.

3-1 Power generation sector

DME - a clean fuel whose combustion gases contain less NOx, carbon monoxide and soot - can be used in gas turbines, diesel engines, boilers, fuel cells, etc. (see Figure 7). However, because it is a new type of synthetic fuel, technologies to accommodate its chemical and physical properties should be developed and demonstrated for the purposes of commercialization.

3-2 Transportation sector

DME is a highly ignitable gas that produces no particulate matter, and hence is a promising alternative fuel for diesel vehicles. Regulations on particulate matter do not apply to DME, and NOx regulations - or new, long-term regulations on NOx emissions - can be complied with by using catalytic converters. However, for use of DME as automotive fuel, minor conversions such as large-capacity fuel pumps and fuel optimization are required. DME and methanol are both suitable as fuels for fuel cells as they can produce hydrogen at low temperatures.

Meanwhile, GTL fuel can be used as transportation fuel without extensive renovation of existing infrastructures. Conventional light oil containing 10-30% of GTL light oil is considered acceptable for use as automobile fuel. In the future, it is expected to substitute for jet fuel.

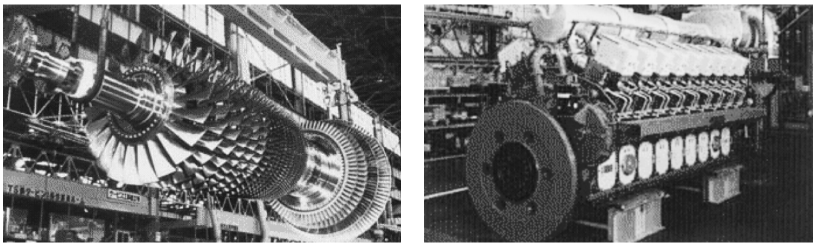
As mentioned in Chapter 2, methanol is already used as automotive fuel, but its use has yet to become widespread because of its toxicity and low calorific value.

Bioethanol is blended with gasoline to be used as automotive fuel. Likewise, BDF is blended with

Table 3 : Applications of synthetic liquid fuels

Applications		DME	GTL Fuel	Methanol	Bioethanol	BDF
Power generation	Thermal power generation	○				
Transp ortation	Gasoline alternative				○	
	Diesel fuel alternative	○	○			○
	LPG alternative					
	Fuel-cell vehicles	○		○		
Industry	Kerosene/heavy-oil alternative	○				
Consumer	Household LPG alternative	○				
	Town gas feedstock	○				
	Kerosene/heavy-oil alternative	○			○	
	Fuel cells	○		○		

Figure 7 : DME-powered generators



(a) Gas turbine generation (b) Diesel engine generation

Source: Reference [9]

light oil for use in diesel vehicles, although such use requires some conversions and more frequent maintenance.

3-3 Industry sector

DME could substitute for LPG as a fuel for simple combustion equipment such as boilers[10]. For relatively complex equipment like glass burners and textile dryers, however, the burners need to be modified to control the flame.

3-4 Consumer sector

DME is a promising LPG alternative fuel for use in household gas appliances. It is recommended that gas appliances designed for LPG, DME and other types of mixed gases be developed to provide users with options and ensure security of fuel supply. Development and selection of relevant technologies hold the key to promoting the use of DME in the consumer sector.

The consumer sector is about 60% dependent on oil fuel (kerosene, heavy oil, etc.) to meet its heating demands (air conditioning, hot-water supply, etc.). Oil fuel blended with bioethanol is currently under review for use in household boilers, which would help reduce CO_2 emissions[10].

4 World trends

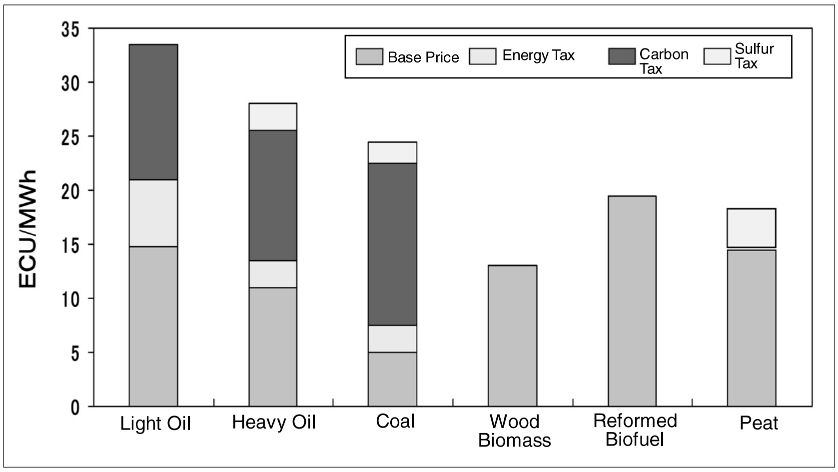
World trends in the development and use of synthetic liquid fuels are summarized below.

4-1 Europe

As part of its measures against global warming, the EU in October 2001 issued the “Renewables Directive”, which aims to double renewables' share of the EU's total primary energy supply, from 6% in 1998 to 12% in 2010[12]. A particularly promising renewable energy source is biomass, whose share for 2010 is set at 5.75%, according to the plan. Unlike in the U.S. and Japan, diesel vehicles are popular in Europe, which is why European carmakers are striving to develop biomass fuels.

In line with the directive, the German

Figure 8 : Fuel costs in Sweden



Data of 1996 (ECU is the former name of EURO) Source: Reference [14]

government is promoting BDF, applying a reduced mineral oil tax rate to biofuels (0.47 euro/liter or ¥63.9/liter based on an exchange rate of ¥136 to the euro). With this abatement in place, BDF is cheaper in Germany than conventional diesel fuel, by 0.12 euro/liter.

Three types of fuel taxes are in place in Sweden, on energy, carbon and sulfur. The energy tax is imposed on fossil fuels and electricity, while the carbon and sulfur taxes are levied on the basis of the amount of CO_2 emissions and the sulfur content of fuels, respectively[13]. These taxes, as shown in Figure 8, are not applied to biofuels - an arrangement to reduce the costs and promote the introduction of such fuels. In the field of alternative automotive fuels, three large-scale facilities (including plants for ethanol and DME production) are in operation, subsidized by the EU and the Swedish Energy Agency. In addition to these, small-scale facilities are located across the country, each of which is engaged in the development of oil alternatives[12].

4-2 North America

The U.S. government is pushing ahead with the development of biofuels as part of its policy to alleviate air pollution, ensure energy security, and promote domestic agriculture. Gasoline blended with 10% bioethanol (E10) is distributed widely in major cities, accounting for some 13% of the total market. Federal subsidies are available for bioethanol (US$0.14/liter or ¥14.7/liter based on an exchange rate of ¥105 to the dollar, to be reduced gradually) and BDF (US$0.27/liter or ¥28.3/liter). In addition, an annual budget of some ¥20 billion is earmarked for research, development, and promotion of biofuels between 2003 and 2007.

Eighty-four plants (including those under construction) located in 19 mid-western states produced a total of 14 million kiloliters of bioethanol in 2004, using cone as raw material[15]. About half of the producers are raw material producers, including farmers. Bioethanol plants in the U.S. are becoming larger in order to pursue economies of scale. As for BDF, 20 plants (of which 15 plants are under construction) produced a total of 100,000 kiloliters in 2003, using soybean oil and waste food oil as raw materials. BDF plants are also becoming larger, although production lags far behind that of bioethanol.

Both Exxon Mobil and ConocoPhillips will commercialize GTL fuel production in Qatar, sometime between 2009 and 2011, using low-cost natural gas as a feedstock to produce 80,000-150,000 barrels a day.

The Canadian government, meanwhile, has supported research and development on ethanol production since the mid-1980s, with ethanol exempted from the federal gasoline tax since 1992. As part of its measures against climate change, the government launched a C$100 million ethanol expansion program in October 2003, setting a target for 35% of the volume of gasoline currently sold in the country to be replaced with "gasoline blended with 10% ethanol" by 2010[12].

4-3 Asia

Malaysia and Indonesia are ranked first and second in global palm oil production, producing 12 million and 8 million tons/year, respectively. Being more plentiful than other vegetable oils, palm oil is cheap and can be readily produced; it is an ideal feedstock for BDF. Malaysia is expected to increase its production by 2 million tons in 2005, and Indonesia by 1-2 million tons in 2006 or 2007. While BDF use has yet to become widespread in these countries, the governments are poised to ramp-up BDF production for export purposes, using palm oil as a feedstock[16]. Japan should cooperate with both Malaysia and Indonesia, offering its BDF production expertise and development funds, to encourage exports from these two countries.

The Chinese government, in its 10th Five-Year Plan (2001-2005), designated E10 (gasoline blended with 10% ethanol) as a priority alternative fuel. In the wake of a surge in international oil prices, E10 demonstration programs were launched in 2004 in five provinces; these programs will be put into practice across the country by the end of 2005[17]. As for DME, about 50,000 tons is produced annually by indirect synthesis (methanol dehydration) for use as an LPG alternative fuel. According to some estimates, annual production is expected to reach one million tons in a few years' time, using natural gas and coal as feedstockss[3].

4-4 Other parts of the world

Using abundant sugar cane as a raw material, Brazil produced about 15 million kiloliters of bioethanol in 2004, most of which was blended with gasoline. Brazil's bioethanol production - based on a policy for stabilizing domestic sugar cane prices - dates back to the 1930s. Brazil has vehicles using three types of alternative fuel: E25 (gasoline blended with 25% ethanol), ethanol, and flex fuels (gasoline, ethanol or any mixture of the two). A total of 2.4 million kiloliters of bioethanol was exported in 2004, of which 0.5-0.8 million kiloliters was for drinks and industrial use. Exports to the U.S. and Europe for fuel use are on the rise. A Brazilian delegation visited Japan in January 2005 to survey Japan's potential as an ethanol market.

In South Africa, Sasol is producing GTL fuel from coal, and Mossgas from natural gas. Their production capacities stand at 100,000 and 30,000 barrels/day, respectively. Domestic oil wholesalers are mandated to purchase locally produced GTL fuel in proportion to their shares of the domestic market. GTL fuel is then blended with oil at tank facilities or at gas stations. The South African government has set the "floor price" of oil to protect the GTL fuel industry; subsidies are provided to Sasol and Mossgas if oil prices dip below the floor price, taking into account the balance between the two[4].

5 Challenges in developing and introducing synthetic liquid fuels

From the viewpoint of energy and fuel policies, challenges in developing and introducing the five promising oil alternatives (synthetic liquid fuels) can be summarized as below:

5-1 Dimethyl ether (DME)

DME, which can be produced from coal and biomass as well as from natural gas, is a clean fuel that is highly ignitable, produces no soot and has excellent combustion characteristics. It has a wide range of applications, and hence is expected to play a vital role in diversifying the supply of primary energy sources. As DME is still slightly more expensive than oil fuels, its cost needs to be reduced by developing applications other than automotive fuel. Specifically, DME-fired power plants should be built and applications for commercial power generation and other industrial processes should be developed to expand the DME market. There is also a need to reduce the operating costs of direct and indirect synthesis processes.

On the other hand, use of DME as automotive fuel requires demonstration and construction of distribution infrastructures dedicated to DME. As for DME vehicles, large capacity fuel pumps are needed to make up for its low calorific value, while measures should be developed to prevent fuel leakage and optimize fuel performance. Medium- to long-term approaches are required (reduced vehicle prices, etc.) and relevant laws and regulations such as DME safety standards and specifications should be improved to facilitate the use of DME.

5-2 Gas-to-liquid fuel (GTL Fuel)

As GTL fuel production projects currently underway are concentrated primarily in the Middle East, promoting this fuel in the domestic market may not necessarily reduce Japan's dependence on the Middle East in the short term. In the long term, however, there is a likelihood that small-to-medium-sized gas fields in Southeast Asia will also start producing GTL fuel in response to growing world demand for light oil, with particular emphasis on Asia. GTL fuel can be produced from biomass and coal as well as from natural gas. This means that eventually it can be produced wherever it is consumed. The development and use of GTL fuel will be essential in diversifying primary energy sources. Another great advantage of this fuel is that it can be used as a automotive fuel, without extensive renovation of existing infrastructures.

