1.1.3 Returning the Results of Science and Technology to the Society - Utilization of Knowledge -

Summary

The "knowledge" created by science and technology has made its way back to society, providing many conveniences to mankind. Science and technology advanced even more rapidly in the 20th century. Overcoming diseases and staying healthy through increased levels of medical standards and hygiene, enhanced convenience in everyday life including the development of transportation and communication, and advancement in dealing with disasters, etc. -these have enabled mankind to conquer chronological and spatial restrictions that limited past human beings and to establish safe and secure societies. Even more recently, the results of science and technology have continued to make their way back to our society and change the way we live; it is clear that science and technology will play a major role in the problem that will become more critical in the future-harmony between human activities and the environment.

Meanwhile, it is not always an easy task to apply the "knowledge," i.e. the outcomes of science and technology, in society. In order to overcome a variety of challenges to apply the results in society, it is necessary to have efforts by researchers, to coordinate the research environment to support them, to promote the communication of information among the industry, academia, and government, and to have public support for research. Often it takes a long period of time to return knowledge to society as an application, and "succession of knowledge" becomes a key for "utilization of knowledge."

In this section we give examples of results coming from Japanese researchers and research institutes that have had significant impact on society in recent years as well as examples of cooperation among the industry, academia, and government, which is the key for science and technology outcomes to make their way back to society.

1.1.3.1 Results of Science and Technology that Have Changed the Society

(1) Maintaining health and overcoming diseases

Advancement in science and technology has improved the standards of medical practice, nutrition, and hygiene conditions. On the other hand, however, health maintenance is now facing new challenges such as how to deal with various metabolism-related syndromes (obesity, diabetes, hyperlipidemia, hypertension, hyperuricemia, etc.) as well as cancer, perhaps resulting from more Western diets. Rapid internationalization is also making it necessary for us to prepare for unknown infectious diseases.

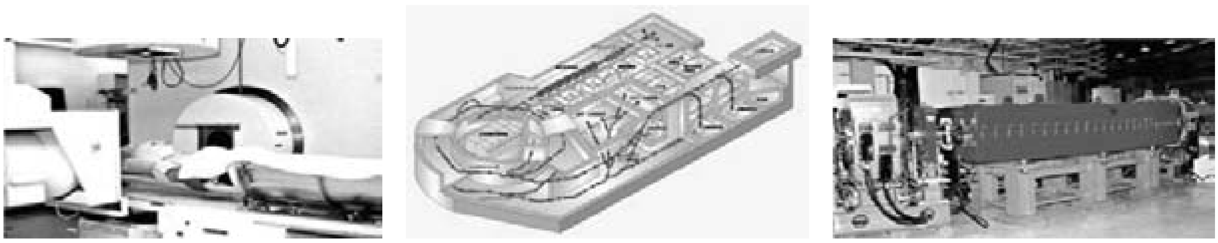
To maintain health, it is of course important to develop preventive methods so that illnesses can be prevented in advance as well as methods for diagnosis. However, medical therapy, which frees people in sickness from their pains, is the central challenge. Here, we give examples of "utilization of knowledge" involved in the development of therapeutic technology, medicine, and related products. Shortening the period of treatment or the number of days hospitalized and preventing recurrence of illness contribute significantly to medical economy, just as improvement in the quality of life (QOL).

("Heavy Ion Cancer Therapy" to overcome "Cancer")

Cancer therapy using heavy ion[26] is provided at the National Institute of Radiological Sciences. In 1993, the world's first heavy ion cancer therapy equipment (HIMAC, or Heavy Ion Medical Accelerator in Chiba)[27] was built, where Dr. Hirohiko Tsujii, the director of the center, and his colleagues provided heavy ion (carbon) cancer therapy to 3,178 patients between the beginning of its clinical trial in 1994 and the end of 2006 (Figures 1-1-17, 1-1-18). The results of HIMAC are due to "Clinical Research in Advancement of Heavy Ion Cancer Therapy" based on the "Third Comprehensive 10-year Strategy for Cancer Control (fiscal 2004 to fiscal 2013)" made jointly by the MEXT (Ministry of Education, Culture, Sports, Science and Technology) and the Ministry of Health, Labour and Welfare.

Radiation therapy has advantages such as not burdening the patients because neither anesthesia nor surgery by incision is necessary. In heavy ion cancer therapy, in particular, the concentration of the beam is so high that interference to benign systems can be kept minimum by aligning the beam peak right to the cancer-damaged spot; in addition, because the heavy ion beam has a powerful ability to annihilate cancer cells, it is expected that even types of cancer that could not have been sufficiently eliminated by conventional radiation can be treated this way (Figure 1-1-19).

