Chapter 2 Future Science and Technology Expected from Japan

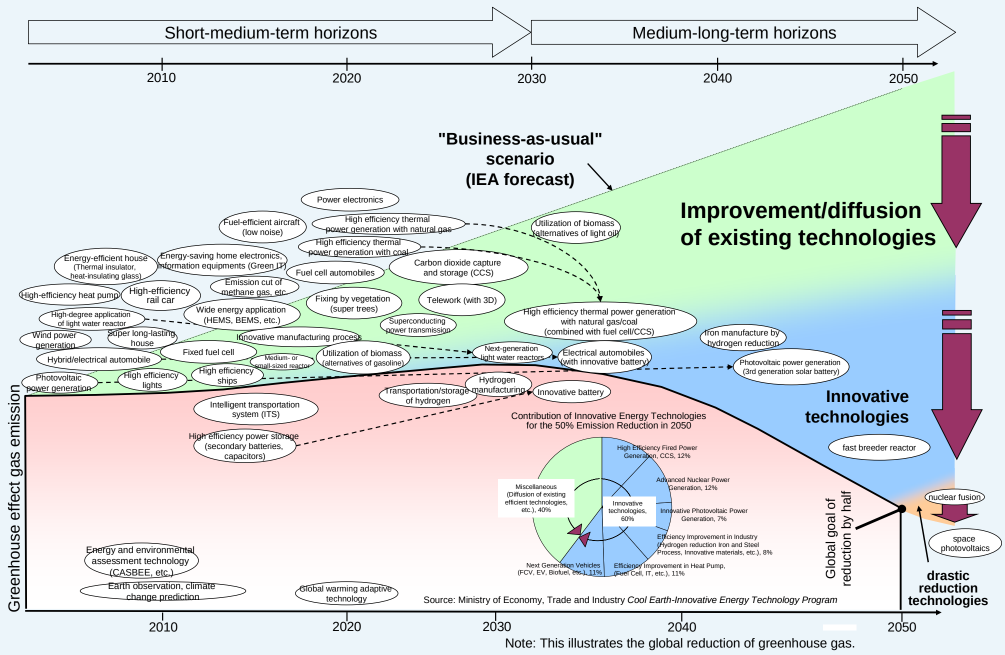
1 Tackling with Global Environmental Problems and its Develpoment

1 Global Environmental Problems Facing Human Beings

During the past several decades, remarkable economic growth and a shift in the industrial structure have occurred along with the development of S&T. However, as a negative aspect of this growth, global problems, such as a population explosion, increasing demand for tightening energy and food supplies, climate change and global warming, and polluted and exhausted water resources have become obvious. The sources of these problems and the areas affected by them are widespread and expected to affect the next generation. Finding solutions to these global problems is an important factor in ensuring the sustained development of the world and an urgent response is required.

There has been growing worldwide concern about problems that affect the global environment problems such as climate change. The ntergovernmental Panel on Climate Change (IPCC) reported in its fourth evaluation report in 2007 that increased greenhouse gasses originating from human activity are the likeliest cause of the increase in the average global temperature observed from the mid 20 century, and the framework after 2013, when the first commitment period of the Kyoto Protocol will end, has been fully discussed at the Conference of the Parties to the UN Framework Convention on Climate Change. In addition, at the G8 Hokkaido Toyako Summit held in July 2008, Japan shared the long-term target proposed by the Parties to the UN Framework Convention on Climate Change of halving the global emission of the greenhouse effect gasses by 2050, and agreed that they would examine and seek the adoption of the target through the negotiation under the treaty. However, it is estimated to be very difficult to achieve the long-term target given the development and dissemination of existing technologies alone and that about 60% of the reduction has to depend on the development and introduction of innovative technologies (Figure 1-2-1). Therefore, innovations through the development of revolutionary technologies in the fields of environment and energy and the reformation of the social system in addition to the development and dissemination of existing technologies have become urgent issues throughout the world.

Figure 1-2-1 Development and Diffusion of Environmental Energy Technologies



Source: Council for Science and Technology Policy *Environmental Energy Technology Innovation Plan*

2 Resolving Global Environmental Problems

(1) Global spread of the "Green New Deal"

As mentioned above, there has been growing concern about global environmental problems in countries around the world, and those countries are cooperating in R&D in the fields of environment and energy. In recent years especially, with the global economic situation rapidly deteriorating, countries including the US have developed the "Green New Deal" for long-term growth, trying to create jobs and spur more demand with enhanced environment and energy measures to resolve global environmental problems.

In his Inaugural Address in January 2009, US President Barack Obama stated: "We'll restore science to its rightful place, and wield technology's wonders to raise health care's quality and lower its cost. We will harness the sun and the winds and the soil to fuel our cars and run our factories." And his stance, emphasizing S&T in the environment and energy fields, is reflected in this address. In addition, Steven Chu, a scientist in the field, was nominated for Secretary of the U.S. Department of Energy (DOE), and the Advanced Research Project Agency – Energy (ARPA-E) of DOE, which has been specified in the America COMPETES Act, was newly established. It was decided that 400 million dollars be allocated to ARPA-E as a provisional budget based on the Economic Stimulus Act. Moreover, the US announced its plan to invest 15 billion dollars per year in technology development such as wind and photovoltaic power generation. Other countries have prioritized investment in the environment and energy so that economic society's change from incandescent and fluorescent lights to LED (Light Emitting Diode) lights and from the internal combustion engine to electrical and fuel-cell vehicles may be accelerated in the future.

Column 5 "Green New Deal" in Selected Countries

Recalling the New Deal that was launched by US President Franklin Roosevelt, the "Green New Deal" is an innovative policy that attempts to resolve global environmental problems and promote long-term growth by creating jobs and spurring demand through environmental/energy measures such as the development of renewable energy and clean energy automobiles. The movement originated in the Green New Deal Group comprising mainly British, but has grown into a global trend in response to the escalation of the economic crisis.

	"Green New Deal" in selected countries
US	• New Energy for America - A campaign pledge by President Obama. A total of $155 billion will be invested in the coming 10 years to develop alternative energy (nuclear power, solar, wind, water, etc.). 12% of all power needs will be provided by alternative energy such as wind and photovoltaic power by 2012, and this will result in the creation of 5 million new jobs. - In his Address to the Joint Session of Congress, President Obama again stated that he will invest $15 billion a year to develop technologies like wind power and solar power, etc. • The first Weekly Address by President Obama since being sworn in as president In conjunction with the policy to disseminate the alternative sources of energy such as photovoltaic and wind power, President Obama has pushed for a reduction in expenses by $2 billion per year by promoting the construction of a new electricity grid of more than 3,000 miles of transmission lines. He will save taxpayers $2 billion a year by making 75% of federal buildings more energy efficient • American Recovery and Reinvestment Act of 2009 - Plan to invest $38 billion in the environment/energy fields - Establishment of ARPA-E, investments in R&D and demonstration of high efficiency/renewable energy technology, and carbon storage and isolation technology • FY 2010 Budget Specify increasing support for DOE towards enhancing federal investment in the basic sciences.
EU	• Energy Policy for Europe (2007 to 2009) Set the objective of increasing the proportion of renewable energies in its energy mix by 20% and the share of biofuels to at least 10% of vehicle fuels by 2020. • European Economic Recovery Plan From the short- and long-term point of view, sets an overall plan for EU recovery from the financial crisis with strategic investments in high-efficiency and clean energy technology.
UK	• Numerical objective Investments of 100 billion dollars by 2020 to build 7,000 wind turbines offshore and create new jobs for 160,000 people. • Establishment of Energy Technologies Institute (ETI) - Reduce carbon dioxide, provide efficient energy, develops technologies for stable energy. - Perform large-scale field trial associated with energy, targeting commercialization of voluntary development technology. - Funding for R&D through a matching fund from the UK government and private sector companies. Plan to provide £5.5 hundred million from the government and a maximum of £5 million per company annually for 10 years. • Establishment of the Department of Energy and Climate Change (DECC) Integrated energy policy of the Department for Business, Enterprise and Regulatory Reform (BERR) and climate change mitigation policy of the Department for Environment, Food and Rural Affairs (DEFRA). • Establishment of the Food and Environment Research Agency (FERA) Integrated the research function under DEFRA.
Germany	• Plan to invest 3 billion Euros in carbon dioxide reduction program with modernized buildings by 2011. Set a target to increase the current 250 thousand jobs to a level surpassing employment in the automotive field by 2020.
China	• Reinforce environment- and energy-related measures with large economic measures equal to 4 trillion Yuan (about 53 trillion and 700 billion yen), including the promotion of nuclear power (95.5 billion Yuan), the establishment of natural gas pipeline (93 billion Yuan), water projects, airports, etc. (17.4 billion Yuan).
Korea	• Promote "Green New Deal Projects" with an investment of 50 trillion Won in the new energy fields such as photovoltaic power generation and fuel cells for 4 years and create new jobs for 960 thousand people.