As mentioned in Chapter 2, a pilot plant using homegrown technology has succeeded in producing GTL fuel in Japan. However, in order to compete with overseas technologies and realize commercial production, a demonstration plant capable of producing several hundred barrels per day should be set up for the purpose of accumulating operational data and building confidence among all the parties concerned. It is also recommended that a large-scale demonstration project be implemented for domestic production, transportation and consumption of this type of fuel. Moreover, to encourage the private sector to commercialize GTL fuel production, a public financing system should be put in place for the construction of GTL fuel plants, which involves some degree of risk.

5-3 Methanol

With research and development underway on direct methanol fuel cells and the international standards for methanol fuel cartridges approved by the United Nations[11], demand is expected to increase for methanol to be used in fuel cells for mobile information devices. Key technologies for producing methanol from natural gas, biomass, and coal are nearing completion. The next challenge is to set up large-scale production facilities and reduce production costs.

5-4 Bioethanol

Bioethanol, when burned, produces less CO_2 emissions than gasoline. For this reason, large-scale introduction of this fuel - to the extent that all gasoline is converted into E3 - contributes to curbing global warming. However, disruptions to supply may occur because Japan is heavily dependent on imports and Brazil is the only country that has excess supply capacity. As for the infrastructures needed to refine and distribute E3 (including import infrastructures and facilities for handling hygroscopic feedstocks), the required capital investment is estimated at no less than ¥350 billion[6]. Bioethanol - as an option in Japan's energy policy - has some negatives, including its higher production cost compared to that of gasoline.

The development and use of bioethanol will be essential in diversifying primary energy sources. The government should therefore provide a series of supportive measures, e.g., improvement of the necessary infrastructures, fuel tax abatement, and development of technology for producing bioethanol from domestic biomass resources such as wood.

5-5 Biodiesel (BDF)

The use of BDF as a transportation fuel can help curb global warming as it produces less CO_2 emissions than light oil. Although BDF produced in Southeast Asia (from palm oil) and Japan (from waste food oil) poses some problems in terms of cost efficiency and stability of supply, the development and use of BDF will be essential in diversifying fuel sources.

Research should be conducted in Japan on the characteristics of "light oil blended with BDF", which can be used for conventional diesel vehicles without causing safety or environmental problems, to set fuel standards. It is also recommended that a fuel tax abatement program be adopted, following the example of Germany and Sweden; two countries in which BDF is being promoted nationwide. On the medium- to long-term basis, technologies should be developed to produce BDF from palm leaves and residues.

6 Recommendations

The world's demand for oil is expected to increase at an average annual rate of 1.9%. With oil demand on the rise in Asia, a surge in oil prices and disruptions to supply could occur at some future point. Meanwhile, development and use of oil alternatives improves compatibility between fuels and reduces geopolitical risks associated with energy supply. As a rule, market mechanisms play a central role in promoting oil alternatives and developing technologies for diversification of fuel sources, but this may not always be the case. A fixed-term national initiative should therefore be put in place to ensure energy security, curb global warming and alleviate air pollution.

In consideration of particularly important issues in promoting synthetic liquid fuels (each of which is described in the previous chapter), and to promote oil alternatives in a strategic and diversified manner, recommendations for support measures and technology development are summarized below (WTO Global Principle also taken into account *5):

(1) Support measures

(i) Infrastructure improvement and demonstration programs

DME, which has a wide range of applications as a fuel, should be promoted from the viewpoint of conserving the environment and ensuring energy security. However, as it is a new type of synthetic fuel, dedicated infrastructures (receiving terminals, storage/distribution facilities, etc.) are needed for its commercialization as automotive fuel. Meanwhile, promotion of gasoline blended with bioethanol involves renovation of existing infrastructures (oil refineries, oil tanks, gas stations, etc.) on the part of private sector in order to prevent degradation due to moisture absorption. Public awareness should be raised about these fuels, and they should simultaneously be promoted through a national initiative. While a bioethanol demonstration program is scheduled for implementation this year by the industry and government, there is a need to continue supporting such a program for the time being. To demonstrate the feasibility of DME, preliminary tests should be conducted in such places as a special economic zone in order to identify problems and pave the way for full-scale commercialization.

(ii) Fuel tax abatement and fuel standardization

Biomass fuels are being promoted in Europe, the U.S. and Brazil as part of national commitments to conserve the environment. Following the examples set by these countries, a tax abatement program should be adopted for the purpose of immediately introducing and promoting biomass fuels: DME, GTL fuel, BDF and bioethanol. Such a preferential tax system is essential in strengthening the competitiveness of these fuels.

As for light oil blended with BDF, its effects on vehicle emissions have yet to be fully assessed. Research should therefore be conducted on the characteristics of this type of blended fuel, as part of the measures to promote BDF, to set fuel standards for its safe and environmentally friendly use in conventional diesel vehicles. Likewise, specifications, quality assurance procedures, etc. for DME should be standardized.

(iii) Preferential treatment

Given the technological and market uncertainties involved, construction of demonstration plants for DME and GTL fuel would pose too great a risk for the private sector if it were to take on the whole responsibility. A fixed-term public support system should therefore be put in place to encourage such construction. Meanwhile, financing of overseas GTL fuel and DME projects should be part of the resources development funding provided by the Japan Bank of International Cooperation (JBIC), and a system should be developed to offer preferential interest rates and higher loan limits. As for projects that will contribute to reducing CO2 emissions, the Clean Development Mechanism (CDM)*6 of the Kyoto Protocol should be mobilized, and international cooperation solicited.

(2) Technology development

(i) Demonstration plants for GTL fuel

From the medium- to long-term perspective, original technologies for GTL fuel production should be developed in order to diversify transportation fuels and address environmental concerns. In 2003, a Japanese private consortium succeeded in setting up a pilot plant (7 barrels/day) for GTL fuel, incorporating homegrown technology and government support measures. The industry and government should cooperate to enhance the international competitiveness of this fuel. To this end, a demonstration plant (capable of producing several hundred barrels per day) should be set up, with the aim of accumulating a meaningful body of operational data by 2010. There is also a need to implement a large-scale demonstration project for domestic production, transportation, and consumption of this type of fuel.

(ii) DME technology

Applications for commercial power generation (thermal power generation, etc.) as well as industrial applications (LPG alternatives) should be promoted in the initial stage of introducing DME. Meanwhile, in the medium- to long-term, a series of approaches should be adopted with a view to commercialization of automotive fuels. At the same time, research and development should be conducted on the prevention of leakage, fuel optimization and large-capacity fuel pumps needed to make up for the low calorific value of DME.

(iii) Biomass fuel technology

The bulk of bioethanol and BDF is produced from plant materials such as sugar cane and palm oil. However, a variety of feedstocks should be used in order to increase supply of biomass fuels. A medium- to long-term national initiative should therefore be put in place for the purpose of developing technologies for converting domestic cellulose resources (non-food resources such as wood, plants and used paper) into bioethanol, and producing biodiesel from palm leaves and residues.

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Notes

*1 In indirect synthesis of DME, synthesis gas is converted into methanol, which is then dehydrated to produce DME. This technology, a combination of established techniques, is now in the commercialization phase. In direct synthesis of DME, synthesis gas is directly converted into DME without producing methanol, an intermediate. This technology, unique to Japan, is still in the development phase. JFE Holdings is playing a central role in running a 100 tons/day pilot plant in Kushiro that has been in operation since December 2003.

*2 As production of DME requires a significant amount of heat for reforming processes, etc., its well-to-tank (mining, transportation and production) emissions of CO_2 per unit calorie are theoretically greater than those of LNG, LPG, and oil. DME contains oxygen and its carbon content is lower than those of LPG and light oil. However, with its calorie per unit weight being some 60% of that of LPG, the amount of emissions associated with its combustion is theoretically the same as those of LPG [6].

*3 Liquid hydrocarbons are produced from CO and H_2 through catalytic reactions, a process discovered by E. Fischer and H. Tropsch (Germany) in 1923.

*4 Shell (U.K. and the Netherlands), Sasol (South Africa), ChevronTexaco (U.S.), ExxonMobil (U.S.), ConocoPhillips (U.S.), BP (U.K.), etc.

*5 The principle, which is in line with OECD guidelines, sets out that: (1) governments as well as laws and regulations should not interfere with the market; (2) research and development programs are authorized only for basic and common techniques that are far from being commercialized; (3) objectives of measures that are close to becoming marketable should be made public within the prescribed time frame so that their achievements are shared worldwide.

*6 A system where Kyoto Protocol signatory and non-signatory countries implement joint projects for reducing greenhouse gases - benefits of which can be shared between the countries concerned. This benefits non-signatory countries in that they can promote their environmental measures through investment and technology transfer from signatory countries.

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5

Trends in Space Transportation Systems in Various Countries
— Changes Arising from Retirement of the Space Shuttle —

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1 Introduction

On February 26, 2005, the Ministry of Land, Infrastructure and Transport launched Multi-Functional Transport Satellite-1R (MTSAT-1R) via H-IIA Launch vehicle No. 7. The failed launch of H-IIA No. 6 in November 2003 had idled the launch vehicle developed by the Japan Aerospace Exploration Agency (JAXA) for a year and three months. The successful launch of the MTSAT-1R into geostationary transfer orbit (GTO) is a restart for the program.

Meanwhile, the United States space transport system also was shut down following the in-flight loss of the Space Shuttle Columbia; however, with a new launch scheduled for July 2005, the program is on the road to recovery. Despite this, the Space Shuttle is now expected to be retired within 10 years due to changes in US space policy that took place during the shutdown.

This report will first discuss the move toward retirement of the Space Shuttle. It will then look at post-Shuttle space transportation systems in terms of five broad categories: (1) manned space transportation systems, (2) transport of supplies to the International Space Station, (3) expendable launch vehicles, (4) deep space exploration beyond the Moon, and (5) reusable launch vehicles. Next, it will discuss projects currently either in development or in operation in various countries.

Finally, the report will examine the appropriate policy for Japan on space transportation systems in light of this international competition on development.

2 Move toward retirement of the Space Shuttle Program

Operation of the Space Shuttle began in spectacular fashion in 1980 with the launch of Columbia. The formal name of the Space Shuttle is “Space Transportation System” (STS), with the component that returns to Earth called the “orbiter.” Five orbiters were manufactured. They have flown over 100 missions to date.

As the name implies, the National Aeronautics and Space Administration (NASA) developed the Space Shuttle design as a system for all forms of space transportation. The concept was that it would transport people and cargo into space, that it could be used repeatedly, and that it would be ready for re-launch about one month after each landing. Initial plans envisioned four Space Shuttles, with dozens of launches every year.

Once actual operation began, however, those plans were immediately frustrated. Because heat-shield tiles suffered serious damage during re-entry and their repair was time-consuming, it became evident that re-launch after one month would be impossible. In addition, insufficient thought was given to repeated operation, and costs blew out to nearly 100 times initial estimates. In recent times, NASA’s best achievement has been eight launches in one year, at a cost of US$4 billion. Because it cannot come close to matching the low cost of expendable launch vehicles that can be deployed for between ¥10 billion and ¥20 billion per launch, the Space Shuttle has not undertaken a mission for the sole purpose of launching satellites since 1992.

The Space Shuttle program has suffered two major accidents and lost two orbiters. On January 28, 1986, Challenger self-destructed immediately after launch when burning gas erupted from a crack in an O-ring on the solid rocket booster (SRB) and caused liquid propellant to explode from the opening. The loss of the seven-member crew was a major blow to US space development. Two years and eight months of preparation ensued before the next launch, in September 1988. Challenger's replacement orbiter, Endeavour, made its first voyage in May 1992. On February 1, 2003, Columbia broke up during re-entry flight over Texas, USA, and was lost along with all seven crewmembers. The accident was caused by insulation detaching from the external tank and damaging part of the reinforced carbon-carbon (RCC) panel on the leading edge of the left wing, allowing superheated air to penetrate during re-entry. With the accident investigation and determination of future policy completed, re-launch is scheduled for July 2005.