The 5-year survival rates of heavy ion therapy are 50%



Heavy ion therapy room　　Diagram of HIMAC　　Heavy ion main accelerator (synchrotron)

Figure 1-1-17 Heavy ion cancer therapy system (HIMAC)

Source and photos provided by the National Institute of Radiological Sciences

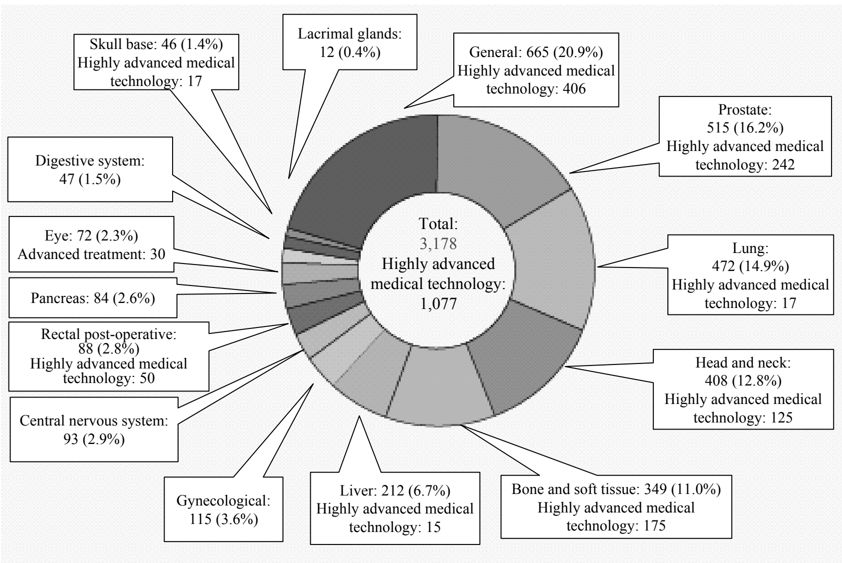


Figure 1-1-18 Number of patients enrolled for heavy ion cancer therapy (June 1994 to Feb. 27, 2007)

Source: National Institute of Radiological Sciences

[26] Heavy ions refer to particles larger than protons; at the National Institute of Radiological Sciences, carbon beams are used.
[27] HIMAC (Heavy Ion Medical Accelerator in Chiba): heavy ion cancer therapy system

for stage-1 cancer, 67% for lung cancer (3 to 5 cm tumors), and 25% even for osteosarcoma, in which surgical removal is impossible. These are sufficiently high treatment success rates compared to the conventional treatment methods.

In 2004 the National Institute for Radiological Sciences began doing research and development in technologies that would lead to size reduction, with the goal of having heavy ion cancer therapy system all over the country. They have succeeded in obtaining a beam with a performance equivalent to the current beam performance, with equipment about 1/3 of the size of the HIMAC. With this success, in 2006, Gunma University began building a compact trial unit, which will be a stepping stone for future popularization. With a view to popularizing heavy ion cancer therapy system in the future, human resources that will be necessary are also being trained (Figure 1-1-20).

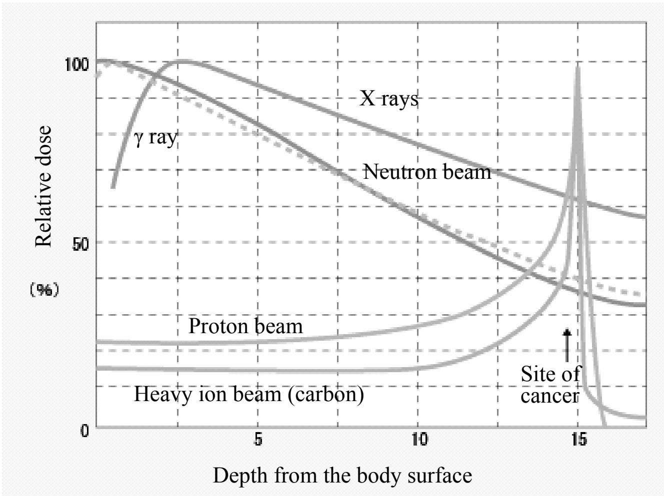


Figure 1-1-19 Comparison of various types of radiation and heavy ion beam

Source: National Institute of Radiological Sciences

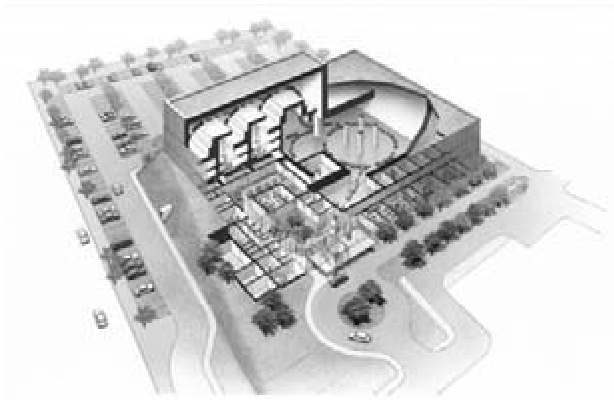


Figure 1-1-20 Compact heavy ion beam radiation facility at Gunma University, under construction (artist's impression of the completed building)

Source: Heavy Ion Medical Center, Gunma University

(Detecting infectious diseases)

In February 2003, in the province of Guangdong of China, 305 people were infected with an acute respiratory illness, and 5 of them died. The cause was the SARS (Severe Acute Respiratory Syndrome) corona virus. Japan is geographically close to China and is in a close relationship in economic and other activities, so this was taken as a serious threat. With progress in globalization, even if a disease began in another country, the active traveling of people could lead to the outbreak and spread of an unknown disease within Japan.