United Nations	• Global Green New Deal - Propose that the nations should keep a balance between economic growth/creating employment and environmental problems by developing renewable energy and transport systems with less carbon dioxide emissions. - Propose the necessity of investing about 1% of the global GDP into finding solutions to environmental problems.

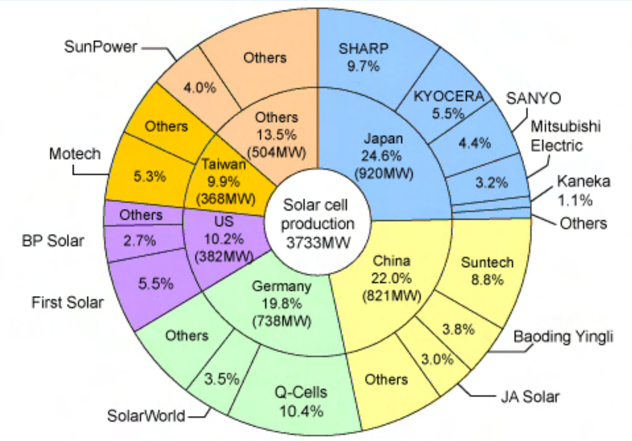
Sources: Prepared by MEXT based on materials by Center for Research and Development Strategy, Japan Science and Technology Agency; National Institute of Science and Technology Policy

Japan has had strong international competitiveness in environmental and energy technologies as evidenced by its advances in nuclear power, LEDs, fuel cells, and solar cells, as achievements resulting from R&D over the years. For example, as other countries have had strong concerns about nuclear power generation as a solution to global warming, Japanese corporations have participated in building new nuclear power plants in the US and China successfully. In addition, at the February 2009 Japan-US Summit Meeting attended by Prime Minister Aso and President Obama, these technologies were brought to international attention as the two leaders agreed to start discussions for specific Japan-US cooperation in the areas of clean energy and energy conservation, and the creation of measures for Japan-US cooperation in the development of bullet train technologies with the knowledge that bullet train transportation produces less greenhouse gas compared to automobiles. Regarding water, for which demand throughout the world is high, Japan has an excellent reputation in membrane technologies such as reverse osmosis membrane, and water-related corporations, NGOs and universities have established a consortium to boost activities that aim at the international development of water businesses.

In the future, however, enhanced investment by countries around the world in R&D in the fields of environment and energy will result in the development and introduction of innovative S&T and the development of new environment/energy-related industries that threaten Japan's edge in environmental and energy technologies. For example, SHARP has given up its position as the world's leading producer of solar cells to Q-Cells, which raises the possibility of future catch-up by US, German and Chinese corporations (Figure 1-2-2).

In the face of such a situation, Japan is required to comprehensively enhance its international competitiveness by further promoting its superior S&T in the fields of environment and energy while paying attention to the developments in other countries. Japan is also required to take the initiative in disseminating its S&T to the world to resolve the global environmental problems. Japan also set the low-carbon revolution as one of the three most prioritized pillars in the J Recovery Plan, compiled by the government in April of this year, and aims to convert restrictions on economic growth to sources for new demand. In addition, the Ministry of the Environment, in cooperation with other ministries and agencies, has responded to the spread of global New Green Deal program by consolidating social overhead capital, such as the installation of photovoltaic power generation panels in the public facilities, and promoting investment to boost energy saving and environmental product consumption. The Ministry has also published the Innovation for Green Economy and Society, that describes job creation and demand stimulation through the development of the world's most advanced environmental technologies and contributions to the world.

Figure 1-2-2 Solar Cell Production Share, by Country/Corporation (2007)



Source: Prepared by Ministry of Economy, Trade and Industry

(2) Japan's approaches to global environmental problems

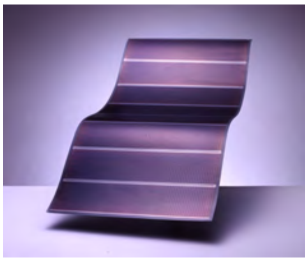
As Japan's approaches to global environmental problems, the Council for Science and Technology Policy (CSTP) established its Environmental Energy Technology Innovation Plan in May 2008, targeting the realization of a globalized low-carbon society, energy security, a balance between environment and economy, and contributions to the developing world. Through this plan, Japan seeks to lead the world in reducing the greenhouse effect gasses and promote enhanced technologies for the development and dissemination of environmental and energy technologies through short-, intermediate-, and long-range strategies in the area of environmental and energy technology. Listed in 1) through 5) below are imperative major R&D items.

In addition, to resolve the global environmental problems we face, enhanced research from the basic level is required. For example, the Japan Science and Technology Agency (JST), in its Basic Research Programs, which facilitates objective basic research, conducts various research under the strategic sector Creation of innovative technologies related to reducing global warming in an effort to realize a sustainable society to realize a low-carbon society as a climate change-easing measure, and delivers information related to cutting-edge environmental science technologies.

1) R&D of renewable energy technologies

Renewable energy technologies, which utilize solar power, wind power, biomass and waste, are expected to be promoted by other countries as energy sources which emit less carbon dioxide and which create less environmental burden. Japan has already introduced measures for the promotion and development of technology to encourage experimental studies and the reduction of installation costs. However, there are many issues that remain unresolved compared to existing energy sources in relation to facilities, efficiency of generation and securing of stable power. For example, photovoltaic power generation, which has been widely introduced into private homes and public facilities, continues to have problems that need to be addressed, problems such as the need to improve efficiency of generation, to reduce generation costs, to assure a stable supply of raw materials and to extend the application of the system. In addition, the technology development that contributes to improving energy efficiency is required as well as the renewable energy technologies.

Under these circumstances, Japan is expected to promote material development, development of second-generation organic thin film/dye-sensitized solar cells which contribute to improved economy and generation efficiency, third generation solar cells, development of biomass application technology which matches the community, development of stabilized wind power generation technology, and development of superconductive materials and heat-resistant materials which contribute to improved energy efficiency. In the future, Japan is expected to contribute greatly to resolving global environmental problems by expanding large-scale generation systems for use by industry and by developing power generation systems for unelectrified regions in the developing world.



Thin-film silicon photovoltaics
Photo: New Energy and Industrial Development Organization

2) Research, development and promotion of nuclear energy

In recent years, global expectations for nuclear energy as a solution to global warming and as a stable source of energy have increased. In discussions by IPCC and the International Energy Agency (IEA), the availability of nuclear power, which does not emit carbon dioxide in the generation process, has been strongly recognized. In addition, the declaration made at the 2008 G8 Hokkaido-Toyako Summit pointed out that the number of countries interested in nuclear power as a means to address concerns about climate change has increased.

For Japan, a country with few natural resources, in advancing measures against global warming and ensuring energy security, nuclear power is an extremely important energy source. Japan sees it as important to place fast breeder reactors (FBR) into practical use in order to considerably increase the share of the nuclear power while assuring the safety of the nuclear fuel cycle. Therefore, it is necessary to promote development of the technologies for next generation light water reactors (LWRs) focusing on the demand for alternative energy around 2030 and later, and R&D for FBR cycle technology, the Key Technologies of National Importance and one that will be the main source of nuclear power in the next generation. Other important matters to promote are innovative technology for the manufacturing of hydrogen which harnesses heat from the nuclear reactor, and R&D related to nuclear fusion technologies which resolve environmental and energy issues over the long-term.

In addition, in securing Safeguards, Safety and Security (3S), Japan is expected to promote joint international research through multicounty frameworks and to contribute to international society by utilizing its superior nuclear power generation technologies.

3) Technological development of clean energy vehicles

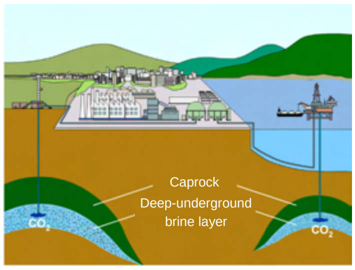
Clean energy vehicles such as electric cars have lower carbon dioxide emissions compared with existing automobiles, which use petroleum fuels. For this reason, global development of the electric automobiles, which create less environmental burden, has become more competitive.