In the International Space Station (ISS) project being built by the USA, Europe, Japan, Russia, and Canada, component parts (modules, trusses, etc.) are to be launched by the Space Shuttle and Russia's Proton launch vehicle. Of those parts, Japanese and European experimental modules can only be launched by the Space Shuttle. In order to meet its international obligations, the USA must therefore keep the Space Shuttle in operation at least until the ISS is completed. However, once construction of the ISS is finished, the USA plans to retire the Space Shuttle as soon as possible and move to a new, more efficient space transportation system that separates crew transport from cargo transport.

3 Trends in development of manned space transportation systems

3-1 USA Crew Exploration Vehicle (CEV)

Prior to retirement of the Space Shuttle, NASA plans to develop the Crew Exploration Vehicle (CEV) as a manned space transportation system capable of everything from low Earth orbit flight to manned exploration of Mars. The initial goals were to achieve manned CEV test flights by 2014, with manned exploration of the Moon taking place between 2015 and 2020, but NASA Administrator Michael Griffin intends to move test flights up to 2010.

In March 2005, NASA issued a request for proposal (RFP) to develop the CEV from September 2005 through December 2008. Two groups responded by the May 2 deadline. A consortium led by Lockheed Martin proposed a winged vehicle with a crew of six. Boeing joined Northrop Grumman, Europe's Alenia Spazio and others with a proposal for a space-docking vehicle with three modules. NASA will study these proposals and is scheduled to announce its

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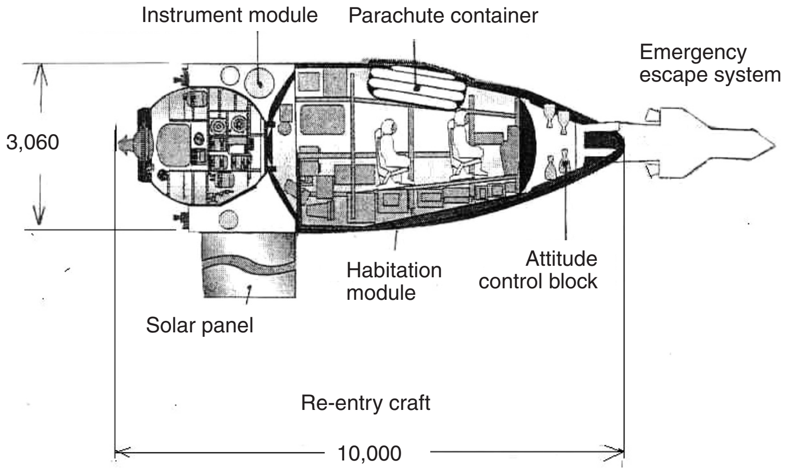
•*Space Shuttle's reusable Solid Rocket Booster (SRB)*

After the SRB completes combustion, it separates and falls back to Earth, where it is collected from the ocean. Because it is made of metal, it can be refilled with propellant and used again. In contrast, Japan's H-IIA rocket utilizes the SRB-A, in which a structure formed by filament winding (FW) is filled with propellant. Once the propellant has burned off, the structure is severely weakened, so it cannot be used again.

•*SRB's oxidizer damages the ozone layer*

The SRB's propellant comprises fuel and an oxidizer, which are blended in a mixer, formed, and solidified. Because the oxidizer contains perchlorate, the SRB's exhaust reportedly damages the ozone layer. In February 2005, the US Environmental Protection Agency (EPA) set the official reference dose of perchlorate at 0.0007 mg per kg of body weight per day.

Figure 1 : Cross-section of lifting body type Kliper[1]



Original diagram © Anatoly Zak

choice of contractor in September 2005.

3-2 Trends in development of new Russian manned spacecraft

In November 2004, Russia's RKK Energia, maker of the Soyuz manned spacecraft, unveiled a full-scale mockup of the Kliper (КЛИПЕР) manned spacecraft, at the KIS experimental station. The model is also scheduled to be exhibited at the Paris Air Show in June 2005. The basic structure and specifications of the current Soyuz spacecraft (3-person crew) differ very little from those of the 40 year-old original, with its cramped and uncomfortable crew space. The Kliper replacement may become the mainstay of crew transport design after the Space Shuttle is retired.

Two configurations for the Kliper have been announced so far. Figure 1 shows a cross-section of the lifting body type. With six-seater capacity (two rows of three), it will not only be able to transport six crew members to the ISS, but can also accommodate four space tourists and a crew of two. The second configuration has wings like the Space Shuttle, but the crew compartment is the same as that of the lifting body type. It is therefore possible that development will proceed in stages, first with the lifting body type and then with the winged type.

The Kliper will be 10 m long, with a diameter of 3 m and a weight of 13 tons. In addition to six astronauts, it will be able to carry about 500 kg of cargo. An emergency escape rocket at the front of the craft similar to that of Soyuz is shown in the published plans. An alternative draft design provides for weight-saving by attaching the escape rocket to the rear of the craft, where it could also be used as a propulsion engine for acceleration. To save development costs, the Ukrainian Zenit launch vehicle is expected to be used as the launch vehicle.

3-3 Competition between European Space Agency member countries on development of manned spacecraft

In Europe, above and beyond national space development programs in various countries, the European Space Agency (ESA) carries out large-scale programs with funding and development input shared among member countries. In the field of manned spaceflight, member countries are engaged in an unprecedented level of competition. This is because the ESA's own manned spaceflight plan has only reached the stage of budget appropriation, and its content is yet to be determined.

The ESA's two largest financing countries, France and Germany, are carrying out technical development for manned spaceflight in their own space development programs. France is developing two manned spacecraft, the Angel and the Pre X, while Germany is developing its own pair, the Phoenix and the Hopper. If development goes well, both countries are thought likely to attempt to have their respective national manned spaceflight programs adopted as the ESA program.

3-4 China's manned spaceflight

In October 2003, China successfully launched Shenzhou 5, becoming the third country to achieve launch of a manned spacecraft. Around September 2005, China plans to carry out a spaceflight of several days with a two-person crew, setting a record by becoming the first country to achieve a multi-astronaut spaceflight within two years of its first solo flight. The Soviet Union took three and one-half years, and the United States three years, to accomplish the same feat. Beginning in 2006, China plans to fly three-person missions, with one member of each complement being a non-astronaut. (See Feature Article 3, July 2004.)

In addition, China plans to dock manned spacecraft with its own space station. The Long March 5 launch vehicle, currently in development, may be ready to launch space station modules by around 2010.

4 Trends in the development of resupply vehicles for the International Space Station

4-1 Russia's Progress resupply vehicle

On February 28, 2005, the Federal Space Agency of Russia (FSA) successfully launched the Progress M-52 resupply vehicle with a Soyuz U launch vehicle. It was the 17th Progress mission to the ISS. The Progress can carry 2.8 tons of payload per launch, of which about 1 ton goes to fill tanks with fuel, oxygen gas, etc. The remainder is cargo, material needed by the ISS astronauts for experiments, food, etc. Until the US Space Shuttle resumes flights, the Progress is handling ISS supply missions single-handedly. Due to supply delays, ISS crewmembers have even had to ration their food at times. Since its first flight in 1978, the Progress has undergone some improvements, but like the Soyuz, it has undergone no major changes from the original model that supplied the Soviet Union's Salyut and Mir space stations. Even if other countries develop and operate resupply vehicles to rival the Progress, there will probably still be a role for this reliable spacecraft over the near future.

4-2 Japan's HTV resupply vehicle

On January 26, 2005, the ISS Heads of Agency meeting held in Canada discussed space transportation systems with a view to eventual retirement of the Space Shuttle. The joint statement[2] issued there includes utilization of the H-2 Transfer Vehicle (HTV) being developed by JAXA to support the ISS program by transporting cargo to the International Space Station. This can be seen as providing Japan's space transportation system with a platform on which to develop its full capabilities alongside Russia's Progress resupply vehicle and Europe's Automated Transfer Vehicle (ATV).

As can be seen in Figure 2, the HTV is cylindrical and divided into pressurized and non-pressurized sections, with the propulsion equipment and guidance control instrumentation at the rear (at right in the photo), and containers

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•*Manned launch*

When a launch vehicle includes people in its payload, it is called a "manned launch." A manned launch differs from cargo-only launches in that it must reliably return its human payload safely to Earth, it must be equipped with an emergency escape system, and environmental conditions such as vibration and noise must be considered. For the launch of the Shenzhou manned spacecraft, China modified the design of its Long March 2E launch vehicle to produce the new Long March 2F. Major changes included adding redundancy in the control system, a self-diagnostic function for malfunctions, and an emergency escape system. In addition, it is believed that during the four test flights dummies were used in place of astronauts, in order to test medical monitoring and to train support personnel.

for the payload in the center. The HTV can transport a maximum cargo of about six tons. The unmanned automated rendezvous technology developed through the Engineering Test Satellite VII (ETS-VII, Kiku 7) is reflected in its ISS docking capability. Japan will replace its obligation to pay for ISS operation by resupplying the station using the HTV. As long as the ISS is in operation, a certain percentage of resupply demand can be expected.

4-3 Europe's Automated Transfer Vehicle (ATV)

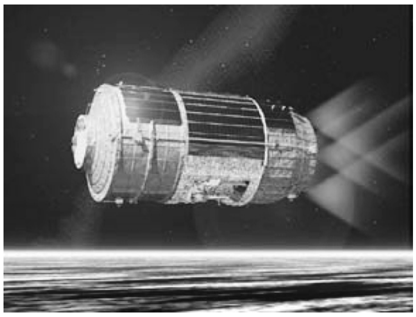
The concept for Europe's ATV has been taking shape since the 1990s. The October 1995 ESA ministerial meeting decided to develop the ATV, and Germany has taken the lead in its development. Current plans call for a 2006 test launch of the Jules Verne as depicted in Figure 3. The development process to date has not always been smooth, with problems such as cost overruns and technical issues arising, but it is currently seen in Europe as a major project that should be continued, even as budgets for other space-related projects are being cut. The ATV is to be launched by Ariane 5 launch vehicle and will automatically rendezvous and dock with the ISS, where it will be able to stay up to six months. About once a year, it will carry experimental equipments, food, and other everyday supplies to the Columbus European experimental module located at the forward starboard section of the ISS. The ATV is designed to carry about 7.5 tons of cargo per launch and to be capable of removing about 6.5 tons of waste from the ISS.

5 Trends in the development of Expendable Launch Vehicles (ELVs)

5-1 USA Evolved Expendable Launch Vehicles (EELVs)

In 1994, the USA announced its national policy on space transportation, with the Department of Defense (DoD) in charge of development of the Evolved Expendable Launch Vehicles(EELVs). Development is based on the Atlas IIAS and Delta II launch vehicles.

Figure 2 : External view of the HTV[3]



Source: Photo by JAXA

Figure 3 : External view of the ATV (Jules Verne)[4]

Source: Photo by ESA

Lockheed Martin has launched five Atlas V (five) launch vehicles since 2003. The weight it can carry into geostationary transfer orbit (GTO) has increased progressively from 3.8 to 8.7 tons. The heavy version aimed for at least 13 tons in GTO, but development has been halted. Meanwhile, Boeing attempted to upgrade the 1.8-ton GTO capacity of the Delta II to 3.8 tons with the Delta III. However, only one of the Delta III's three launches succeeded, and Boeing instead brought to market the Delta IV, which it had been developing along with the GTO 13-ton class. By 2004, the Delta IV Medium had successfully launched three geostationary satellites of about the GTO 3-ton class, and in the sense that it was an upgrade from the Delta II, the launch vehicle was a success. However, the first launch of the Delta IV Heavy (Figure 4) with a GTO 6-ton demonstration satellite in December 2004, was unsatisfactory because of a shorter than expected first-stage burn. According to materials released so far, cavitation (bubbles) in the liquid oxygen supply pipe apparently caused the first-stage burn to terminate. Boeing is already preparing a Delta IV Heavy to launch a DoD Defense Support Program (DSP) satellite.