Under these circumstances, supported by the Special Coordination Funds for Promoting Science and Technology in 2003, a research group led by Hiroshi Yoshikura, the director-general of the National Institute of Infectious Diseases of the Ministry of Health, Labour and Welfare, carried out the project "Urgent Research Study on the Diagnostic and Testing Methods of SARS." They developed a method for detecting the SARS virus and a method for identifying a viral respiratory infectious disease.

The SARS test sample thus developed is able to detect the virus within 20 minutes. With the cooperation of Hong Kong, Vietnam, Mongolia, Taiwan, and Singapore, the test was administered to the specimens (stool, blood serum, throat specimens, etc.) of those patients who were sick for a long period of time with a variety of symptoms. Even within 5 days after their symptoms began, the detection rate of the virus was quite high, at 80% or more. The test sample was jointly developed by Prof. Koichi Morita (Institute of Tropical Medicine, Nagasaki University), Dr. Masato Tashiro (National Institute of Infectious Diseases), and Eiken Chemical Co., Ltd. In December 2003, it was approved as an in-vitro diagnostics by the Ministry of Health, Labour and Welfare, and it was distributed to public health institutes and quarantine stations all over the country to prevent the SARS virus from entering the country.

(Overcoming lifestyle-related diseases - development of medicine to lower the cholesterol level)

Coronary artery diseases (cardiac arrest, cardiac infarction, etc.) due to hypercholesterolemia are becoming a very serious type of illness in Japan, second only to cancer. Various anti-cholesterolemic agents had been discussed to improve the conditions by the late 1960s, but there were problems with their effectiveness. The development of "statin drugs[28]," later referred to as the "penicillin of arteriosclerosis and cholesterol," was aided by significant contribution of the research results of Dr. Akira Endo (currently the director of the Biopharm Research Laboratories, Inc. and professor emeritus of Tokyo University of Agriculture and Technology).

Dr. Endo, after graduating from Tohoku University, began doing research at a pharmaceutical company in 1957. Through his 2-year experience of studying in the United States (at the Albert Einstein College of Medicine in New York as a postdoctoral researcher) starting in 1967, he became aware of the importance of research in anti-cholesterolemic agents, and he discovered a substance called "compactin" from penicillium. However, due to problems related to the effectiveness, its development as a medicine was suspended in 1980.

Dr. Endo then moved on to the Tokyo University of Agriculture and Technology in 1979 and, in his research supported by Grant-in-Aid for Scientific Research, discovered a substance called "Manacolin K" (a.k.a. mevinollin, lovastatin) from a mold (fungus) called "*Monascus purpureus*" (beni koji mold, red malt mold[29]). About the same time, the same substance was discovered from a different fungus by the U.S. pharmaceutical company Merck. The discovery of this substance was a breakthrough, leading to speedy advancement in the development of statin drugs afterwards.

Sales of statin drugs began in 1987 in the United States and 1989 in Japan. It is said that there are about 30 million people around the world who suffer from hypercholesterolemia, a lifestyle-related disease. Statin drugs are useful in the treatment and prevention of heart diseases and brain diseases.

"I was strongly motivated to get into medicinal development by the autobiography of Fleming[30], which I read while I was at Tohoku University. Compared to today's university environment, the amount of research funds and the scale of laboratory equipment available were much smaller, with just a few co-researchers. I knew that I could not compete in the American-style research

[28] "Statin" refers to any substance that lowers cholesterol in the blood (an anti- cholesterolemic agent). According to fundamental clinical research in recent years, statin is proved effective for Alzheimer's disease and osteoporosis as well.

[29] Red malt has been used as health food since ancient times in China. It is used in red bean curds, Chinese white liquors (*shaoxingjiu*), vinegar, and food additives (red coloring), as well as Chinese medicine.

[30] Alexander Fleming, discoverer of penicillin. He received a Nobel Prize in Physiology or Medicine for the "discovery of penicillin" with H. W. Florey and E. B. Chain in 1945. Fleming had submitted a paper concerning the discovery of penicillin back in 1926, but the importance of this work was not recognized for a long time. It was Florey and Chain who applied this substance for medicinal purposes.

method, so I considered molds and mushrooms, which Americans do not use very much. My knowledge on natural organisms and attitude of perseverance led me to the discovery of critical substances," says Dr. Endo. The young researchers with whom he worked at the time are said to be leaders in universities and companies now, carrying on the research style of Dr. Endo.

(Medicines made from "immunology," a strength of Japan)

Human bodies are equipped with a defense system called "immunity," which builds resistance against invasion of foreign, dangerous substances such as bacteria, and lymphocytes contribute to this system. Medicine that uses this operation of the human body is called antibody medicine.