Electric vehicle
(FY2008 Mitsubishi Motors iMiEV for fleet monitoring)
Photo: Mitsubishi Motors Corporation

Especially in the case of electric automobiles, for which early promotion is expected, issues for further introduction are: improved secondary batteries, technologies to supply power quickly and easily, motor technologies, and improvement in light-weight material technologies. For example, as for lithium-ion secondary batteries which have now become the most popular, it is necessary in the short range to promote R&D related to advanced battery materials for the improvement of performance and economy based on large capacity. In addition, in the intermediate and long term, for higher secondary battery performance, the development of innovative secondary batteries based on new principles rather than as a mere extension of improved lithium-ion batteries, is expected.

4) R&D for Carbon Dioxide Capture and Storage (CCS) technology

CCS technology, which separates and captures the carbon dioxide generated from the thermal power plant for storage underground, is considered a critical technology for the reduction of carbon dioxide emissions, and the Action Plan for Achieving a Low-carbon Society, which was decided by the Cabinet in July 2008, states that large-scale evaluation of CCS will be started in a timely manner from 2009.



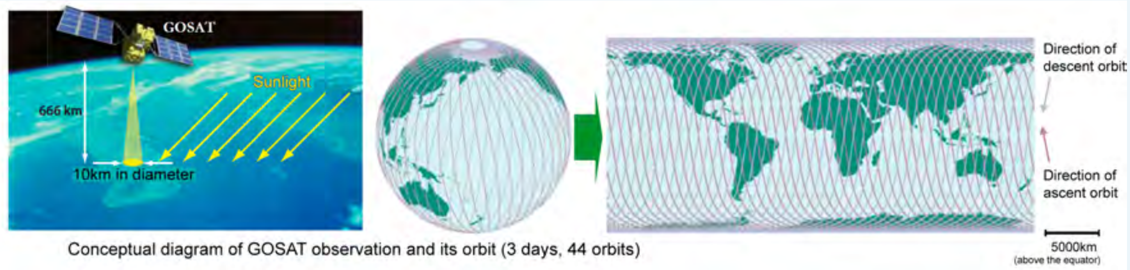
Conceptual diagram of carbon dioxide isolation
Source: Research Institute of Innovative Technology for the Earth

R&D has been conducted by the Research Institute of Innovative Technology for the Earth (RITE) and similar institutes. In order to advance the technology to practical use, it is pointed out that there are many issues such as not only improved economy but advanced environmental impact assessment and monitoring, the creation or improvement of laws and ordinances, and ensuring social receptivity. To address these issues, the Ministry of Economy, Trade and Industry (METI) instituted sustentative experiment for carbon dioxide reduction technologies [literal translation] in 2008, which substantiates a system for the separation, capture, injection and storage of 100 thousand tons of carbon dioxide annually with the aim of putting CCS to practical use by 2020. In the future, it is necessary to substantiate a series of technologies from separation/capture to storage as well as to establish simulation and monitoring techniques for the prediction of long range carbon dioxide behavior.

5) Observation of the earth and climate change prediction

Observation of the earth, climate change prediction and assessment of the indirect impact of global warming on human health and the ecosystem are necessary to understand the global warming process and reduce the uncertainty of climate change prediction. IPCC is planning, in its 5th evaluation report to be delivered after 2013, more sophisticated systems of climate change prediction, such as impact evaluation per region. Japan is required to continue promoting research on advanced prediction models, clarification of climate change response processes for the continental and ocean regions, and long range climate change prediction. As for the observation of the earth, establishment of Global Earth Observation System (GEOSS), which shares observation data (including climate change data) all over the world, is in progress. The Greenhouse Gases Observation Satellite "IBUKI" (GOSAT), which observes the spherical distribution of greenhouse gasses without deviation, was launched in January 2009, and is expected to contribute to further promotion of GEOSS establishment and global warming measures by analyzing and providing observation data (Figure 1-2-3).

Figure 1-2-3 Greenhouse Gases Observation Satellite "IBUKI" (GOSAT)



・GOSAT observes almost the entire globe surface uniformly.
・GOSAT performs frequent observation by returning to the same position every 3 days/44 orbits.
Source: National Institute for Environmental Studies

3 International Efforts as Science and Technology Diplomacy

For Japan, as a country with few natural resources, it is increasingly important to utilize S&T in diplomacy as well as in seeking to further development of S&T derived from Japan, in order to maintain and improve Japan's position in international society. Global level problems, including environmental problems, are especially difficult to resolve by a single country's effort alone. Therefore, Japan must actively use the world's leading scientific and technological capability in organic cooperation with other countries.

This resulted in Toward the Reinforcement of Science and Technology Diplomacy (May 2008) by CSTP, and Science and Technology Research Partnership for Sustainable Development, organized by MEXT and adopted by the Ministry of Foreing Affairs (MOFA) has as a part of its S&T diplomacy, which links S&T with the diplomacy and develops them mutually. JST promotes this project based on the needs of developing countries by cooperating with the Japan International Cooperation Agency (JICA), which conducts collaborative international research on global problems with Official Development Assistance (ODA), acquires new knowledge that contributes to the resolution of global problems, and seeks improved capability in developing countries to facilitate independent R&D. In addition to the issues introduced in the Column 6, there has been a growing concern about water problems, and international cooperation such as the provision of information which contributes to water source management and the reduction of flood and drought in the developing countries, R&D and promotion of Japanese-style high-efficiency water circulating systems, development of treatments for emerging or reemerging infectious diseases, and overall disaster countermeasures for volcanoes, is in progress, and further development in the future is expected.

Column 6 Science and Technology Research Partnership for Sustainable Development

Under the Science and Technology Research Partnership for Sustainable Development, 12 international research projects (7 in environment/energy; 3 in natural disaster prevention; 2 in infectious diseases control have been selected mainly for the areas of Asia and Africa.

Climate change adaptation in developing countries is an important issue to be measured, in particular, rises in sea level around island countries is a visible and serious problem. Funafuti, the capital city of Tuvalu, an island state in the South Pacific, is now said to be in danger of submersion because palm trees have fallen as a result of shore erosion, water springs from the ground during high tide, and residences and roads are flooded by water. In addition, the situation is made more serious by the problem of damage to the costal ecosystem (destruction of reefs and foraminifera) caused mainly by water pollution from household wastewater and animal waste discharge.

Shore erosion in Tuvalu
Photo: Prof. Hajime Kayanne, The University of Tokyo

This resulted in the initiation of a joint international research program that supports the establishment of a management plan for understanding the process of island formation (sand) by reefs and foraminifera, and long-term maintenance of the island through the specification of impediments caused by human activities. In the future, independent research by the local residents is expected to contribute to countries which are facing a similar crisis.

Researchers from Japan on the front line of the task accomplishment are expected to act as "Japan's face" in S&T diplomacy; namely, as special envoys of S&T. And they are getting close attention from developing countries.

2 Towards Sustaining and Reinforcing Monodzukuri

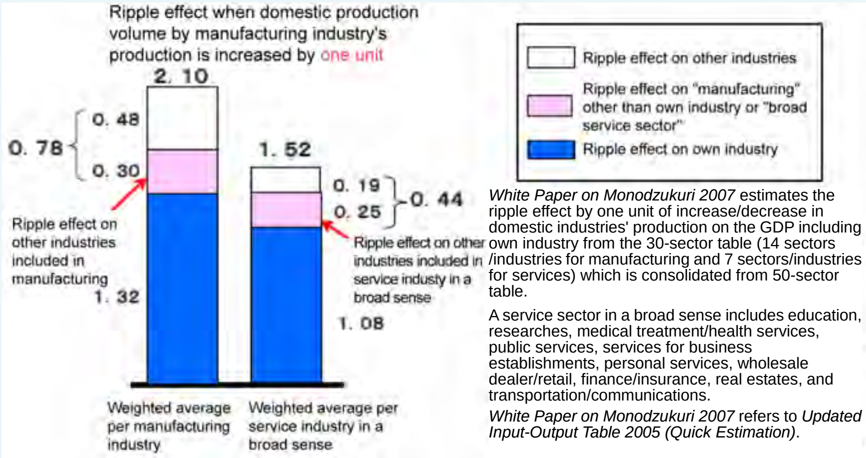
1 Circumstances surrounding Japan's Monodzukuri

Japan, as a country with few natural resources, relies on the import of many of foods and raw energy materials from overseas, and the export of industrial products has played a major role in the acquisition of necessary foreign money. For Japan, for which trade is the basis of economic activity, sustaining and reinforcement of the manufacturing industry which produces industrial products (so-called "Monodzukuri") is an important issue. In addition, sustaining and reinforcement of Monodzukuri, which has a ripple effect on other industries, is also indispensable in maintaining the quality and affluence of the lives of the citizenry (Figure 1-2-4). Moreover, higher Monodzukuri technologies also contribute to resolving global environmental problems.