Figure 4 : External view of the Delta IV Heavy

Source: Photo by Boeings

5-2 Europe's augmented Ariane 5

In Europe, the corporation Arianespace operates the Ariane launch vehicle, which has launched about half the world's geostationary communications satellites. The ESA's development program is aiming for the GTO 10-ton class with the Ariane 5E/ESC-A. The first launch, in December 2002, failed to insert the satellite into the prescribed orbit; however, on February 12, 2005, the same type of launch vehicle successfully inserted a communications satellite, proving its ability to launch 7.5 tons into GTO. The Ariane 5E/ESC-A is aimed at reducing costs by carrying two large geostationary satellites in one launch. If costs are lowered, the Ariane will be even more competitive.

5-3 An international joint venture's Sea Launch system

Recently, a new method of marine-based launches has been garnering attention. This method offers the advantage of being able to launch from the high seas on the equator, the optimal location for launching geostationary satellites. This permits maximum use of launch vehicle capability. Because launch vehicle preparation can be carried out onboard ship on the way to the range, work time is also reduced. Four corporations from the USA, Russia, Ukraine, and Norway, founded Sea Launch Co.[5] as a joint venture. The company's ships and a launch vehicle are shown in Figure 5. The sea launch platform is a former ocean oil-drilling platform. The 130-m long Odyssey platform is semi-submersible and self-propelled.

After launching a demonstration satellite into GTO in March 1999, Sea Launch carried out 14 more GTO launches up to March 2005. Of the 15 launches, only one, the March 2000 launch of an ICO satellite into a medium-altitude circular orbit, was unsuccessful. Thus, Sea Launch has successfully launched 13 satellites. Orbit insertion accuracy has improved with each launch.

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•*Multistage launch vehicle*

Launch vehicles use two or three stages to reach the desired speed and altitude, with each stage falling away after its fuel has burned out. These vehicles are called "multistage launch vehicles." The theory was first described in 1929 by the Russian, Konstantin Eduardovich Tsiolkovsky.

Launch vehicles launching geostationary satellites usually have three stages, propelling themselves until they reach geostationary transfer orbit (GTO). The first stage lifts the launch vehicle out of the atmosphere to space altitude, and the second accelerates it to satellite speed. The third stage changes the orbital plane to enter GTO. Then the payload satellite's apogee engine moves the satellite into geostationary drift orbit.

Japan's H-IIA can enter GTO even though it only has two stages. This is because the second-stage engine (LE-5B) can reignite and carry out the role of a third stage. This is advanced technology that stands up against any in the world. Russia's Proton launch vehicle, on the other hand, has four stages. The fourth stage is equivalent to a satellite's apogee engine, so the launch vehicle performs the role of attaining geostationary drift orbit.

Initially, satellites were about 20 km out of place, but recently error has been negligible. According to the Sea Launch work schedule, it takes three to four weeks from the time the satellite is loaded on the Assembly and Command Ship until it is launched, including one week to travel by sea from the Home Port to the range. To date, the shortest period between launches has been 53 days. The most recent launch took place on April 26, 2005, on the equator at 154° west longitude. The payload was a US DIRECTV Spaceway broadcast satellite (GTO weight 6.1 tons). The previous launch was on March 1, so the interval of 56 days was a near record for the company.

Figure 5 : A Sea Launch launch Vehicle (Zenit-3SL) being worked on

Foreground: Odyssey Launch Platform
Background: Assembly and Command Ship
Source: Photo by Sea Launch

5-4 China's next-generation launch vehicle

Trends in China, which is developing launch vehicles in the heaviest classes after those of Europe and the USA, are noteworthy.

At the 54th International Astronautical Convention (IAC), held in Bremen, Germany in October 2003, a Chinese scientist announced the new Long March launch vehicle[6]. The design of China's Long March launch vehicles developed from type 1 through type 4 from a military-use vehicle for missile launch to one that can be used for launching satellites. Because the developers used unsymmetrical dimethyl hydrazine (UDMH)

Supplement

• *"Geostationary transfer orbit" and "geostationary drift orbit"*

Geostationary earth orbit (GEO) is a circular orbit about 35,786 km above Earth's surface, with an orbital inclination of 0°. The orbital period is 23 hours and 56 minutes, matching Earth's rotation speed, so the satellite appears to be stationary as it orbits above the equator. In fact, it is traveling at over 10,000 kmph. Geostationary transfer orbit (GTO) is an elliptical orbit that ranges from a perigee of about 200 km to an apogee of about 36,000 km, over a period of around 12 hours. In the case of a launch from Tanegashima (30° north latitude) to the east, with a satellite inserted into GTO by launch vehicle, the satellite must consume a large amount of fuel through its apogee engine in order to transfer to geostationary drift orbit; therefore, the satellite's weight drops by about one-half compared to its weight at GTO insertion. When a satellite is launched toward the east from near the equator, required fuel consumption decreases, so the ratio is higher. Geostationary drift orbit is almost the same as geostationary earth orbit, but a small difference in period and a slight orbital inclination keep the orbit from becoming geostationary. Conversely, the satellite's geostationary position can be changed by controlling it so it drifts. The geostationary position of the US weather satellite GOES 9, which substituted for GMS-5 (Himawari 5) until MTSAT-1R began operating, was shifted from 105° west longitude to 155° east longitude.

• *"Range" and "launch pad"*

In order to launch satellites by a launch vehicle, a location from which to launch the vehicle is needed. This is the "range". At the range, the vehicle's stages are assembled and inspected, and the satellite, fairing, and so on are assembled and integrated with the vehicle so that the launch vehicle can be placed at the "launch pad," from which it will be launched. The range also includes control and supervising facilities.

as fuel, toxicity became a problem. China is currently using its experience in launching more than 80 Long March launch vehicles to engage in R&D on the Long March 5 series, with the aim of simplifying the launch process and increasing reliability.

The Long March 5 is assembled from combinations of seven kinds of modules with diameters of 5 m (stages one and two), 3.35 m (stages one, two, and three), and 2.25 m (stages one and two). The 5-m diameter first stage and second stage, the 3.35-m third stage, and the 2.25-m second stage are each equipped with a pair of engines that use liquid oxygen and liquid hydrogen as propellants to produce 50 tons of thrust. The remaining three modules (the 3.35-m first and second stage and the 2.25-m first stage) are each equipped with two engines that utilize liquid oxygen and kerosene to produce 120 tons of thrust. The fuelled weights of the first stage are 173.5 tons (5-m), 144 tons (3.35-m), and 64 tons (2.25-m). The second stage of 5-m module is only capable of entering low orbit, but adding an HO Module utilizing existing liquid oxygen/liquid hydrogen engines enables GTO insertion. Within the Long March 5 series, the strongest model, the 504/HO, adds four 3.35-m modules around a 5-m module with the aim of being able to insert 15 tons into geostationary transfer orbit. It may become the world's most powerful in terms of launch capability.

Looking at the Long March 5's design concept, it differs from launch vehicles in the Long March 2,3 and 4 series in that it can flexibly adjust its launch capability according to payload for anything from small satellites to heavy ones, and its engines use pollution-free or low-pollution liquids as fuel. Liquid-fuel engines are also desirable from a reliability standpoint, because they can be test-fired before use, and during launch, ignition can be confirmed before liftoff.

China plans to construct its fourth range on Hainan at 20° north latitude, so that island may become the site for Long March 5 launches.

Along with the Republic of Korea building its first range in Oenarodo, Cholla-namdo, China's construction of a new range bears watching.

5-5 India's PSLV and GSLV expendable launch vehicles

The Indian Space Research Organization (ISRO), which leads Indian space development, successfully launched India's first satellite with its own expendable satellite launch vehicle (SLV), in 1980. Subsequently, augmented (ASLV), polar orbit (PSLV), and geostationary orbit (GSLV) versions were also developed. Through 1997, two out of four SLV launches, three out of four ASLV launches and two out of four PSLV launches failed, for a dismal success rate of only 41.7 percent. However, since 1999 India has conducted eight consecutive successful launches of medium-sized satellites, including three geostationary satellites. Launch capacity is roughly one-half that of the Japanese H-IIA.

In 2001, India successfully launched a GSAT geostationary satellite with a GSLV for the first time. India's INSAT operational geostationary satellite carries instruments for communications and weather missions. So far, 13 INSAT satellites have been launched by European and US launch vehicles, but in the future they may be launched by India's own GSLV.

5-6 Japan's augmented-type H-IIA launch vehicle

The mainstay of Japan's launch vehicle, the H-IIA, has launched seven times, all successfully except for 6th H-IIA launch vehicle which failed by malfunction of SRB-A separation. Once the number of successful launches increases and reliability of the H-IIA's design is established, its operation will transfer- from JAXA to Mitsubishi Heavy Industries (MHI). Currently, Rocket System Corp. (RSC) is commissioned by JAXA or customers, and in turn commissions space-related businesses to carry out launch-related work. However, following the shift to the private sector MHI will be the primary actor, bringing together the products and personnel of relevant companies to prepare for launches and ultimately looking to JAXA for launch control only. This is expected to begin with contracts for fiscal 2006. This will provide clear separation between Japan's day-to-day launch operations and new development.

In charge of new launch vehicle development, JAXA has looked at several configurations for the augmented H-IIA and is aiming for the ability to insert 6 tons into GTO by increasing diameter from 4 m to 5 m and equipping two main engines inside of the first stage. If this performance goal is realized, the augmented-type H-IIA will be able to launch an HTV into low orbit and will be able to accept commercial orders to launch the world's heaviest communications satellites, such as Intelsat 10 (GTO 5.6 tons).

6 Deep space exploration beyond the moon

The energy required to reach space altitudes is expressed as "ΔV" (Delta V), or "velocity increment." Figure 6 shows the ΔV needed to fly from an altitude of 10 km to a distance of almost 1 light year[7].

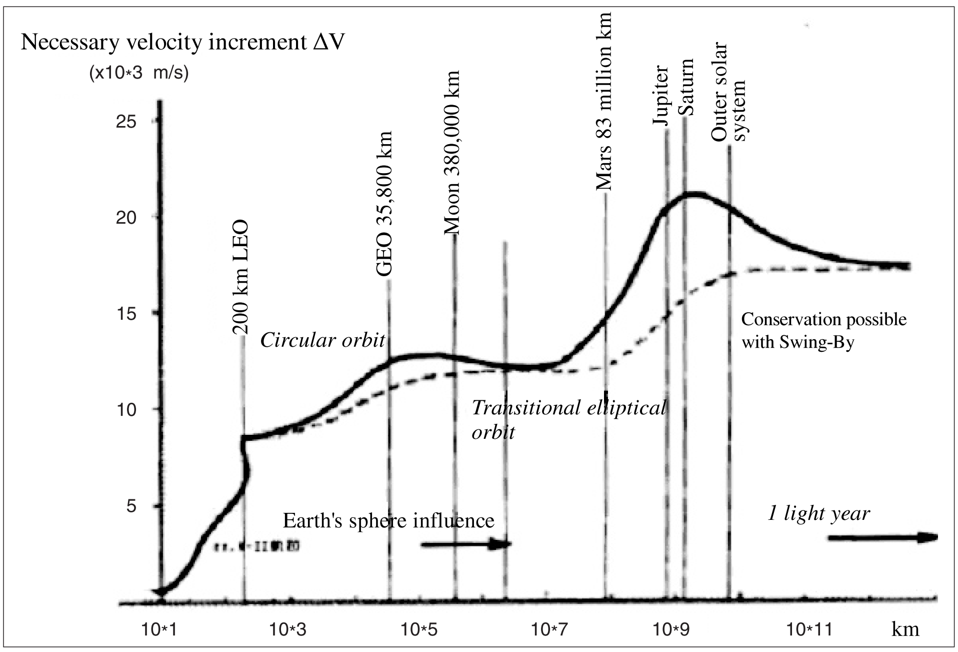
As can be seen in Figure 6, the velocity increment required to reach an altitude of 200 km is 8 km/s, while that needed to reach geostationary earth orbit (GEO) or the Moon is only slightly higher at 12 km/s. The distance to Mars is 200 times the distance to the Moon, while the distance to Jupiter or Saturn is thousands of times greater, but the velocity increment needed to reach them is less than one might expect. In such deep-space flight, rather than the launch vehicle only, propulsion systems installed in the probes handle an important part of the ΔV. In addition, flight plans for planetary probes conserve ΔV by using a method called "swing-by" to utilize the gravity of Earth or other celestial bodies for acceleration.