Tocilizumab (humanized anti-human interleukin-6 (IL-6) receptor antibody)[31] is an antibody medicine originated in Japan, and it is the world's first IL-6 inhibitor. Results of basic research conducted at Osaka University, supported by Grant-in-Aid for Scientific Research and the Health and Labour Sciences Research Grants, led to the invention of a medicine against Castleman's disease[32] in 2005 through subsequent collaboration with Chugai Pharmaceutical Co., Ltd. At present, this medicine is going through a clinical study for its effectiveness in "joint rheumatism."

In 1986, Prof. Tadamitsu Kishimoto discovered the genes of IL-6 for the first time in the world. Chugai Pharmaceutical Co., Ltd., which was doing research on antibodies against lymphocytes, began its collaborative research with Osaka University around that time by sending research fellows to the university. Research by a group led by Prof. Kishimoto showed that IL-6 is the cause of a variety of immunity-related diseases. In 1988, a substance that acquires IL-6 was discovered, and it had high expectations to be used medicinally. However, later the substance was found to enhance the work of IL-6 instead, causing a big challenge.

Based on research results of English researchers around the same time, Osaka University was making IL-6 antibodies by the immune system of mice, and their effect was experimentally recognized. Meanwhile, the difficulty that an antibody of mice cannot be applied to humans was overcome by using genetic engineering to modify the mouse antibody for human genes[33], a result of collaborative research with the MRC National Institute for Medical Research in UK. This opened a path toward medicinal development.

In 1989, Prof. Kazuyuki Yoshizaki, et. al. announced that Castleman's disease is caused by IL-6. In 2000, clinical trials by Prof. Norihiro Nishimoto, et. al. contributed to the development of the first antibody in Japan.

What led to this success is the powerful school of immunology research at Osaka University. There is an accumulation and succession of knowledge, beginning with Prof. Yuichi Yamamura, a former president of the university, a pioneer in cancer immunity treatment, and the first president of the Japanese Society for Immunology, going down to Prof. Kishimoto, and, more recently, Prof. Akira. The knowledge and accumulation of the basic research on lymphocytes and immunity done by Prof. Kishimoto led to the prediction of the existence of IL-6, which was yet unknown. Dr. Toshio Hirano (currently a professor at Osaka University), a collaborator of Prof. Kishimoto at that time, was hired as an associate professor by former university president Yamamura, and, without any of today's high-performance analyzing equipment, he isolated the IL-6 genes after 8 years of hard work; this achievement provided the most crucial key to the success. Then, the production of a mass culture of antibodies, which is a technological strength of a corporation, enabled the clinical trial.

This is an example where the "knowledge" and "people" developed by basic research enabled the research results to make their way back to society through collaborative research with a company.

[31] Interleukin (IL) is a protein secreted by white blood cells and is a substance with an immunity function. To date, over 30 types are known. Among them, IL-2 is used for immunity treatment for cancer.

[32] Castleman's disease is a lymphoproliferative disorder with about 1500 patients in Japan. The medicine for its treatment is designated as an orphan drug under the Pharmaceutical Affairs Law.

[33] Using methods of genetic engineering, the "(humanized) monoclonal antibody" was made.

[Column 3]

Toward a Safe and Secure Society

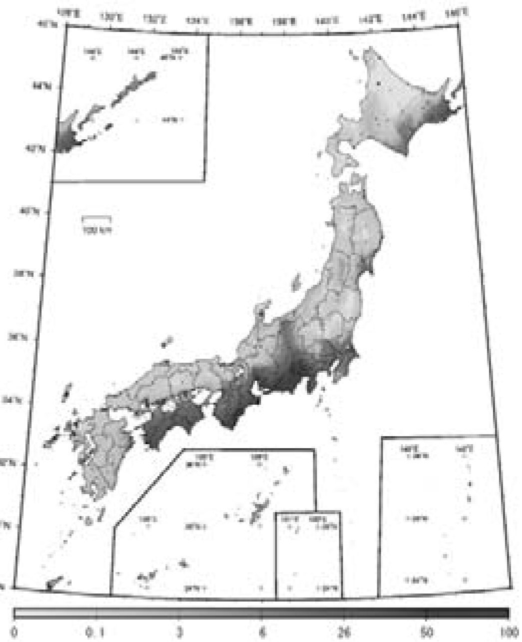
1. "Seismic Prediction Map"

On March 25, 2007, the "Noto Peninsula Earthquake of 2007" registered a magnitude of 6.9 and measured 6 Upper on the seismic intensity scale, reminding us once again that Japan is an earthquake-prone group of islands. Regardless of where one lives in Japan, earthquakes are not that far from anyone's life, suggesting that it is necessary to thoroughly prepare for earthquakes. What then can we do to prepare ourselves for earthquakes in our daily life? One thing that answers this question is the Probabilistic Seismic Hazard Map of Japan. In this map, all predicted earthquakes in the future are taken into account, and the quakes in every square kilometer of every part of the Japanese islands are predicted. This map is prepared by the Headquarters for Earthquake Research Promotion, and it is quite unique; nothing of this kind exists elsewhere in the world.