However, Japan's Monodzukuri is facing a huge environmental change with the advent of such innovations as modularized products. Research conducted by the National Science Foundation (NSF) shows that the share of international sales of Japanese products has decreased to the level of China (Figure 1-2-5).

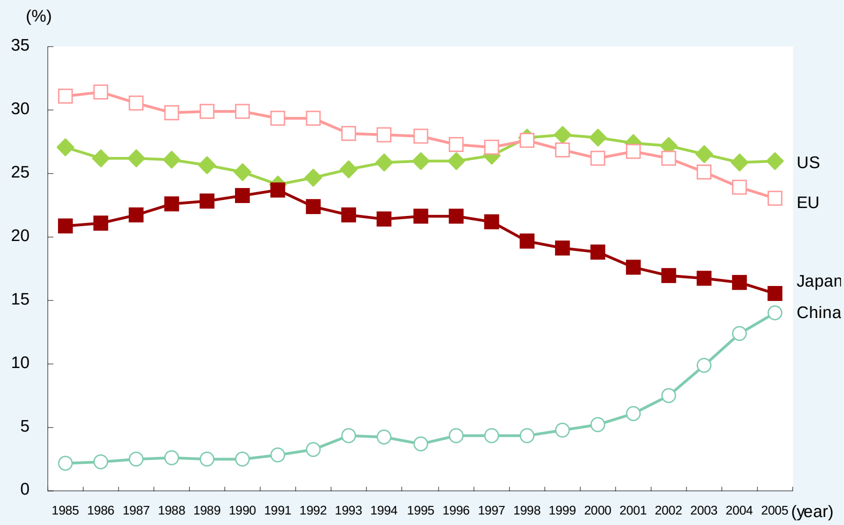
In addition, largely as a result of the global economic crisis, job opportunities in Japan have rapidly decreased, which is a critical social problem.

Figure 1-2-4 Ripple Effect of Manufacturing Industry on Entire Industry



Source: National Institute of Science and Technology Policy *Current Situation and Proposals for Promotion of Science-based MONODZUKURI technology field in Japan*

Figure 1-2-5 Trends in Sales Share of Manufacturing Industry in Selected Countries



Source: National Science Foundation *Science and Engineering Indicators 2008*

As described in Chapter 1, Section 1, the development of modularized products is accelerating the polarization of competitiveness, where the market share for final products is decreasing while the share for materials continues to be dominated by Japan. Therefore, in order to maintain and reinforce Japan's Monodzukuri, it is important to create new industries which have a high economic ripple effect and the potential for employment absorption comparable to what the automobile or electronics industries have and to maintain competitiveness in the field of raw materials.

2 Towards New Innovation for Monodzukuri

For Japan to respond to environmental change and continuously lead the world in Monodzukuri, it is important to advance Monodzukuri and the creation of products and business models based on excellent technology which will not easily be copied by other countries.

This requires the creation of new innovation through the following approaches.

(1) Sustaining and advancing core technologies

While products have been modularized, some Japanese corporations have maintained their international competitiveness by maintaining their competitiveness in raw materials and by securing high technology in the core fields related to products, such as the optical pickups used for optical discs, which are not easily copied.

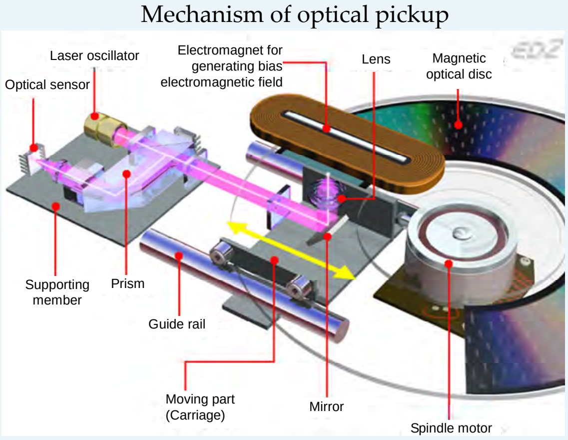
Column 7 Japan's Core Optical Disc Technology Beyond Follower Countries (Optical Pickup)

In the product commercialization and diffusion of optical disc such as CD, DVD, and Blu-ray Disc (BD), the technological development of Japanese corporations took a major role and Japan enjoyed a high share in the world market of optical disc player/recorder by the mid-1990s. However, as modularization has considerably developed with market expansion, the share of Japanese corporations is lower than that of Taiwanese corporations that got into the business later.

Even under these circumstances, Japanese corporations continue to have 70 to 90% of the market share for optical pickups, a core technology for optical discs. Optical pickups read and record digital data on the surface of optical discs, and consist of a lens and such to allow the laser to radiate adequately. The optical pickup is a core device comparable to the central processing unit (CPU) of a personal computer and which accounts for more than 30% of the cost of the optical disc system.

Optical pickup manufacture comprises many processes which call for extremely high skill and "suriawase" (integration) techniques of know-how and requires the "master technology" that Japanese corporations are good at. Customer requirements are difficult and versatile, including such demands as speed-up, miniaturization and low-profile. In order to meet these requirements, through further "suriawase," Japanese corporations are considered to have established the core technology which is beyond follower countries.

Mechanism of optical pickup



Source: Prof. Koichi Ogawa, The University of Tokyo *New Standardization and Business Strategy as Japanese-Style Innovation (11)* [literal translation]

However, East-Asian countries are now engaging in the reinforcement of their raw material industries. For example, South Korea, with concerns about its large trade deficit with Japan, established its Basic Plan for Parts and Raw Materials Development [literal translation] to seek a rapid catch-up through the manufacture of raw materials. This greatly increases the possibility of tough competition for international market shares from Asian countries even in raw materials.

Therefore, it is necessary for Japan to step up its efforts to maintain/ secure competitiveness in the field of raw materials.

In this regard, reflecting the approach to science and innovation described in Chapter 1, Section 1, the methods by which the results of the basic research by universities and R&D corporations engaging in basic research, will be developed to other corporations, is the key to maintaining competitiveness.

Column 8 Korea's Basic Plan for Parts and Raw Materials Development

The Basic Plan for Parts and Raw Materials Development [literal translation] is a policy which is actively promoted by the government of Korea to support technological development and the acquisition of intellectual property rights by corporations in the fields of parts and raw materials, the cause of the large trade deficit with Japan.

Korea's National Science and Technology Council adopted in January 2009 the Second Plan based on the Act on Special Measures concerning Parts and Raw Materials Specialized Corporations [literal translation].

In response to the failure of the primary plan to fully achieve the original target, the second plan sets the target of making Korea one of the world's top five in the fields of parts and raw materials in 2012, raising the level of innovating basic and fundamental technologies in the fields to 90% compared to advanced countries, and achieving a 90-billion dollar trade surplus in the fields, by achieving technology development and market expansion with a 1,300 billion-won investment.

Major items which must be achieved in the plan are as follows:

(1) Secure 100 core technologies in the fields of parts and raw materials to promote balanced growth with the environment as well as to find items which require short-/medium-/long-term R&D related to the items mainly imported from Japan to support technological development.

(2) Develop 60 items of raw material technologies to lead the future.

(3) Foster 100 global parts and raw materials corporations with more than 10% of world's share by M&A of overseas corporations, capital alliances, and joint ventures.

(4) Analyze the needs of the human resources engaged in the parts and raw materials industry, establish an overall training and education program, and foster 50,000 human calitals dedicated to the fields of parts and raw materials.

Source: Center for Research and Development Strategy, Japan Science and Technology Agency

Blue LED and hard disk drive (HDD) with vertical magnetic recording method are famous as cases where Japanese corporations have enjoyed a large international share in the field of raw materials by utilizing the results of basic research at universities.

As for semiconductors, the advancement of capability has relied on the microfabrication technologies of semiconductor manufacturing. However, as described in Chapter 1, Section 1, it has been pointed out that IT fundamental technologies are reaching a substantial limit at the 10-nanometer level for miniaturization of the semiconductor integrated circuits, and advanced performance on the extension of existing micro fabrication technique may not be expected as the scale of the micro fabrication reaches the atomic level. Therefore, in order to develop next generation semiconductors, it is necessary to break through physical limitations by retroactively studying the basic science, including exploring new material.