NASA has launched solar system probes such as Ulysses (Sun), MESSENGER (Mercury), Magellan (Venus), Lunar Prospector (Moon), Mars Observer (Mars), Galileo (Jupiter), Cassini (Saturn), Voyager (now outside the solar system), and Stardust (comet). Cassini made a close approach to Saturn's moon Titan in December 2004, and in January 2005 it released the ESA-developed Huygens toward that moon.

The Soviet Union launched deep space probes such as Venera (Venus), Luna (Moon), Mars (Mars), and Vega (comet).

In Japan, JAXA's Institute of Space and Astronautical Science (ISAS) used solid rockets (the L-3SII and M-V) to launch Hagoromo (Moon), Nozomi (Mars), Suisei (comet), Hayabusa (asteroid), etc. Nozomi failed to reach Mars because of a malfunction in an oxidizer pressure valve, but Hayabusa reached the asteroid Itokawa, and is due to return with samples during 2005. In order to make that flight, Hayabusa was equipped with its own ion-engine propulsion system. This kind of Sample Return mission,

Figure 6 : Energy ΔV needed to reach from Earth[7]



which brings a small sample back to Earth from deep space, certainly qualifies as a type of space transportation system.

7 Reusable launch vehicle

Reusable launch vehicles are designed so that the vehicle can be recovered and refueled for the next flight. The two main categories of reusable launch vehicle are single-stage to orbit (SSTO) and two-stage to orbit (TSTO). In the case of two-stage reusable launch vehicle, the first stage may be a conventional aircraft, with the second stage fired in the air.

When either a single-stage or a two-stage reusable system is used, the only major recurring costs are the fuel consumed and the work performed. Therefore, costs can be much lower than they are for expendable launch vehicles, which face huge manufacturing investment for each launch. Reusable launch vehicles are especially effective for missions to launch materials for ultralarge satellites that must be assembled in orbit. With all of humanity facing an energy crisis as fossil-fuel resources run out, development of space solar power systems (SSPS) is one potential alternative energy strategy. However, if the costs of launching such systems are enormous, and more energy is required to develop and operate them than they can harvest, such development plans are not viable. When the Space Shuttle appeared it seemed that realization of space solar power systems might be within reach, but because the Space Shuttle uses expendable external tanks (ETs) and thus is not completely reusable, and because maintenance and repair after recovery takes longer than expected, construction plans for space solar power systems quickly faded away.

Not only the Space Shuttle but also the reusable launch vehicles that have been developed in various countries have experienced a series of challenges and failures. Below, I review past projects to develop reusable launch vehicles in several countries:

(1) USA

(i) Based on the 1994 national policy on space transport, NASA was placed in charge of developing a Reusable Launch Vehicle (RLV) as a successor to the Space Shuttle. NASA attempted to develop a lifting-body type X-33 experimental craft, but the composite tanks could not be lightened as expected and development was abandoned.

(ii) Then McDonnell Douglas (now merged to Boeing) developed the vertical takeoff and landing Delta Clipper for the US Department of Defense (DoD). Following its first flight in 1993, the Delta Clipper flew more than 10 successful test flights, but in 1996 it tipped over when landing because of a faulty strut, and was destroyed by fire.

(2) Russia

The Soviet Union in 1988 launched the Buran

Supplement

• *"Solid propellant rockets" and "liquid propellant rockets"*

A "solid propellant rocket" is a multistage launch vehicle in which where the propulsion equipment for every stage is a solid rocket motor. A "liquid propellant rockets" is a launch vehicle propelled by a liquid propellant engine.

During the Cold War "space race" between the USA and the USSR, almost all US and Soviet launch vehicles were liquid propellant rockets propelled by liquid propellant engines only. A typical example is Russia's Soyuz launch vehicle, which has five liquid engines (20 combusters) per vehicle. Including the Soviet era, more than 1,000 have been launched over a 40-year period. The largest type in Europe's discontinued Ariane IV series, the 44L, used eight liquid propellant engines for the first stage.

In Japan, the University of Tokyo succeeded in horizontally firing a solid-propellant pencil rocket in April 1955. Since then, the ISAS has developed the all-stage solid K (kappa), L (lambda), and M (mu) rocket series.

unmanned recoverable spacecraft with an Energia launch vehicle and successfully recovered it, but financial difficulties led to abandonment of the program.

(3) Europe

The ESA was attempting to launch the Hermes small recoverable spacecraft atop of Ariane 5 launch vehicle, but budget cuts led to development being aborted.

(4) Japan

During the 1990s, then National Space Development Agency (NASDA) and then National Aerospace Laboratory (NAL) collaborated to research and develop the horizontal-landing, recoverable H-2 Orbiting Plane (HOPE), launched by H-II launch vehicle. They also carried out test flights of the related Hypersonic Flight Experimental (HYFLEX) and Automatic Landing Flight Experimental (ALFLEX). The HYFLEX flew successfully, but it was lost into sea and could not be recovered. This prevented detailed analysis of changes in the craft's materials after re-entry. In 2003, High Speed Flight Demonstration (HSFD), in which the craft was released and landed under its own power, was carried out on Christmas Island in the Republic of Kiribati. However, the project remains frozen without an actual HOPE having been manufactured. In March 2005, JAXA announced its long-term vision. This includes not only continued operation and development of the H-IIA launch vehicle that is the basic of Japan's space transportation system, but also assertion of the need to develop a reusable launch vehicle transportation system. The basic concept is to work on new initiatives to improve the reliability of manned launches to the extent possible by carrying out small-scale reuse[8].

In the USA, the Ansari X Prize Foundation's prize scheme has stimulated private-sector competition in manned spaceflight. (See February 2005 "Topics.") The US company, SpaceX, is attempting not only to launch satellites but also to launch a private-sector space station, and to develop a manned spacecraft that can rendezvous and dock with the station. The group includes scientists who have previously worked in launch vehicle development in other space-related companies. It is possible that the free thinking of the private sector may race ahead of stagnating government projects and realize a true reusable launch vehicle. Expectations are high for the creation of spacecraft based on novel ideas.

In addition, research on "space elevators," a space transportation system concept that is completely different from all the chemical launch vehicles mentioned above, is proceeding apace. (See April 2005 "Topics 8.")

8 Conclusion: Discussion of how to proceed with development of Japanese space transportation systems

The time has come for Japan to clarify its basic strategy for ongoing research and development in the technical field of space transportation systems. In light of the trends in various countries described above, this report offers the following suggestions:

Supplement

•Costs of reusable launch vehicles

The development of reusable launch vehicles requires vast amounts of funding. This kind of funding is called "nonrecurring costs." In contrast, the funds needed to regularly operate a completed system are referred to as "recurring costs." Nonrecurring costs are lower with expendable launch vehicles than with reusable systems, but recurring costs can be more than 10 times as great. For example, overall costs would be approximately even for 100 launches with either type of system, but in the case of construction of a giant structure in space, such as a space solar power system (SSPS) which would require 200 or 300 launches to supply parts, costs would be much lower with a reusable launch vehicle.

(1) Implement use of the H-2 Transfer Vehicle (HTV)

Following retirement of the Space Shuttle, the HTV may be assigned a portion part of supply transportation to the International Space Station. The HTV is only a load at launch; but when it approaches the final destination it arrives under its own power and can fulfill an important role in space transportation. Japan should apply the robot technology that is its specialty to develop its own automatic rendezvous technology, starting with a focus on efforts to bring the HTV into practical use and secure a position in the International Space Station project.

(2) Maintain and develop technology for medium-sized expendable launch vehicles

Demand for commercial geostationary satellite launches amounts to only 20 to 30 annually. Furthermore, with the USA, Europe, Russia, and China all competing fiercely for market share, it is very difficult for the H-IIA to win orders. However, maintaining launch operations and the manufacturing technology needed for the 280,000 parts used in launch vehicles can still play a role in terms of technical development and transmission of industrial techniques such as materials development and manufacturing technologies. In addition, it can also make direct and indirect contributions to the creation of knowledge through space experiments in fields such as life science and environmental research. Japan should not only pursue world-leading launch capacity for the augmented version of the H-IIA, it must also maintain the basic launch vehicle technology that can reliably and flexibly launch the many medium-sized payloads that exist.

One possible direction for development is to equip the augmented version of the H-IIA with a propulsion system comprising liquid propellant engines only, as with the USA's evolved expendable launch vehicles and China's Long March 5 series. This technology might also enhance reliability. Another direction is to aim for technology that allows stage-two engines to be reignited multiple times for satellite insertion into geostationary drift orbit, without needing to use the satellite's apogee engine. This would lower the manufacturing costs of geostationary satellites and allow the weight of instruments loaded on the satellite to be increased. Alternatively, multiple satellites could be launched with a single launch vehicle, lowering launch costs per satellite. Such a space transportation system could be very competitive internationally.

(3) Foster basic technologies through development of reusable launch vehicles

In the development of space solar power systems, projects in which the energy invested in development and operation would be greater than that harvested by the system are not viable. A reusable launch vehicle must be developed, so that the power system can be assembled in orbit while conserving resources and energy, and reducing launch costs. However, based on past failures in other countries, certain technical aspects are not yet mature: development of lightweight structural materials that can bear the heat of re-entry (a particular issue with reusable systems), innovative propulsion systems, etc. Until now, "accumulating basic technologies" and "demonstration through repeated operation" have been considered completely different categories. However, the complexion of reusable launch vehicle development differs from that of conventional expendable launch vehicle development, and it is possible to foster basic technology to improve the system's reliability, life, and overall toughness while carrying out repeated demonstrations. Preparing a system to foster realistic basic technology through repeated demonstrations may also be very significant.

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Masashi Okada, Leader of Next-launcher R&D Team, leader of the Space Transportation Systems Engineering Department; and members of the International Relations Department.

Abbreviations

•*ALFLEX*	Automatic Landing Flight Experimental (Japan)
•*ASLV*	Augmented Satellite Launch Vehicle (India)
•*ATV*	Automated Transfer Vehicle (Europe)
•*CEV*	Crew Exploration Vehicle (USA)
•*DoD*	USA Department of Defense
•*DSP*	Defense Support Program (USA early warning satellite against missiles)
•*EELV*	Evolved Expendable Launch Vehicle (USA)
•*ELV*	Expendable Launch Vehicle
•*EPA*	USA Environmental Protection Agency
•*ESA*	European Space Agency
•*ET*	External Tank (Space Shuttle)
•*ETS*	Engineering Test Satellite (Japan)
•*FSA*	Federal Space Agency of Russia
•*FW*	Filament Winding (A method of manufacturing composite materials. Bundles of plastic impregnated with carbon fiber are wound around a form and hardened to create structures of various shapes.)
•*GEO*	Geostationary Earth Orbit (circular orbit approximately 35,786 km above Earth's surface)
•*GSLV*	Geostationary Satellite Launch Vehicle (India)
•*GTO*	Geostationary Transfer Orbit (elliptical orbit ranging from 200 km to 36,000 km)
•*HOPE*	H-2 Orbiting Plane (Japan)
•*HSFD*	High Speed Flight Demonstration (Japan)
•*HTV*	H-2 Transfer Vehicle (Japan)
•*HYFLEX*	Hypersonic Flight Experimental (Japan)
•*IAC*	International Astronautical Convention (An annual conference sponsored by the International Astronautical Federation [IAF]. The 2005 convention was held in Fukuoka.)
•*ICO*	Intermediate Circular Orbit
•*ISAS*	Institute of Space and Astronautical Science (part of the Ministry of Education, Culture, Sports, Science and Technology until September 2003; now a part of the Japan Aerospace Exploration Agency)
•*ISRO*	Indian Space Research Organization
•*ISS*	International Space Station
•*JAXA*	Japan Aerospace Exploration Agency
•*KIS*	**Контрольно-Испытательная Станция** Kontrolno-Isptatelnaya Stantsiya (Complex Integrated Stand)
•*MHI*	Mitsubishi Heavy Industries
•*MTSAT*	Multi-Functional Transport Satellite(Japan)
•*NASA*	National Aeronautics and Space Administration(USA)
•*PSLV*	Polar Satellite Launch Vehicle (India)
•*RCC*	Reinforced Carbon-Carbon
•*RFP*	Request for Proposal (a method for fairly selecting contractors)
•*RKK*	**Ракетно-Космицеская Корпорация** Raketno-Kosmicheskaya Korporatsiya (Rocket Space Corporation [Russia])
•*RLV*	Reusable Launch Vehicle (USA)
•RSC	Rocket System Corporation (http://www.rocketsystem.co.jp)
•*SRB*	Solid Rocket Booster
•*SSC*	Shirako Space Consulting (http://www2s.biglobe.ne.jp/~gshirako/)
•*SSPS*	Space Solar Power System
•*SSTO*	Single Stage to Orbit
•*STS*	Space Transportation System (formal name of the Space Shuttle)
•*TSTO*	Two Stage to Orbit
•*UDMH*	Unsymmetrical Dimethyl Hydrazine

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6

The Current Status and Future Role of Senior Scientists in Universities

— Effective Use of the Senior Generation of Researchers —

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1 Introduction

Japan's population has the world's longest life expectancy. Today, for example, 65 year-olds cannot be considered elderly, and many continue to be active[1]. "Senior" has many meanings, such as "elder", "experienced person", "superior", "retiree", and so forth. In this article, we use the term to refer to those in universities and companies who are close to or just past retirement age, and we refer to such researchers as "senior scientists". "Senior scientists", for the purposes of this article, specifically means those who have accumulated intellectual reserves and skills and are capable of actively utilizing them in scientific and technical research and development, rather than all researchers of that age.