Shown below in the figure is the possibility that an earthquake of seismic intensity of 6 Lower or above will hit the region within the next 30 years. With a measure of 6-, houses that are not earthquake-resistant may collapse. In particular, some measure should be taken for those buildings built long ago, such as inspecting them for earthquake resistance. Areas shown in red or dark brown in the map below have extremely high probability of having a large-scale earthquake, so houses and buildings that are not sufficiently rigid should be immediately reinforced or replaced. Areas shown in yellow are not safe either; whatever can be done right away, such as securing furniture, should be done everywhere in the country.

We need to prepare ourselves, as much as humanly possible, against natural disasters that suddenly affect us, using these results of science and technology.

Probabilistic Seismic Hazard Map of Japan



Probability (%)

Source: Headquarters for Earthquake Research Promotion

2. "Earthquake resistance experimental research using E-Defense"

To build an urban infrastructure system consisting of earthquake-resistant buildings, roads, and bridges is an urgent challenge Japan is facing as an earthquake-prone nation. The Hanshin-Awaji Earthquake taught us the possibility of an earthquake far more powerful than those assumed in earthquake-resistant design and the vulnerability, or lack of safety, of old buildings. Through these lessons, it became evident that we need to observe the motion of buildings and structures until they collapse so as to understand the residual strength of the structures and to verify, in advance, the effectiveness of earthquake-resistant reinforcement and quake-control technology.

The 3-Dimensional Full Scale Earthquake Testing Facility (E-Defense) at the National Research Institute for Earth Science and Disaster Prevention is the "ultimate validation method for earthquake-resistance engineering," capable of simulating damage and collapse of structures by applying powerful shaking to the actual structures. Figure 1 is a schematic picture of the equipment, consisting of a steel table of dimensions 20m by 15m and 24 force-generators to simulate quakes equivalent to actual 3-dimensional ground tremors. Structures weighing up to 1,200 tons (equivalent to an actual 6-story condominium building) can be placed on the steel table, and the simulation is capable of creating a quake of seismic intensity 7. No other earthquake simulators around the world come even close to the scale of this facility.

Since its opening in April 2005, E-Defense has already carried out over 10 full-scale experiments. Photo 1 shows one of these experiments, in which two residential buildings with identical wooden structure, built 30 years ago, are hit by a tremor of seismic intensity 7 simultaneously. The house on the left in the photo is without reinforcement while the one on the right has been reinforced with minimum earthquake-resistant reinforcement (at beam crossings, joints, etc.). Whereas the non-reinforced house collapsed easily, the house with earthquake-resistant reinforcement withstood the quake. This experiment shows clearly the importance of earthquake-resistant reinforcement from the standpoint of protecting human lives.

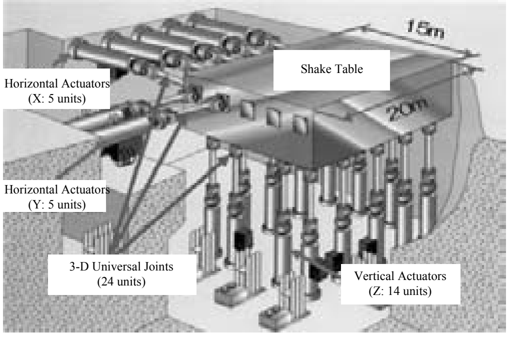


Figure 1: E-Defense earthquake table

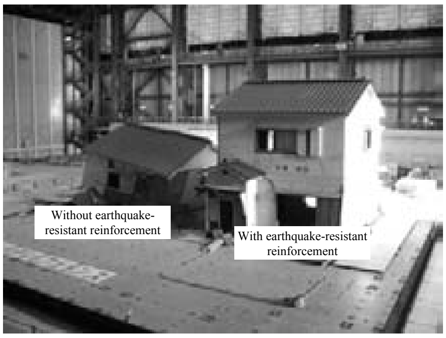


Photo 1: Wooden-house collapsing experiment

Source and photo provided by the National Research Institute for Earth Science and Disaster Prevention

3. "Daichi," Advanced Land Observing Satellite (ALOS)

"Daichi," an advanced land observing satellite developed by the Japan Aerospace Exploration Agency, was launched on January 24, 2006, on H-IIA rocket No.8 at the Tanegashima Space Center.

"Daichi" is an earth observation satellite developed to obtain high-resolution land observation data on a global scale for the purpose of making maps, making regional observations, obtaining disaster status information, searching for resources, and making other contributions. Its size is one of the largest in the world, with a mass of approximately 4 tons. The total width with solar cell panels opened up is approximately 28m, and it revolves around the earth on a north-south path at an altitude of about 700 km, making one complete rotation around the globe approximately every 100 minutes while observing all land regions all around the world.