Advanced Industrial Science and Technology (AIST) started R&D on miniaturization technique as part of its Semiconductor MIRAI Project from FY 2001 to achieve results which enabled us to see the miniaturization limits of the semiconductor. As R&D on nanoelectronics became necessary for the realization of fabrication techniques at the atomic level, which will be required in the future, the Nanodevice Innovation Researcher Center (NIRC) was established in April 2008. Moreover, it has been a place that links the basic technologies to the demonstration of the devices by organizing a nano-electronics innovation platform as well as cooperating with other organizations in NIRC and external institutes. Based on these results, it is necessary to promote low-power consumption and high-efficiency semiconductor circuits with innovative devices and high performance with 3-dimensional semiconductor devices.

In order to develop excellent technology in the fields forming the foundation of material products which will not be easily copied by other countries, it is still necessary to approach innovation through basic research and cooperation among corporations, universities and R&D corporations, and the government hand-in-hand with the private sector.

(2) Approaches to new Monodzukuri

The advantage of Japan's Monodzukuri largely depends on the "master technology" which has been gained over many years by human resources engaged in Monodzukuri. However, there are growing concerns about losing these valuable human resources through retirement, the so-called "The Year 2007 Problem."

However, in recent years, applying highly advanced IT and simulation techniques to Monodzukuri sites has been allowing "master technology" to be visualized and systematized into technology, which was once considered impossible. In addition, it is important not only to pass on the high Monodzukuri skills by utilizing IT or simulation but also to respond to further advancements in Monodzukuri. For example, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) which owns Earth Simulator[1], runs the Program for Strategic Industrial Use of Earth Simulator with support from the MEXT Program for Strategic Use of Advanced Large-scale Research Facilities to encourage the use of simulations for Monodzukuri so that dissemination of these approaches is expected (Figure 1-2-6).

Moreover, in recent years, the role of services for Monodzukuri has become increasingly important, prompting the creation of the so-called Manufacturing and Distribution Business [literal translation], which integrates and handles services from the customer orders to product manufacturing, logistics, and maintenance, etc. through a process of systematizing.

The integration of Monodzukuri and service creates businesses and employment in new forms, and establishes new added value to Monodzukuri, which translates into an advantage for Japan. This requires consideration for integration between Monodzukuri and service in promoting the service science/engineering, which will be described later.

1 A super computer introduced in 2002. It is owned by JAMSTEC and has the highest calculation capability in the world. It has been used for the research of global climate change and has received a high praise. Recently, it has been used for industrial purposes.

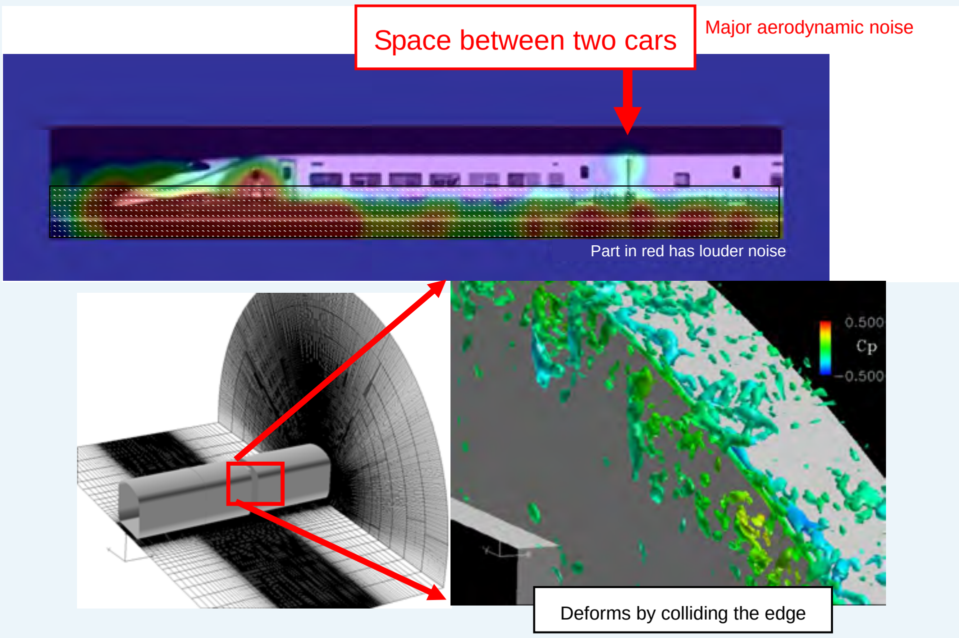
Figure 1-2-6 Aerodynamic Noise Simulation for Shinkansen (Bullet Trains)

It was well known that complex air flow circulates around Shinkansen (bullet trains) moving at high speed to cause aerodynamic noise (wind roar). However, it is difficult to identify the source of the turbulence in practical experiments to better understand the noise mechanism.

Explaining the turbulence around cars moving at high speed requires enormous calculations that only high-performance super computers are capable of.

East Japan Railway Company has performed aerodynamic noise simulations utilizing Earth Simulator which has the highest calculation capability in the world when launched.

This has made it possible to analyze turbulence such as swirl deformation, something that was difficult in the past, and it is expected to be useful for explaining the noise mechanism and contribute to the development of low-noise cars.



Sources: East Japan Railway Company; Japan Agency for Marine-Earth Science and Technology

(3) Improvement of MOT capacity

In order to maintain and reinforce international competitiveness in Monodzukuri, it is necessary not only to focus on the technological innovation but also to create wide-ranging innovation which focuses on the establishment of a business model for market share acquisition.

Amid the development of modularized products, it is difficult to succeed against fierce international competition by maintaining core technology utilizing the advantage of full "suriawase" (integration) techniques including “master technology” only. This requires strategic approaches which integrate technology, intellectual property, standards, and international cooperation, by achieving world standards strategically with business models in mind and the outsourcing of assembly process to corporations in developing countries.

In a broad sense, major technology management includes the establishment of a business model, which aims at global share acquisition, by integrating innovative technology and idea/concept, and exploiting a brand image without specializing in technology as in the case of iPod.

Moreover, as for the role of R&D itself, amid the open and globalized innovations described in Chapter 1, Section 1, the role of cooperation with external institutes such as universities and other corporations must be considered in terms of advanced strategy, such as different utilizations between open innovations accompanied by shared information with external institutes and closed innovations linked to the establishment of core technologies.

Based on the understanding that reinforced technology management is indispensible, the Industrial Technology Enhancement Act was revised in May 2007. The Act clarifies the responsibility of the government and entrepreneurs to enhance technology management capability and stipulates that the government take the necessary measures for enhancing technology management. Moreover, in the R&D-Capacity Strengthening Act [literal translation], promotions for knowledge acquisition related to S&T Management [literal translation] was positioned as the responsibility of the government.

In addition, in response to the growing need for advanced training to prepare professionals to be socially and internationally active, a system of professional schools was founded in FY 2003. Under the system, 30 universities established 32 majors related to business or management of technology (MOT), and they are expected to play a vital role in the development of S&T and the globalization of socioeconomic society, have been established as of 2009.

Moreover, the suggestion that different utilization between open and closed innovation for intellectual property rights such as patents is required was made by the Expert Panel on Reinforcing Competitiveness by Intellectual Property [literal translation] of the Intellectual Property Strategy Headquarters in March 2008.

As described above, approaches for comprehensive reinforcement of technology management are required to further enhance the international competitiveness of Monodzukuri.

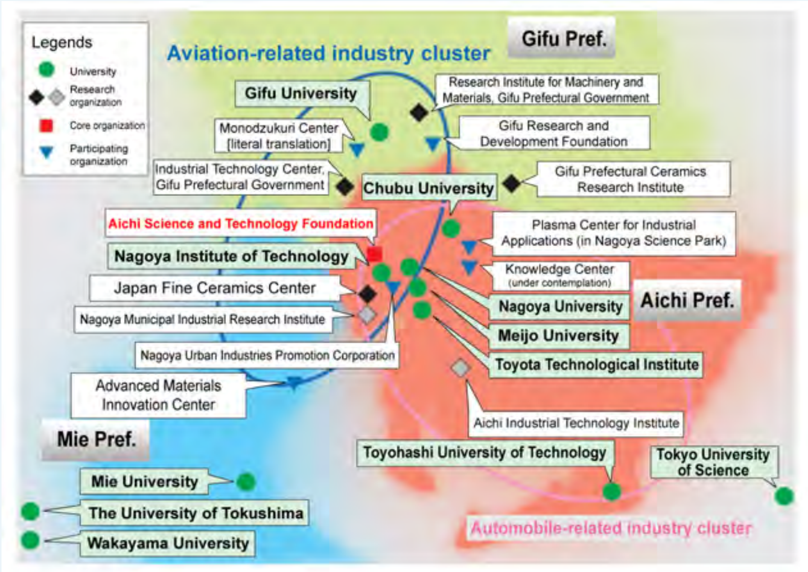
(4) Cluster formation and fostering human capitals for sustaining and reinforcing Monodzukuri

As described above, Japan's Monodzukuri has an extremely high share for raw materials, and there are many leading small- and medium-sized firms locally, called niche-top firms, with a greater than 50% share in international product sales. Regional industrial agglomerations including these niche-top firms function as a basis that supports Japan's Monodzukuri, and measures for sustaining and developing these firms, such as the Knowledge Cluster Initiative by MEXT and the Industrial Cluster Project by METI, have been carried out. For the further advancement of accelerated technology development in cooperation with research institutes such as universities, it is required to further develop the regional industrial agglomerations by establishing centers that promote regional cooperation with the private sector, universities and government agencies, in order to create regional firms with high technologies in the future and maintain Japan's competitiveness (Figure 1-2-7).