2 Comparison of World Retirement Ages and Labor Force Populations

2-1 Comparison of labor force populations

As illustrated in Table 1, the standard retirement age in each developed country, including Japan, is the age at which payment of retirement benefits begins[2]. Even in the United States, where there is no national retirement age, each employer implements a similar policy. In virtually every country, because of increased longevity, the trend has been to raise the age at which retirement benefits begin; accordingly

Table 1 : Standard retirement ages and ages at which retirement benefits begin in Japan, USA, and major European countries

Country	Standard retirement age	Age at which retirement benefits begin
Japan	Age 60. In addition, employers are required to make an effort to retain workers until age 65. (Law for the Stabilization of Employment of the Aged)	Age 60 (special payment of old-age pension, males). Under a 1994 revision, it is being raised in stages, from 2001 through 2013, to age 65.
USA	No mandatory retirement age (Age Discrimination in Employment Act)	Age 65 (age 62 possible with reduced benefits). Under a 1983 revision, it is being raised in stages, from 2000 through 2027, to age 67.
UK	Age 65 (age 60 for most women at present). Laws guarantee that workers cannot be dismissed for age alone before retirement age or the age at which employees ordinarily retire.	Men aged 65, women aged 60. Under a 1994 revision, the age designated for women in labor agreements will be raised in stages to age 65 by 2020.
Germany	Age 65. This is generally designated by labor agreements.	Age 65 (age 60 possible with reduced benefits). There are some exceptions with early payments, but they are being phased out.
France	Age 60. This is generally designated by company rules.	Age 60. The age was lowered from 65 to 60 in fiscal 1983, in order to encourage early retirement by the elderly and secure employment for the young.

Source: Charts 4-7, reference[2]

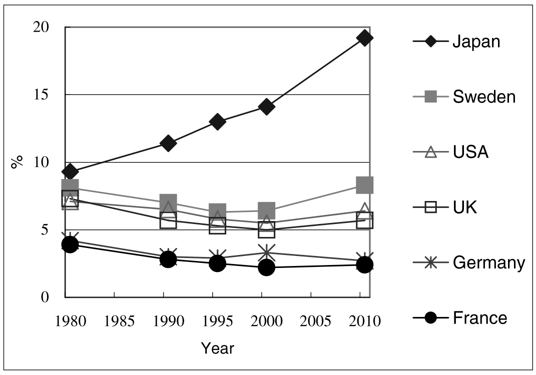
the retirement age has risen to 65 in most cases. France, alone among developed countries, has lowered its retirement age, from 65 to 60, in order to provide employment opportunities for younger workers.

In Japan as well, most companies are raising the retirement age in stages to 65 by 2013. Japan's solid employment system provided a guarantee of a stable living income. It made Japanese workplaces secure places to work and was a motivating power behind the nation's postwar recovery and development. As can be seen in Figure 1, the labor force population aged 60 and above is much larger in Japan than in other major developed countries[3, 4]. Along with demonstrating the diligence of the Japanese, this confirms the existence of a long-lived, vigorous labor force that has passed retirement age.

2-2 The year 2007 problem

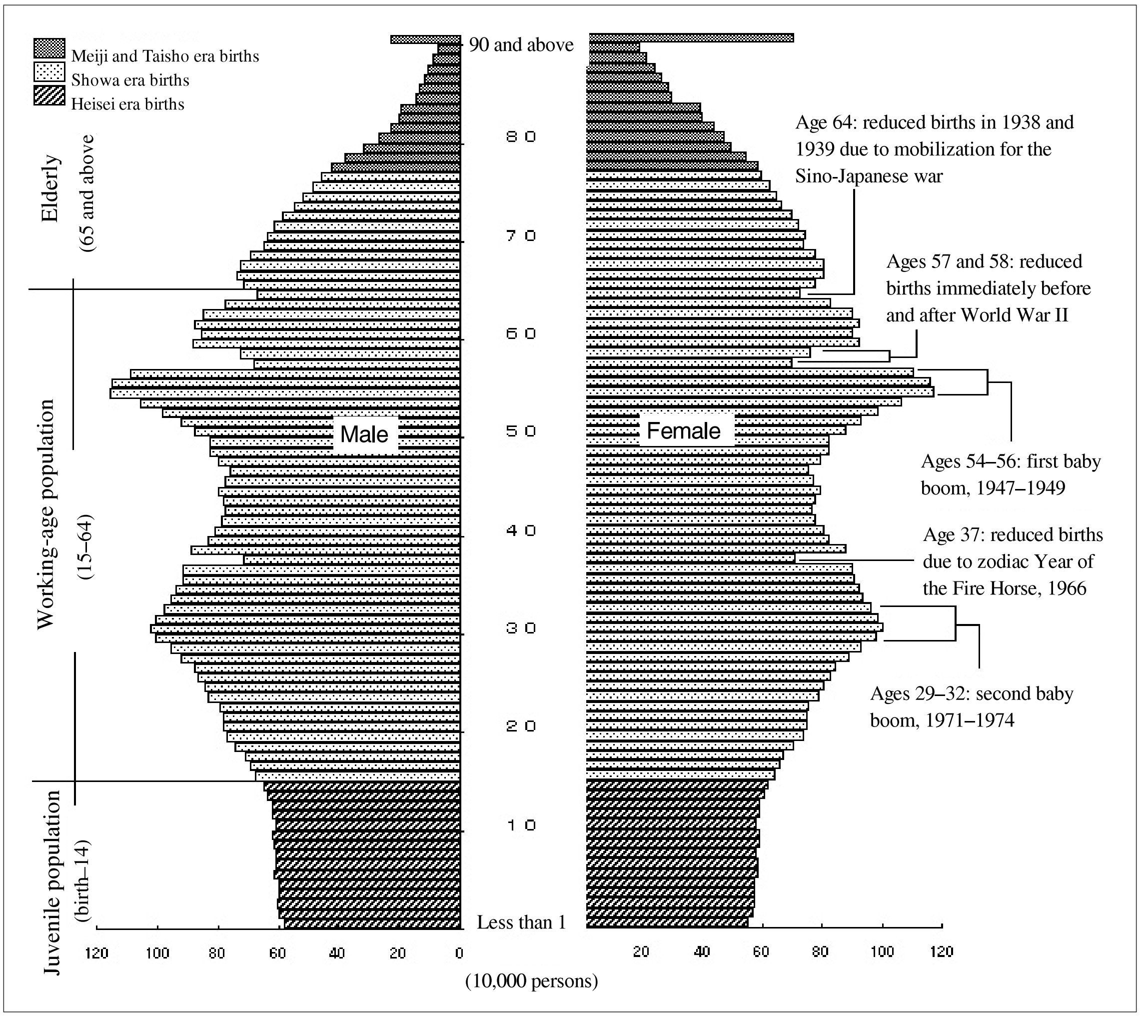
With an average lifespan of 82 years, Japanese enjoy the world's longest life expectancy. In addition, the birthrate has dropped all the way to 1.29, making Japan the country where the phenomenon of a low birthrate and a graying

Figure 1 : International comparison of labor force population (percentage age 60 and above)



Source: Prepared by STFC based on reference [3]

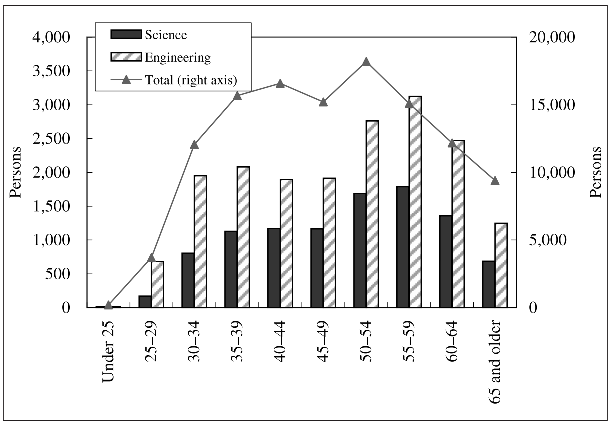
Figure 2 : Japan's population structure



Note: Population aged 90 and above cannot be calculated by year, so it is combined as "90 and above".

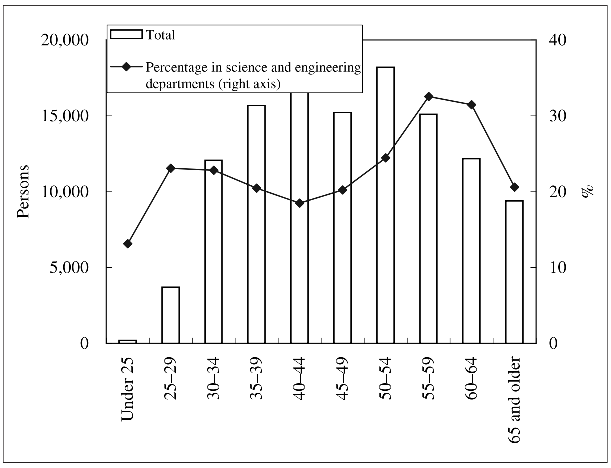
Source: Reference [5]

Figure 3 : Number and age distribution of faculty in university science and engineering departments in 2001



* Ages as of October 1, 2001

Figure 4 : Total university faculty and percentage in science and engineering departments



Source: Prepared by STFC based on reference [9]

society is advancing faster than anywhere else in the world. Japan's responses to its aging society are therefore being watched as precedents for the rest of the world. As can be seen in Figure 2, Japan's population structure forms an inverted pyramid[5]. This structure differs from those of other countries, and typifies a low birthrate and an aging population. The large population aged 54 to 56 in the chart is Japan's first baby boom, called "*dankai*" in Japanese. These baby boomers, Japan's dankai generation, are also identified as the "year 2007 problem" because this large demographic that is about to reach retirement age is rich in experience and expertise and remains vigorously active. The retirement of the dankai generation is being studied from numerous perspectives. The Policy Research Institute of the Ministry of Finance formed a study group in November 2003, and has published a report. According to that report, the retirement of a large number of people between 2007 and 2010 will have a major impact on Japan's economy, reducing the GDP by an estimated ¥16 trillion. The reasons given are increases in the pension burden and local welfare costs, a hollowing-out of technology, and unemployment due to managerial restructuring[6]. The dankai generation includes many of the people who have led Japan's economic and technical development, and many of those who are even older are still active on the front lines of their fields, even after retirement age[7, 8].