"Daichi" is equipped with three sensors, with which it can observe the conditions of land in detail: a "Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)," capable of obtaining 3-D topographical data by capturing the earth's images in three directions, which are right below the satellite, in front of and below the satellite at an angle, and behind and below the satellite at an angle, with a ground resolution of 2.5m; an "Advanced Visible and Near Infrared Radiometer-2 (AVNIR-2)," capable of photographing the earth with color images with a ground resolution of 10m; and a "Phased-array L-band Synthetic Aperture Radar (PALSAR)," capable of observation day or night, regardless of the weather. Some of these sensors have an oscillation function so that if a disaster occurs somewhere on the earth and emergency observation is necessary, it can observe the affected region immediately.

"Daichi" observed the landslide on the island of Leyte in the Philippines in February 2006, and the eruption of Mt. Merapi in the Java Island in Indonesia, providing its images to disaster-related agencies, etc. through international disaster charters.

"Daichi" is expected to be used even more widely, not only for making maps and understanding disaster situations, but also for providing data closely related to the lives of the people.

For instance, the Japan Coast Guard is planning to use the drift-ice data obtained by Daichi's radar on a trial basis to provide drift-ice information in the Sea of Okhotsk in winter. This type of information will be useful for safe navigation of ships. Further, the Ministry of Agriculture, Forestry and Fisheries is planning to use Daichi's data for management of planted acreage of paddy field rice while the Geographical Survey Institute is planning to use the data to update maps, both on trial bases. Already, these data are prepared based on ground measurements and aerial photographs, but we can expect "Daichi" to supplement the information and improve its accuracy in the future.

4. Japan's space technology found in everyday life - spin-off

It has been over 50 years since Japan's space program began, and there are many satellites that are useful in our lives, such as weather satellites, communication satellites, and broadcasting satellites. However, technologies originally developed for space are not used only in space; they are already used in many different ways in our lives. When a new technology developed primarily for space activities is used as a technology to support and contribute to our daily lives, we call it a "spin-off (technology transfer)." Here are some examples.

- Ignition technology for solid rockets

  →air bags

  Nissan Motors, Co., Ltd. has developed an air bag that inflates instantaneously, using the technology used to undock/release auxiliary rockets and satellites from rockets instantaneously.

- Structure design technology for weight reduction and enhanced strength for rockets, etc.
  →diamond-cut cans
  Canned liqueur "*Hyoketsu*" is characterized by its diamond-cut can shape.
  A diamond-cut can has a design in which trusses, triangular skeleton structures, are combined in 3 dimensions. This is due to a structure design technology in which space engineering research has attempted to reduce the weight without sacrificing the strength. The material costs can be saved because of the weight reduction.

<Other examples>

- Heat insulator technology for rocket tip
  → insulator coating for construction
- Washing technology for space
  → washing machines
- H-II rocket joint technology
  →Seismic-isolation multilayer rubber bearings
- Sensor technology for earth observation satellites
  → sugar content sensor for fruits
- Explosion blast propagation simulation program in rocket launching
  → the engine (leading) vehicle design in linear-motor cars and bullet trains

Space technology is characterized by extreme environment compatibility (almost weightless environment, wide temperature range, radiation, etc.), demand for light weight, power restriction, and high reliability. Space technology, with these characteristics, has infinite possibilities to provide spin-offs to make our lives more pleasant and convenient. We can expect many more "spin-offs from space technology" in the future.

(2) Harmony between human activities and the earth's environment

(Future prediction of the earth's environment by the Earth Simulator, etc.)

The Earth Simulator is a supercomputer with the highest level of computation capabilities in the world as of the time of the commencement of its operation. Installed by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), its operation began in 2002. It is able to carry out 40 trillion calculations in one second.

The Earth Simulator is a cutting-edge tool that can simulate the earth's conditions on a supercomputer. Various conditions of the earth can be simulated. In particular, its simulation of global-level climate changes is highly recognized around the world and has contributed significantly to the search in the field of global environment.

On February 2, 2007, predictions of the effects of global warming on the world were officially published in the Fourth Assessment Report by Working Group I of the "Intergovernmental Panel on Climate Change" (IPCC) of the United Nations. This report states that the probability that the present warming is caused by man is "quite high," concluding that human activities since the Industrial Revolution have contributed much more than natural factors. The report modified the average temperature increase on the earth by the end of this century predicted in the third report 6 years ago of "1.4 to 5.8 degrees" up to "2.4 to 6.4 degrees" if society continues to depend on fossil energies such as petroleum and coal. Conventionally, it was unknown if the main factors of warming were human-caused or natural phenomena; however, using scientific methods they have proved clearly that warming is caused by human activities; this report had considerable impact on people around the world by changing their current awareness on warming.