Figure 1-2-7 Nagoya Nano-Technology Manufacturing Cluster

In the Nagoya Nano-Technology Manufacturing Cluster, one of the clusters selected under the Cluster Knowledge Initiative, "sustainable development as a world-leading Monodzukuri center" [literal translation] is set as a strategy to seek enhancement of parts processing technology by SMEs and mid-level enterprises which support the base of the automotive, machine tool and aircraft industries by utilizing advanced nanotechnology.

Specifically, with "creating world-class, environment-friendly advanced functionality materials" as a concept and with advanced plasma nano-science/engineering as a core, the cluster promotes R&D on high functionality for material which contributes to energy saving and environmental impact reduction, and advanced nano-fabrication techniques. It also supports the dissemination of research results and applied research/trial development, and promotes regional cooperation for technology transfer and commercialization to SMSs and mid-level enterprises.



Source: Aichi Science and Technology Foundation

In contrast to these industrial agglomerations, the human resources that have supported Japan's Monodzukuri and industrial agglomerations are facing the loss of high Monodzukuri skills because of the retirement of the baby-boomer generation, while newly-employed individuals have remained at a low level (so-called "The Year 2007 Problem"). As the population is expected to decrease in the intermediate and long term, fostering and securing human resources for Monodzukuri is an urgent issue.

This resulted in the establishment of the Craftsman 21 Project [literal translation] by MEXT and METI in FY 2007, which develops human resources in Monodzukuri through cooperation between professional high schools and local industries. In addition, the two ministries also develop human resources through joint industry-university programs such as internships targeting college of technology or university students, promote activities by doctoral degree holders in industry, and improve the skills and motivation of engineers through a Consulting Engineer system and awards that recognize excellent engineers.

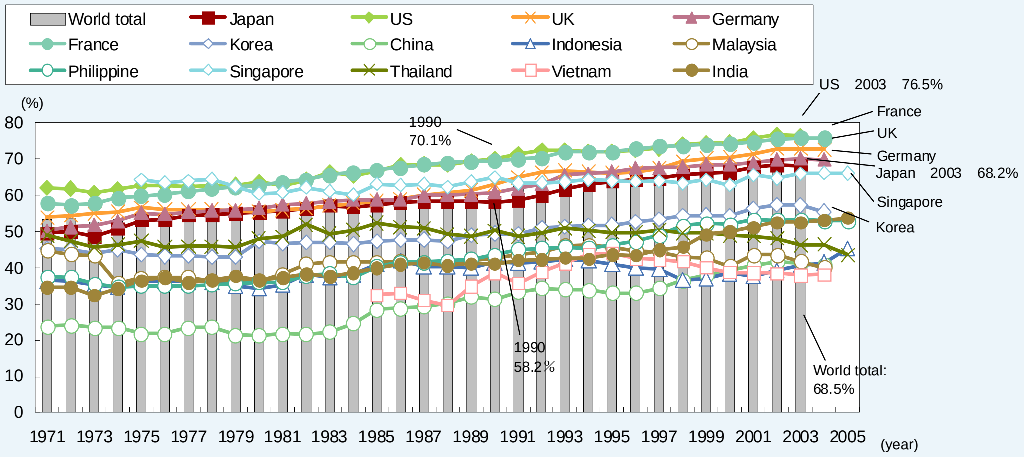
As described above, it is necessary to continuously address reinforced base and human resource development for Monodzukuri through regional cooperation among the private sector, universities and government agencies, for maintenance/reinforcement of Monodzukuri as a Japanese advantage.

3 Towards Promoting Services

1 Need for Promotion of Service Science and Engineering

The percentage shift of the service sector in GDP shows an increasing tendency globally after the 1970s, and the importance of the service sector in the world economy is growing (Figure 1-2-8).

Figure 1-2-8 Trends in Service Industry-to-GDP Ratio in Selected Countries



Source: Ministry of Economy, Trade and Industry *White Paper on International Economy and Trade 2007*
Note: "World" in the graph implies the "World" described in The World Bank *World Development Indicators*
Source: Prepared by MEXT based on The World Bank *World Development Indicators*

The percentage of the service sector in Japan's GDP is approximately 70%, which supports high employment; however, productivity remains lower than in Western nations (Table 1-2-9). This requires Japan to improve the productivity of the service sector by introducing scientific and engineering approaches to services, improve the quality of life, create added value, and achieve exploit of new disciplines. Accomplishing this makes promotion of Service Science/ Engineering indispensable (Figure 1-2-10).

Scientific handling of services has been advancing, especially in the US, and the promotion of service science is prescribed in the America COMPETES Act. In addition, in the Western nations, promotion of research funding measures and the establishment of specialized research institutes are in progress. In Britain, for example, the Public Services Innovation Laboratory, which targets innovations in public services such as health, has been established.

Table 1-2-9 Manufacturing- and Service-industry Labor Productivity Growth Rates, by Selected Country

Labor productivity growth rate (1995 to 2003)

	Manufacturing industry (%)	Service industry (%)
US	3.3	2.3
Britain	2.0	1.3
Germany	1.7	0.9
Japan	4.1	0.8

Source: Prepared by MEXT based on OECD *Compendium of Productivity Indicator 2005*

Figure 1-2-10 Examples of Service Science/Engineering in Daily Life

(1) One convenient card (Contactless IC card)

FeliCa is contactless IC card, developed by SONY, a technology which is used widely in automated ticket gates and for payment at stores. About 1 million cards have been issued in Japan as of the end of 2008.

The Octopus Card in Hong Kong first adopted FeliCa technology in 1997 and East Japan Railway Company adopted it for its Suica in 2003. Thereafter, it has been used in Singapore, India and Thailand, and the technology is spreading throughout the world.

This card is useful in reducing congestion at ticket gates during morning and evening rush hours, and as it can be used as electronic money, just one card is accepted for various services at the station or commercial facilities around town affiliated with the railroad. The opportunities for using this card are expected to increase.

Source: Sony Corporation

(2) Innovation in video-sharing services (Synvie)

In recent years, video-sharing services, which share uploaded videos over the internet, have seen large growth as the broadband communication infrastructure has become widespread.

Well-known services include YouTube in the US, which not only has an enormous number of viewers each day from around the world, but was used to great effect by candidates in the 2008 US presidential election. In addition, Nintendo, Kadokawa Shoten Publishing and others are utilizing it as an advertising medium.

Japanese innovation related to these services includes the case of Nico Nico Douga. The Nico Nico Douga not only won the Good Design Award in 2007 for this superior idea, which combines a comment-posting function with the video-sharing services, but also won the Prix Ars Electronica 2008, which recognizes innovation in the media arts.

Source: Daisuke Yamamoto, Assistant Professor, Nagoya Institute of Technology

An example of R&D associated with advanced communication via current video services is Synvie, developed by Daisuke Yamamoto (Assistant Professor at Nagoya Institute of Technology) during his graduate studies at Nagoya University. His studies were supported by the Information-Technology Promotion Agency, Japan's Exploratory Software Project. Further development of this technology was supported by the Intellectual Contents Platform for Supporting People [literal translation] program under the Special Coordination Funds for Promoting Science and Technology from FY 2005 through FY 2007. The function has been extended at the lab of Prof. Nagao, Graduate School of Information Science, Nagoya University, and nonprofit open experimental services continue now.

In the future, communications over the internet using video and other media are predicted to expand throughout the world, and expected to bring advanced communications such as formation of wisdom of crowds with global-scale communications.