2-3 Age distribution of university faculty in Japan

The age distribution of university faculty in Japan, as seen in Figure 2, is quite similar to the population structure for the nation as a whole. Figure 3 and Figure 4 depict the age distribution of faculty in university science and engineering departments and the percentage of all faculty accounted for by science and engineering faculty in 2001[9]. The *dankai* generation in these charts falls into the 50-54 and 55-59 groups. Looking at the whole, this generation is large, making up a particularly high percentage in engineering departments. The mass compulsory retirement of the *dankai* generation will increase employment opportunities for young people, so the phenomenon is not without its positive aspects, but the knowledge and experience that have been amassed by the dankai generation are important intellectual resources for Japan, and they cannot be obtained by younger workers.

3 Conditions of senior scientists in universities

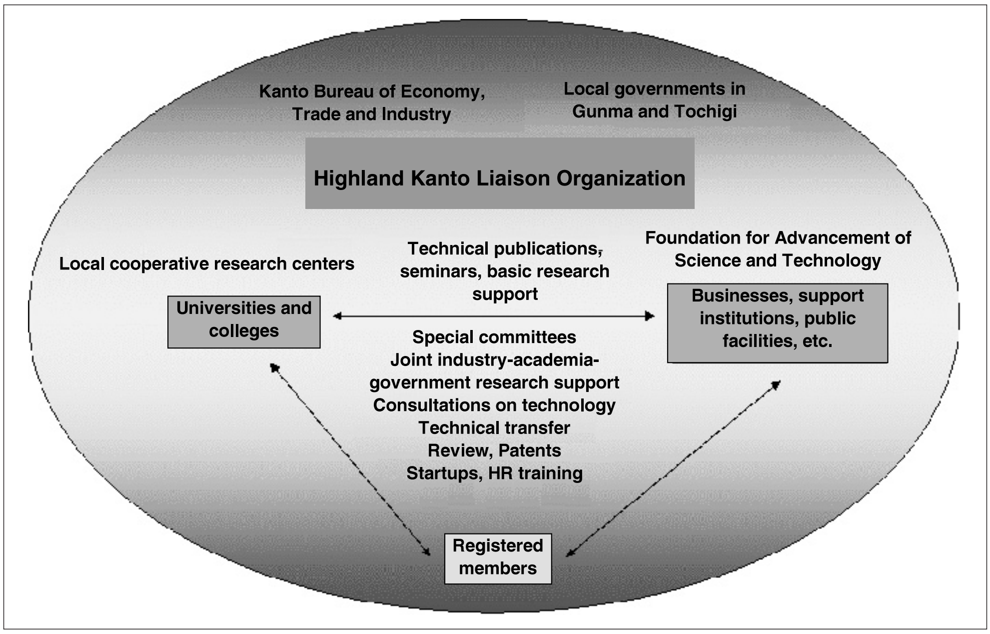
3-1 Cases in Japanese universities and academic societies

Until now, retirement age in Japanese universities has varied widely between private and national and other public universities. At the University of Tokyo and Tokyo Institute of Technology, the retirement age was 60, while at other national and other public universities it ranges from 63 to 65. At many private universities, the retirement age was 65 to 70, while some set no maximum age, at all. However, with the age at which retirement benefits begin being raised in stages to 65, most universities are also shifting to a retirement age of 65. Some universities have systems under which faculty who have reached retirement age are released from managerial responsibilities and employed for fixed terms to provide lectures, and so forth. In such cases, they are positioned differently from ordinary adjunct faculty. The result has been that, after retirement, professors from national and other public universities would typically continue teaching and research as professors at private universities. However, the incidence of such cases is expected to decrease.

Recently, academic societies have also been taking note of the importance of the social contributions of senior scientists, and accordingly have been promoting various measures. For example, the Institute of Electrical Engineers of Japan registers the career data of longtime members with a high degree of technical ability and specialized expertise, recognizes them as "IEEJ Professionals" (provisional name) in their specialties or preferred fields, and provides "knowledge and experience distribution services" enabling those members to remain active as technical consultants, teachers, experiment leaders, and so forth. In a survey taken regarding the new service, about 70 percent of members responding were 50 or older, and members in that age group indicated that they were very interested in such intellectual service activities[10]. This shows that senior-age personnel also recognize the need to pass on their accumulated expertise and are actively interested in doing so.

The Highland Kanto Liaison Organization, an NPO established mainly by local university faculty, is a specified non-profit corporation with individual members from nearby prefectural universities, local businesses, universities, colleges, and research institutions, and supporting members such as local public entities. Including the introduction of senior engineers in their vision, they carry out activities in order to contribute to the development of industry and universities in the northern Kanto region. A complete overview of the organization is shown in Figure 5. The organization carries out such activities as registering people with many years of experience in universities and businesses as scientists or engineers, and referring them as coordinators to link university-generated technologies with markets, as researchers for small and medium enterprises needing technology, and so forth. Senior researchers are at the core of these activities[11]. It has not been

Figure 5: Diagram of the Highland Kanto Liaison Organization's program implementation



Source: Prepared by STFC based on Highland Kanto Liaison Organization website [11] unusual for universities to welcome professors who have worked as corporate researchers or have other practical experience, and the practice has become widespread. Recently, there have been many cases of people leaving corporations for full-time university employment, but adjunct faculty members are common where education requires special techniques or experience. This shows the great need to bring practical experience into education[12].

3-2 Conditions in North America

The United States of America passed the Age Discrimination in Employment Act (ADEA) in 1969. It prohibits discrimination based on age, gender, etc., in the employment of those aged 40 and above. The NPO, American Association of Retired Persons (AARP), actively supports retirees. This organization is the world's largest NPO, with 35 million members aged 50 and older in the United States.

The perception of retirement in North America differs from that of Japan. For example, scientists who are able to obtain outside funding will not be forced out of their organizations and can continue their research. Accordingly, consciousness of outside funding is very different than it is in Japan. Professors and associate professors with good records in education and research during fixed employment terms receive the right to lifetime employment (tenure). Ordinarily, tenure is awarded through a strict evaluation process that includes the number of papers published, recommendations from full professors who work for outside of foreign countries' professors. Faculty who are unable to obtain tenure must change organizations. Moreover, those who cannot obtain funding mainly from outside sources are unable to conduct research. Because they are unable to hire graduate students and technicians to actually carry out their research, the scope of their research activities is narrowed. They also lack funds to travel in order to present their results. Furthermore, outside funding comprises part of university revenue for overheads, so universities try to lure outstanding professors with large grants away from each other. Salaries are paid in relation to classes, so many universities pay for only nine months of the year. Naturally, a portion of research grants can be allocated as the professor's own salary.

In Canada, there is one national university; all the rest are provincial institutions. All faculty members are civil servants and thus are paid for 12 months of the year. Under provincial government guidelines, retirement comes when the combination of age and years of employment reaches 80. "Retirement" means retirement from teaching, and because research may continue as long as funding can be obtained, it is not unusual for professors to take early retirement from teaching and specialize in research only. Indeed, there are many professors over 70 who maintain laboratories and work as active scientists. The percentage of overhead going to the university varies by the type of university, department, course, and funding, but in any event, outside funding stands next to tuition in importance as a revenue source. To help obtain outside funding, universities have research support departments that manage funds and support research. This is because younger scientists, in particular, may be skilled researchers but have yet to develop the ability to manage funds well, so the departments play a large supporting role as research promotion advisors. The existence of such organizations helps to vitalize research, and because they enable scientists to concentrate on research, many venture corporations have been established by veteran professors and scientists who have made discoveries that have commercial applications. In one example, a 70-year-old professor discovered and commercialized a new method of manufacturing isotopes using a nuclear reactor rather than an accelerator, as had been necessary in the past. Universities encourage such commercialization because, when a significant amount of that type of work is carried out within a university, its revenues increase through overhead payments. On the other hand, many such ventures go bankrupt, so greater management ability is needed from both research services and researchers[13, 14].

The high value placed on people in research and development and the systems for promoting energetic research activities, even by those over 60, are among the major reasons why North

America leads the world in technology.

3-3 Conditions in Europe

State universities predominate in Germany, and their faculty members are civil servants with lifetime appointments guaranteed until retirement age. As in other countries in Europe, the retirement age is generally 65. However, in 2002 the higher education system was revised and the position of professors was significantly altered. Particularly significant is the systemic shift of the linchpin of research to younger scientists. The revision established positions at universities for independent associate professors who specialize in research under fixed-term contracts, and eliminated the system of assistants who played a supporting role in research. One major point of the revision was to introduce competitive principles within universities to a greater degree than before. Under the old law, professors received only basic salaries. The revisions enabled them to receive both their basic salaries and merit pay commensurate with their outside funding. Adoption of the competitive principle of obtaining outside funding is a worldwide trend.

All universities in France are national, and all professors are national civil servants, so all employment of professors is based on open recruitment. The National Council of Universities creates a list of qualified candidates based on a strict examination of research leadership qualifications (academic degrees), work experience in the relevant fields, experience as a visiting professor, and so forth. Those registered on the list may respond to universities' public recruitment advertising and be selected by the universities for employment. Professors account for about 30 percent of faculty. There are no salary differences between universities, and employment is guaranteed until retirement at age 65. However, a system is in place to allow professors who are still rearing children to defer their retirement. There are three ranks for professors, with only those who have especially outstanding research results reaching the highest. Upon reaching retirement age, these academics attain the status of "professor emeritus". Professors emeritus may postpone their retirement. Universities recommend candidates for professor emeritus status, but receiving that honor from the national government is extremely rare. There are not many professors emeritus in France. Therefore, although some post-retirement researchers form venture companies and continue working, there are not many professors who actively continue their research. This situation is dependent on national policy in France, where the population structure is still pyramidal.

In Poland, the general retirement age is 65 for men and 60 for women in universities. There are two types of positions for professors. Professors of the upper rank can be appointed by presidential recommendation. These specially appointed professors receive special treatment in comparison with ordinary professors. As with other occupations, professors retire at age 60, but specially appointed professors have the right to retain their positions until age 65, and the national government guarantees their right to engage in education and research activities until age 70 if they so desire. Specially appointed professors who retire at 70 may also work on national committees if they are in good health.

3-4 Conditions in Taiwan

In Taiwan as well, the retirement age for civil servants and university faculty is 65. Professors may postpone retirement until age 70, but in that case they are subject to annual evaluation. The evaluations are based on research status, the securing of outside funding, and so forth. In the case of corporations, retirement age varies by 5 to 10 years. Currently, many retired engineers from Taiwan travel to developing countries such as Vietnam and Malaysia to make transnational contributions by providing technical advice. Retirees are considered appropriate for the work because they can provide technical guidance with technologies they have already mastered. Taiwan is expected to continue such exchanges, mainly in Southeast Asia, and is also aiming to train personnel for mainland China.

4 Relationships between universities and high schools

4-1 *Corporate personnel and the educational world*

Universities and businesses already have relationships based on education and job recruit, but with the recent conversion of national universities into independent corporations and the adoption of open recruiting, their collaboration has become stronger than in the past. Unlike university faculty, primary and secondary school teachers must hold teaching credentials. However, since 2000, principals without teaching credentials may be hired if they have the same or greater qualifications than other faculty members. The number of principals hired from the private sector has increased year-on-year, starting with 3 in Hiroshima and Tokyo in the first school year, 2000, climbing to 9 in 2001, and then rising annually to 23 (2002), 54 (2003), and 76 (2004). Because it is a new system, there are various problems on-site, but in many cases the positive effect on education has exceeded expectations. Many of the principals hired through this system were senior people in corporations, and their fresh leadership perspectives are definitely adding vitality to classrooms.

4-2 *The relationship between high school coursework and university entrance exams*

According to 2002 statistics, lectures and exchanges by university faculty at high schools were carried out in 1,291 institutions in 10 municipal and 45 prefectural school districts[15]. In fact, not only educational effects, but also new initiatives in education that Japanese universities have not been involved in, are needed. This is related to the government's high school curriculum guidelines and university entrance examination methods. The guidelines, which are revised about every 10 years, currently divide most subjects into two parts. For example, science courses are divided into "I" and "II" for general science, physics, chemistry, biology, and earth sciences. Because these courses are electives, many students graduate from high school without having covered them systematically. Moreover, because many high schools divide their students into science-oriented and literature-oriented curricula upon matriculation, it is difficult for students who switch partway through to cover these fields systematically.