This fourth evaluation report of the IPCC quoted many of the results of Japanese researchers that have used the Earth Simulator, including the "Calculations to Predict Global Warming to A.D. 2100," carried out in the "Project for Sustainable Coexistence of Humans, Nature and the Earth" of MEXT by Profs. Akimasa Sumi and Masahide Kimoto of the Center for Climate System Research at the University of Tokyo, Dr. Toru Nozawa of the National Institute for Environmental Studies, and Seita Emori, the group leader of the Frontier Research Center for Global Change at JAMSTEC (Figure 1-1-21).

(Photovoltaic power generation)

Dependence on fossil energies further accelerates global warming. There is an urgent need to promote science and technology related to the environment, energy, and resources. To this end, the importance of R&D in photovoltaic power generation is ever increasing. Photovoltaic power generation is the form of generating power by directly exchanging the solar light energy to electricity using semiconductors called solar cells. Not only does it save energy since it uses solar energy, which

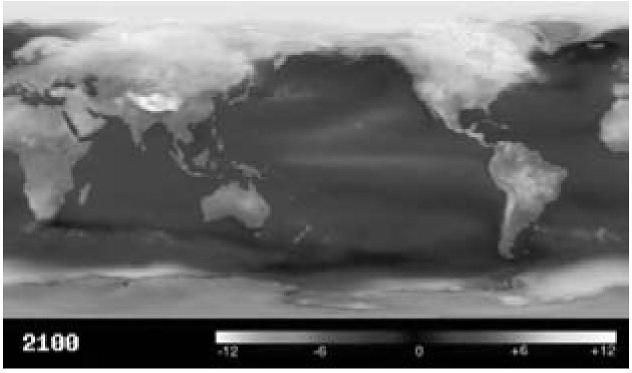


Figure 1-1-21 Simulation results of global warming 100 years from now

Sources provided by the Center for Climate System Research at the University of Tokyo, National Institute for Environmental Studies, Frontier Research Center for Global Change

does not deplete, it is also getting much attention because it is a clean energy without any waste to be discharged.

The history of solar cells goes back to the mid 19th century, but its practical implementation began in 1954, when Bell Laboratories of the United States first developed silicon solar cells. In Japan, the cells were first used in 1958, when they were installed at an unmanned microwave relay station. It was not until the mid 1960s when their mass production was planned. Incidentally, the generating efficiency of the silicon solar cells developed at Bell Labs in the U.S. was about 6% whereas the efficiency of solar cells now is about 12 to 15%. It is said that theoretically an efficiency of 30% could be attained.

In 1993, the "New Sunshine Plan" was begun with the goal of simultaneously "achieving economic growth, securing stable energy, and addressing global environmental problems"; R&D projects were carried out for common basic technology for photovoltaic power generation systems, popularizing photovoltaic power generation via cost reduction, and new-generation solar cell technology, etc. by the New Energy and Industrial Technology Development Organization. As a result, they advanced the technology that allowed them to reach the target, "keeping the manufacturing costs at 140 yen or less per watt," which they had hoped to reach by year 2000. Through these technology-developing projects, Japan now has about half of the production share of the world's solar cells.

Technology development is continued toward achieving generation costs equivalent to a typical household power bill and further popularizing photovoltaic power generation.

(3) Toward more convenient and pleasant daily life

Research in information and communication fields is producing results that are drastically changing our lives, such as cellular phones, Internet, and car GPS systems.

Promotion of science and technology is indispensable if we are to achieve a technological revolution closely linked to our daily lives and to bring about a more convenient society. Here, we list some examples which are already integral parts of our daily lives but the principle or technology of which has only recently been discovered. We also discuss the status of government investment funds in Japan, which have been supporting these researchers, their research environments, and the implementation of their technologies.

(Realization of large-capacity memory units by perpendicular magnetic recording system)

Progress in IT revolution has brought about an era in which we are surrounded by cellular phones and personal computers every day. These products have large-capacity memory storage units, with a superior function of retaining a lot of information. Until recently, one could only imagine a world in which a person could enjoy a movie by opening a notebook PC or could record a TV program on a cellular phone. These are now realities. The progress is unstoppable. What is allowing these storage units to have such large memory capacities is the hard disk drive (HDD).

The HDD is a storage device in which data, as magnetic information, are recorded on an aluminum or glass disk covered with a thin magnetic layer. The type

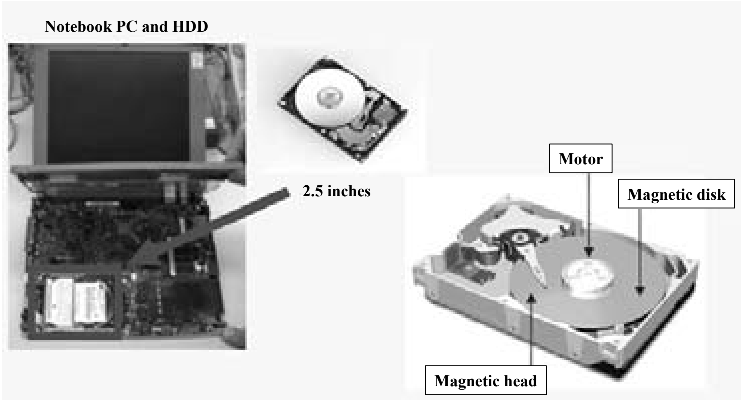


Figure 1-1-22 HDD structure and example of its use

Source: Council for Science and Technology Policy of the Cabinet Office

that is widely used is 2.5 or 3.5 inches (63.5 or 88.9mm) in diameter; even if it is smaller than a little wallet or a toddler's lunch box, it can store a large amount of information (Figure 1-1-22). By installing an HDD instead of a conventional videotape, the user can record a long TV program. With smaller, lighter video players, we can carry the images around and enjoy them anywhere. Notebook PCs are getting even smaller and lighter. Our lifestyles are thus changing drastically.