2 Service Science and Engineering Promotion

Japan has lagged behind the US and other countries in service science/ engineering, and an effort has just begun to be made as the R&D-Capacity Strengthening Act [literal translation] (2008) Article 47 provides, "the government … shall survey the role of R&D promotion associated with the application of natural science to social science or business management and reflect the results in the promotion of R&D systems and government-funded R&D."

As the Act came into effect, MEXT held a Promotion of Service Science and Engineering Investigative Commission and a report was compiled in January 2009. Based on the suggestions made by the report, service science/engineering must be promoted.

Column 9 Investigative Commission for Promoting Service Science and Engineering

At the Investigative Commission for Promoting Service Science and Engineering [literal translation] which is attended by experts from industry and academia, since August 2008, participants reviewed the measures concerning service science and engineering that Japan must promote in the future and published their findings in the report *Seeking New Possibility for Services: Suggestion for Service Innovation* [literal translation] in January 2009. The key points listed in the report are as follows:

1. Basic investigative research and panoramic organization of social issues, technologies and methodology, and competent persons conducting research
2. Building common understanding and network formation among research, corporations, public organizations and NPOs in the various fields
3. With cooperation among relevant persons, establishment of research system to create economic and social value-added services
4. Formation of NOE (Networks of Excellence) type research centers to build interagency networks taking the core agency as a hub with cross-field network functions
5. Development of competent persons through environmental improvement to promote the participation/recruitment of young researchers, education in service science and engineering for universities/ graduate schools, and participation of researchers in the existing fields
6. Building a mechanism to promote the utilization and distribution of data

4 Towards Promoting Science and Technology Needed for the Future Lives of the Japanese Public

In the current situation where various needs of the Japanese public, including the achievement of a secure and safe society and improvement of quality of life exist, these needs must be properly met with innovations in S&T.

1 S&T Promotion Contributing to Establishment of Safe and Secure Society

In recent years, as threats to the lives of the Japanese public, such as natural disaster, fatal accidents, crime, and food problems, have occurred with increasing frequency both nationally and internationally, S&T are expected to provide help. In June 2006, CSTP listed seven items: (i) large-scale natural disasters, (ii) grave accidents, (iii) emerging and reemerging infectious diseases, (iv) food safety problems, (v) terrorism, (vi) information security, (vii) various crimes as dangerous situations that threaten safe and security, which should be handled through S&T, and suggested measures for the promotion of S&T that contribute to safety. In addition, in handling devastating natural disasters which affect multiple countries and terrorism or similar problems which are common among the countries of the world, international cooperation is important.

Japan also has an obligation to positively address these problems.

The major R&D associated with large-scale natural disasters, emerging and reemerging infectious diseases, food safety problems, and terrorism which the Japanese public is interested in, is described below.

(1) Large-scale natural disasters

Natural disasters such as earthquakes, typhoons, and volcanic eruptions have caused great damage to people, property, and the economy. Recent examples of such natural disasters include the Noto Hanto and Niigataken Chuetsu-oki Earthquakes in 2007, the Iwate-Miyagi Nairiku Earthquake in 2008, and torrential downpours. Such an environment makes it important to promote measures to minimize the damage and disruption brought on by the power of nature.

Institutions concerned with cooperation have carried out research and surveys for earthquake disaster prevention under the policies of the government's Headquarters for Earthquake Research Promotion. The result of this activity is the creation of National Seismic Hazard Maps for Japan, which shows the possible distribution of earthquakes with an intensity 5 or greater within the next 30 years, and data which contribute to the clarification of the mechanism of generation in highly damaging "epicentral earthquakes beneath the cities" and improvements in earthquake-resistant buildings.

However, earthquakes that have occurred with the seismic centers in the costal areas which have as yet not been adequately surveyed or researched, and an earthquake in the Tokai/Tonankai/Nankai region is predicted to be highly probable and highly devastating. Moreover, as there are still technical issues with the Earthquake Early Warning System and the warning will not be triggered around the seismic center in cases of near-surface earthquakes on land. Because of this, further research and surveys on earthquakes are required. Another issue is that the observation network for the ocean, which is indispensable for earthquake research and surveys, is insufficient compared to the observation network set up for the land.

In the future, in order to monitor these situations, Japan will promote research and survey activities on advanced earthquake early warning associated with earthquakes in coastal areas with the potential to seriously affect Japan's social/economic activities, reinforce the observation network in the ocean, and realize highly accurate earthquake prediction and the effective early detection of earthquake/tsunami.

Regarding volcanoes, Japan has worked on R&D for eruption prediction and disaster prevention, making a great deal of progress and gathering useful information such as knowledge about the precursors of a volcanic eruption; however, there are still issues such as inadequate prediction of eruption shifts and aging observation facilities. To address these issues, Japan will reinforce the observation/research and surveys on volcanic activities.

Moreover, as the torrential rains which caused extensive damage from July to August 2008 highlighted, how well the amount of rain and subsequent damage can be predicted is the big issue for disaster prevention. In response high-precision prediction system development has been reinforced with the Multi-parameter Radar (High-Resolution Meteorological Radar System) by the National Research Institute for Earth Science and Disaster Prevention (NIED).

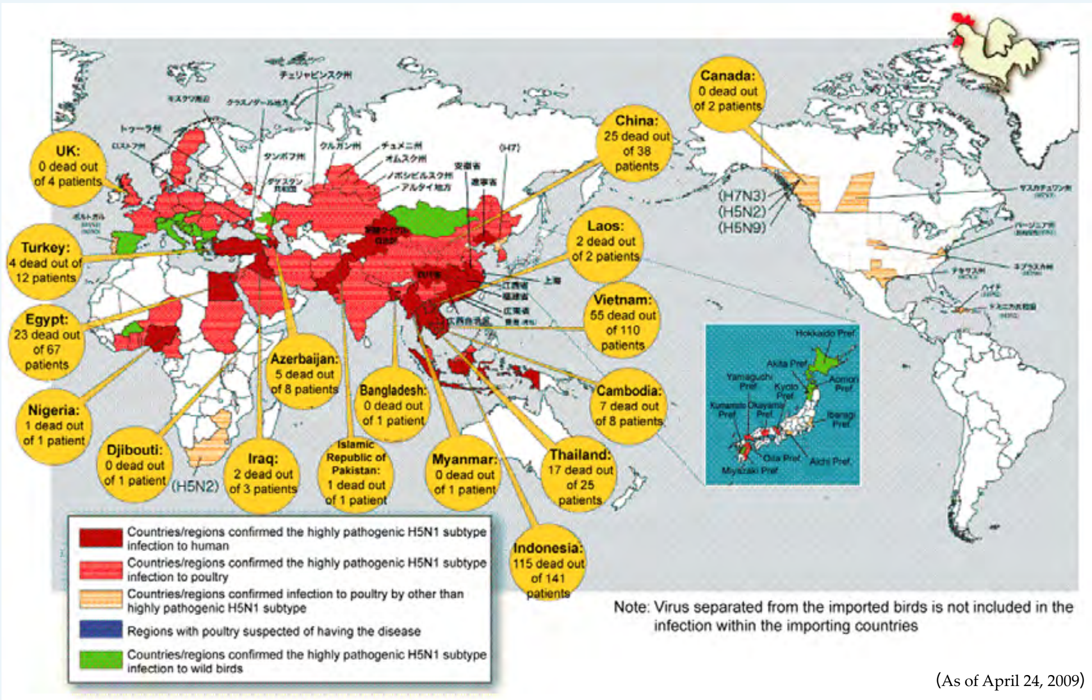
(2) Emerging and reemerging infectious diseases

In recent years, Severe Acute Respiratory Syndrome (SARS) and Highly Pathogenic Avian Influenza (Figure 1-2-11) have emerged, and mutations of bird flu or similar viruses have caused concern about the potential for the development of a super-flu which may be transmitted from person to person. Therefore, responses to emerging and reemerging infectious diseases are urgent issues. Moreover, these infectious diseases have the potential to quickly spread around the world with the development of the transportation, which raises concerns about devastating damage to life, society and economy.

To establish a system that concentrates human resources, and research facilities and resources on infectious diseases, and to respond quickly to suspected cases are urgent issues. It is pointed out that rapid research cannot be conducted domestically as acquiring the necessary information on pathogens takes time.

Japan has been establishing research centers in cooperation with local institutes in developing countries in Asia and Africa with existing or potential cases of emerging and reemerging infectious disease, and has been organizing internal systems to intensively and continuously conduct basic researches that support measures for infectious diseases. In the future, it is necessary to promote such research, secure human resources who are ready to respond to emergency cases in Japan as well as reinforce training for researchers who are expected to be active for years to come. In addition, it is necessary to prepare for emerging and reemerging infectious diseases, whose timing cannot be predicted, by establishing a production system able to provide vaccines to citizens even in emergency situations.