Meanwhile, university entrance examination methods are diversifying and covering fewer subjects, so even some subjects that will be required within majors after entering university are not required in entrance exams. High school subjects such as mathematics and science are cumulative, and are the foundation for study in science and engineering fields, in particular. However, some students have not covered them sufficiently. Therefore, gaps appear in the educational levels of new university students, and basic academic ability must be developed in order for university education to proceed smoothly. This necessitates remedial education, either before or after admission, to bring new students to a level in basic subjects that will serve as a proper foundation. In fact, many universities have begun implementing such remedial courses, but when professors and other current faculty are placed in charge of such courses it can take time away from their research. However, remedial courses will be increasingly necessary for some time, in order to maintain and improve the educational level of universities.

5 Proposals

5-1 *Activities in universities that suit the abilities and desires of senior scientists*

Currently, almost all universities, and especially national universities, have age-based mandatory retirement systems. However, allowing those senior scientists with ability and the capacity to obtain outside funding to remain at their universities and continue their research, as is done in North America, is desirable even from the standpoint of their potential contribution to science and technology. Following his compulsory retirement, the genetic scientist Professor Yoshiaki Ito (formerly of Kyoto University) moved his entire laboratory, including assistants and graduate students, to the National University of Singapore's Institute of Molecular and Cell Biology (IMCB), where he is actively engaged in research. As this example shows, deciding retirement by age without regard for results or abilities is a waste of the skills of researchers who could still work actively. Not only does it create a brain drain, it lowers the research ambitions of researchers on the verge of retirement age, and possibly harms the national interest[16]. An increasing number of universities are actually permitting specially appointed professors to postpone retirement, but this sort of system should also be based on a transparent evaluation process. Furthermore, although a growing number of university faculty positions are being filled through public recruitment, currently job offers invariably carry age restrictions. Employment should be offered through fair evaluations based on ability, giving senior scientists the chance to apply as well[17].

The variation in the academic levels of new university students is also seen as a problem. Unless both the government's high school curriculum guidelines and university entrance examinations are improved, the phenomenon of uneven academic foundations will continue, and could even worsen. Therefore, many universities offer remedial classes in order to maintain their educational levels, but covering such courses by assigning full-time faculty members increases the burden on them and may interfere with their research. With the introduction of assistant professorships*1 which enable younger university faculty members to continue to compete on the basis of their research results and take on a certain degree of educational responsibility, there is potential to reduce assistant professors' burdens by entrusting such supplemental course leadership to senior scientists who are rich in research and educational experience.

Furthermore, it is feared that with the retirement of those people who have been involved in postwar technology all the way from development to application, such technologies will not be passed on. In particular, classes in fields such as nuclear energy and electrical power are being eliminated due to their unpopularity with students, and the passing on of knowledge and experience in those fields remains a major concern. This problem reaches to the core of Japan's energy system. Senior researchers are key to passing on technologies in fields that have achieved a certain degree of maturity. Rather than forcing skilled researchers who have supported Japan's development, in name and fact, to retire solely on the basis of age, they should be put to effective use. As described above, systems that enable senior researchers to remain active in various ways are being created, but it cannot be denied that they are only a small part of the solution. The decrease in the number of researchers in mature fields such as nuclear energy and electric power is a problem. Now, while there are still active professors who can teach such classes, is the time to build networks for passing on such technologies. It is necessary to create venues where senior researchers from the dankai generation, who are facing retirement, can contribute to technical succession and future technical development. Incidentally, it is not only in Japan that heavy electrical fields are becoming unpopular; this is a worldwide trend. Poor in resources and having the world's longest life expectancy, Japan needs to focus urgently on equipping the nation for 20 or 30 years hence by making effective use of the accumulated intellectual resources of senior personnel[18].

5-2 Support by senior researchers for university education, and new contributions to industry

The gross domestic products (GDP) of countries are almost proportional to the rate of business startups in those countries, so improving the startup rate is an important policy for any country. Japan's startup rate ranks among the lowest in the world, but it was not always that way. After World War II, as Japan's industrial recovery surged, the startup rate was high, and so was the rate of economic growth. The likely reason for Japan having been able to maintain a high GDP, despite the low startup rate that followed the period of postwar industrial recovery, is the expansion of production systems for industrial products. However, in recent years production of goods such as automobiles and electronics products, which are the foundation

Table 2 : International comparison of ages at which engineers can work at the forefront of their fields (%)

	Under 30	30 - 34	35 - 39	40 - 44	45 - 49	50 and over	Age not relevant
Japan	2.2	17.1	29.7	30.6	4.7	0.5	14.6
USA	0.8	1.4	2.2	2.2	1.9	12.9	77.8
UK	1.7	1.7	6.2	5.4	5.4	7.4	72.3
Germany	1.0	0.8	4.4	5.2	7.0	8.8	71.8

Source: Prepared by STFC based on “US engineers and Japanese engineers: Engineer careers and skills development” by the Japan Productivity Center, and other materials.

of “monozukuri” (manufacture by skilled labor) and have supported Japanese industry, has been moving offshore, and the trend of annually increasing dependence on overseas production is expected to continue[19]. With their venues for activity in Japan being eliminated, there is concern that a technical brain drain of retired engineers moving to China to provide technical leadership will result.

Until recently, university scientists in Japan were evaluated solely on the number of research papers they published. As a result, many professors were enthusiastic about research but had little interest in joint research with corporations, obtaining patents, and so forth. However, with industry-academia collaboration flourishing in recent years, patents have also come to be part of researchers’ performance evaluations. If research results can be linked to patents, that means the results will be applied. The obtaining of patents is another source of satisfaction for researchers, and also contributes to the development of science and technology. Corporations have long had patent departments, and, since the 1998 revision of the TLO Law, many universities have established departments to oversee intellectual property. The number of university-generated patents is increasing. On the other hand, some say that, even as evaluations and the need for research success are becoming stricter for faculty members, the time they have available for research is decreasing. Therefore, if post-retirement senior researchers can join technology licensing organizations (TLOs) and other organizations, to support active faculty members who are busy every day with teaching, research, and administrative duties, they can fulfill a management role for universities and outside bodies (corporations). Invigoration to prevent university systems from becoming conservative is also necessary, as is broad preparation of systems and venues to allow some type of free agent participation. And, regarding startups, the creation of publicly funded companies that carry out research in rented laboratory space, and other responsible but low-risk small enterprises, is one possibility. If senior researchers are able to utilize their experience and work as managers in such ways, bringing in younger scientists and working together should certainly bring about numerous mutual benefits. If they can apply for patents and start businesses without worrying about serious risk, senior researchers can effectively utilize their accumulated knowledge and open the way to new technical development. At present, the risks associated with startup failure in Japan are so high that it is difficult to start a new business. Supporting decreased risk in order to avoid stifling the impetus to start businesses would be a major contribution to scientific and technical research and development, and should light a fire under the progress of the next generation of Japanese science and technology.

In addition, JICA conducts a senior volunteer program for utilizing senior personnel, with most activity directed toward developing countries. In such ways, a step at a time, Japan is beginning to utilize its active senior personnel after retirement, and is beginning to recognize both their role and the results they are obtaining.

The results of a survey on the ages at which engineers can work at the forefront of their fields are shown in Table 2. Over 60 percent of those responding in Japan nominated ages between 35 and 44, but over 70 percent of those responding in the U.S. and Europe said that age is irrelevant. Furthermore, over 10 percent of those responding in the U.S. nominated age 50 and over.

Creating systems to provide a full range of choices to all workers approaching retirement age should make an important contribution to addressing the issues arising out of a declining birthrate, a graying society, and decreasing interest in science.

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Glossary

*1 Assistant professor

This position is held by candidates who carry out education and research in pursuit of future professorships. An employment system comprising professors, associate professors, and assistant professors is expected to be adopted within a few years.

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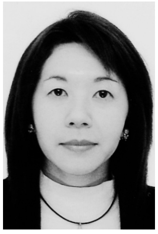

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About SCIENCE AND TECHNOLOGY FORESIGHT CENTER

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.

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

The following are major activities:

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

— STFC builds an information network linking about 2000 experts of various science and technology fields in the industrial, academic and government sectors. They are in the front line or have advanced knowledge in their fields.

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

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

2. Research into trends in major science and technology fields

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

— The research results are published as feature articles for "Science Technology Trends" (monthly report).

3. S&T foresight and benchmarking

— S&T foresight is conducted every five years to grasp the direction of technological development in coming 30 years with the cooperation of experts in various fields.

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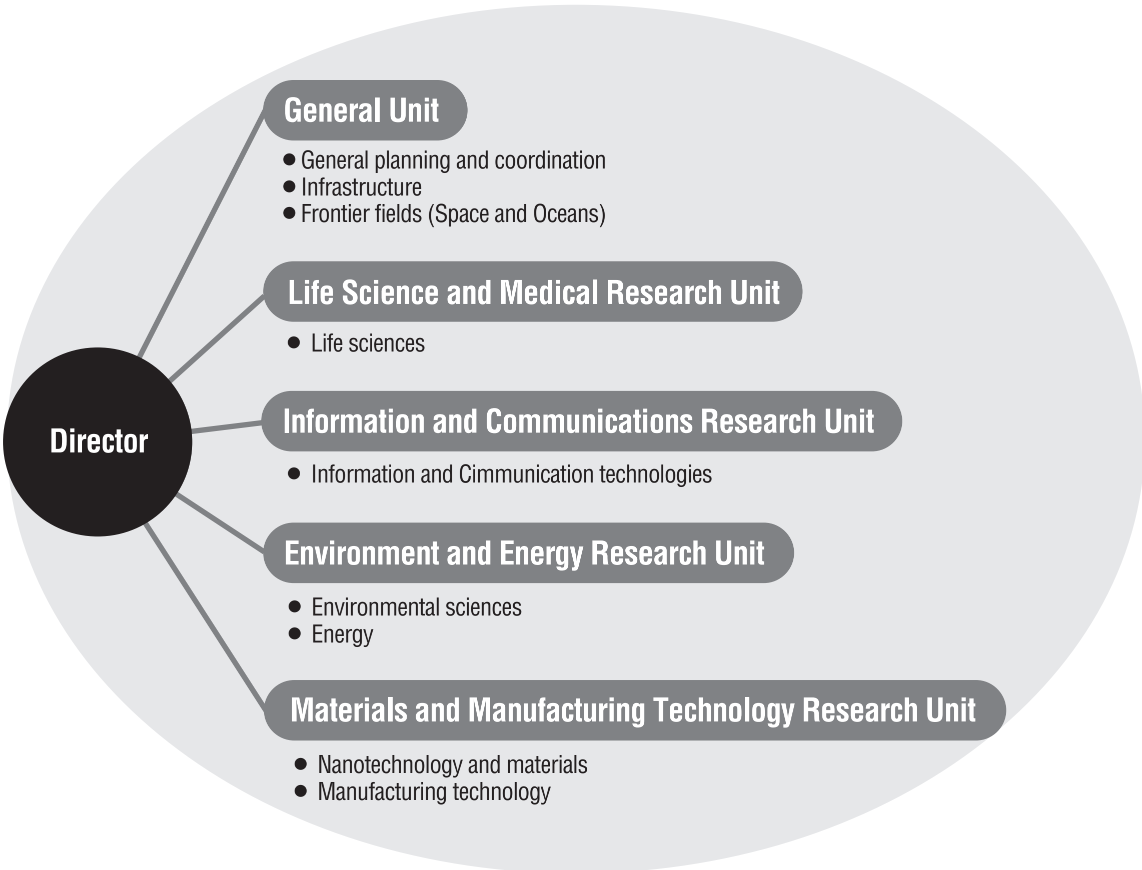
— The research results are published as NISTEP report.

Organization of the Science and Technology Foresight Center



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