Figure 1-2-11 Distribution Map of Highly Pathogenic Avian Influenza Based on Official Announcement



Source: National Institute of Infectious Diseases

(3) Food safety problems

In the past few years, there have been a number of threats to food safety, including mislabeling by unscrupulous individuals in Japan and tainted Chinese-made frozen dumplings that have raised great concerns. As the mislabeling of rice, Japan's staple food, has also come to light, the Japanese sincerely hope to resolve these food safety problems in the distribution system.

The solution to these threats requires the quick detection of harmful microorganisms and chemicals and the reduction of damage at all stages of production, processing and distribution of foods. In addition, research is needed to improve the ability to identify the source of and differences in quality of marine/farm/animal products through differences in genetic and other components.

(4) Terrorism

After the simultaneous multiple terrorist attacks that took place in the US, on September 11, 2001, other terrorist attacks have been carried out around the world and establishing countermeasures has become a common problem. It is an urgently important to prevent terrorist attacks, which claim large numbers of lives in a matter of moments, and create great damage. It is necessary to reinforce S&T that contribute to the development of equipment and material for unopened detection[1] [literal translation], quick and reliable on-site detection, identification, and decontamination to target terrorism-related materials such as explosives, nuclear materials, biological agents[2], biotoxin and chemical agents. However, as almost all of the equipment designed for the detection of terrorism-related materials is imported from overseas and much of it has been developed for military purpose, many of the technologies used for this equipment has not been disclosed. This requires Japan to develop original detection technology.

Training for biochemical terror
Source: Metropolitan Police Department

Moreover, in order to contribute to international security as well as take advantage of the considerable knowledge and experience of other countries to fortify Japan's R&D efforts, it is necessary to reinforce cooperation for terrorism countermeasure technologies, including the sharing of confidential information with advanced overseas nations.

2 Promotion of S&T Contributing to Improvement of Quality of Life

S&T have contributed to the achievement of rich, safe and secure lives; but people are shifting their emphasis to a search for mental richness. In the future, it will be necessary to achieve mental richness and improve quality of life by satisfying people's curiosity through new discoveries, and the promotion of S&T for health, and S&T that addresses the issues of the aging population.

(1) S&T for health of the Japanese public

Developments in S&T have achieved improvements in the level of medicine, nutrition and sanitary conditions, and have contributed greatly to the extension of the average life expectancy in

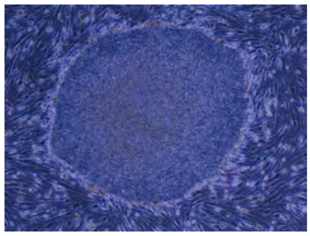
1 To detect dangerous materials hidden in sealed containers without opening.
2 Pathogenic microbes and their toxins used for biological weapons.

Japan. However, from the viewpoint of truly improved quality of life, further effort to extend the healthy life expectancy as well as the average life expectancy is required.

Japan's achievements in basic research in the fields of life science, some of which have appeared in major scientific journals such as *Nature* and *Science*, are highly valued internationally. It is necessary to develop by taking advantage of these achievements innovative diagnostic methods and medical treatments for intractable/adult diseases such as spinal cord damage, cardiac infarction, diabetes and cancer, which is the leading cause of death in Japan, as well as for mental disorders such as depression and Alzheimer's disease. However, as Japan does not have a sufficient support system for clinical and translational research, and the pharmaceutical processes are prolonged and inefficient, the results of Japan's superior basic research have not been fully put into practical use as chemicals and medical equipment for the benefit of society.

In the future, it is necessary to rapidly feed back leading-edge medical treatments to the people by reinforcing the institutes which support translational research, improving infrastructure for the clinical trials and clinical research and taking advantage of the Super Special Consortia for supporting the development of cutting-edge medical care (Super Special Consortia), as well as promoting translational research to apply these results to the development of innovative diagnosis and medical treatments for the next generation.

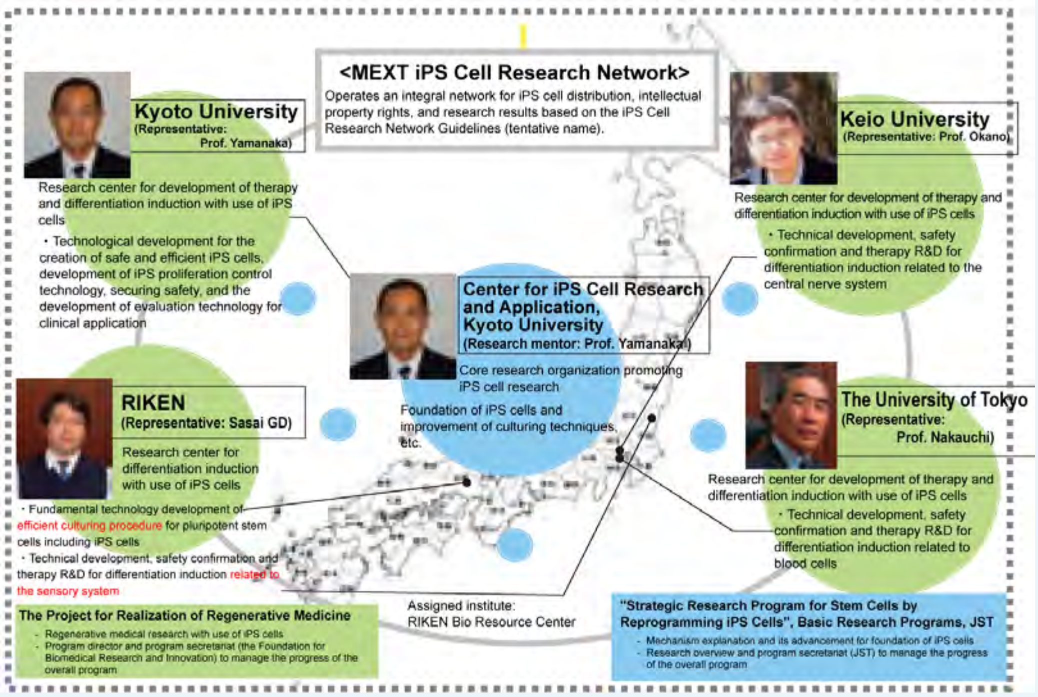
The team of Prof. Shinya Yamanaka, Kyoto University, announced they succeeded in reproducing human iPS cells[1] (induced pluripotent stem cells) in November 2007. This is a technology from Japan which can contribute to the explanation of disease mechanisms and drug discovery, with the possibility of completely changing existing medical treatments. Kyoto University patented human iPS cell reproduction methods in Japan in September 2008. It is necessary to promote associated research such as the Project for the Realization of Regenerative Medicine (Figure 1-2-12) by MEXT, so as to advance the clinical applications and bring good news to people who suffer from intractable diseases.



iPS cells
Photo: Prof. Shinya Yamanaka, Kyoto University

1 Cells capable of differentiating into cells/tissues in a living body and propagating themselves. Artificially derived from human somatic cells, by inducing a certain genes into them.

Figure 1-2-12 Project for Realization of Regenerative Medicine



Source: Prepared by MEXT

(2) S&T in response to aging society

Japan will be facing a super-aging society by 2025, when more than 30% of the population is predicted to be aged 65 years or older. It is required to establish a society where elderly people are able to find a purpose in life more easily than now. As the birthrate is declining, it is estimated that a shortfall in human resources who care and support the elderly people and the physically disabled people will advance in the future and the burden on care personnel will become heavier.

ROBOT SUIT HAL™
Photo: Prof. Yoshiyuki Sankai, The University of Tsukuba

With this in mind, it is important to make it possible for people to achieve mental richness and to establish a society that gives people a purpose in life by enriching the lives of the elderly and physically disabled and by increasing opportunities for contact with society through the development/ practical application of self-reliance support robots and easy-to-operate automobiles. For example, CYBERDYNE Inc., a venture from the University of Tsukuba, has developed a wearable suit, HAL, intended to extend/amplify/assist human functions. This suit is the world's first robot suit which is able to extend and amplify the body functions and enabled patients with intractable diseases to move their legs. In addition, CYBERDYNE started leasing HAL to care/welfare facilities through Daiwa House Industry Co., Ltd. so that the technology has become more accessible. In addition to further R&D, it is necessary to establish safety standards and promote the dissemination to society in the future.