It used to be said that there are limits to the reduction of size and weight of magnetic recording units. To reduce the size and weight, it is necessary to increase the storage density; to that end, the magnetic layer that stores the information (bits) on the disk must be made thin, and the ultra-fine magnetic grains that make up the layer must be made smaller. However, this would reduce the magnetic energy that can be stored in each particle. This makes the disk vulnerable to temperature changes and other factors that can disturb the magnetic direction, creating the danger that the stored information may be lost after some years. Therefore, it was thought that the longitudinal magnetic recording method used in conventional HDD units would soon reach its limits.

The breakthrough in this regard was the perpendicular magnetic recording method. With the conventional longitudinal magnetic recording method, the storage density was limited to about 120 gigabits (120 billion bits) per square inch (23 MB per mm^2). In contrast, the storage density using this new method can go beyond 8 times as much as this, over 1 terabit (1 trillion bits) per square inch (194 MB per mm^2). 2.5-inch HDD units in the class of 200 gigabits per square inch are already being used by Japanese companies. Many HDD units are already using this new method, and it is expected that many more PCs and household products will contain these in the future.

The person who first proposed this perpendicular magnetic recording system, which is now gaining popularity around the globe, is Prof. Shunichi Iwasaki, who at that time was professor at Tohoku University. He began his research on magnetic storage back in 1951. Prof. Iwasaki was working hard on his research of magnetic storage under the direction of Prof. Kenzo Nagai, also of Tohoku University; at age 51, he announced the high density of the perpendicular magnetic recording system in an international conference in 1977. The announcement of this new, revolutionary technology was accepted with great excitement, and it attracted a lot of attention as a future technology. However, partly because its implementation was originally attempted for flexible disks[34], there was a period of uncertainty between the late 1980s and the early 1990s. In 1989, Prof. Iwasaki retired, at which time the research at Tohoku University was succeeded by Prof. Yoshihisa Nakamura (currently of the Japan Science and Technology Agency), who had been supporting Prof. Iwasaki up to that time. He switched the research to a research project on HDD using the perpendicular magnetic recording system, but the technology of HDD using the longitudinal magnetic recording method continued to be improved, even leading some to conclude that the perpendicular magnetic recording method is unnecessary. However, even during such times, he continued his research with endurance to show the superiority of the perpendicular magnetic recording. The break came around 2000. When the conventional method actually approached its limitations, students taught by Profs. Iwasaki and Nakamura, seeking new-generation technologies, finally implemented the

[34] Generally, these are referred to as floppy disks (FDD), but the JIS uses this term.

method in the private sector. This triggered a rapid increase in the HDD market, which was about 2.5 trillion yen in 2004 but is expected to be as much as 6 trillion yen in a few years. All HDD units are very likely going to be replaced with those using the perpendicular magnetic recording method (Figure 1-1-23).

We would like to point out two factors that helped Japan come up with the perpendicular magnetic recording method, one of Japan's most innovative technologies. One is the on-site "succession of knowledge" under industry-academia-government collaboration at Tohoku University and at companies that carried out technological exchanges and joint research with the university.

The search in the perpendicular magnetic recording method had its root in the continuous basic research at a university before its implementation. As mentioned earlier, Tohoku University was one of the few research centers of magnetic storage in Japan since the 1930s under Prof. Nagai. Prof. Iwasaki, who went into research in magnetic storage as suggested by Prof. Nagai at Tohoku University, came up with the perpendicular magnetic recording method that can attain super high density, based upon the theoretical understanding of the storage mechanism. Confident of its innovative value, he proposed its basic theory and continued to do research toward its implementation. The group led by Profs. Iwasaki and Nakamura did not keep the search shut in at the university; they promoted technological exchange with companies. At the Akita Research Institute of Advanced Studies, under the direction of the institute's director, Kazuhiro Ouchi, who also belonged to the group led by Profs. Iwasaki and Nakamura, research toward implementation was carried out as a collaborative effort by the industry and the academia. Even after Prof. Iwasaki retired in 1989, the research went forward, led by Prof. Nakamura. Through dedicated cooperation with companies with whom the university was doing joint research, the group was able to achieve the implementation. In other words, this series of "succession and development of knowledge" both on campus and in companies, which continued unceasingly, made it possible for them to actually implement the innovative technology and made it a reality.

We can also see continued support in terms of public

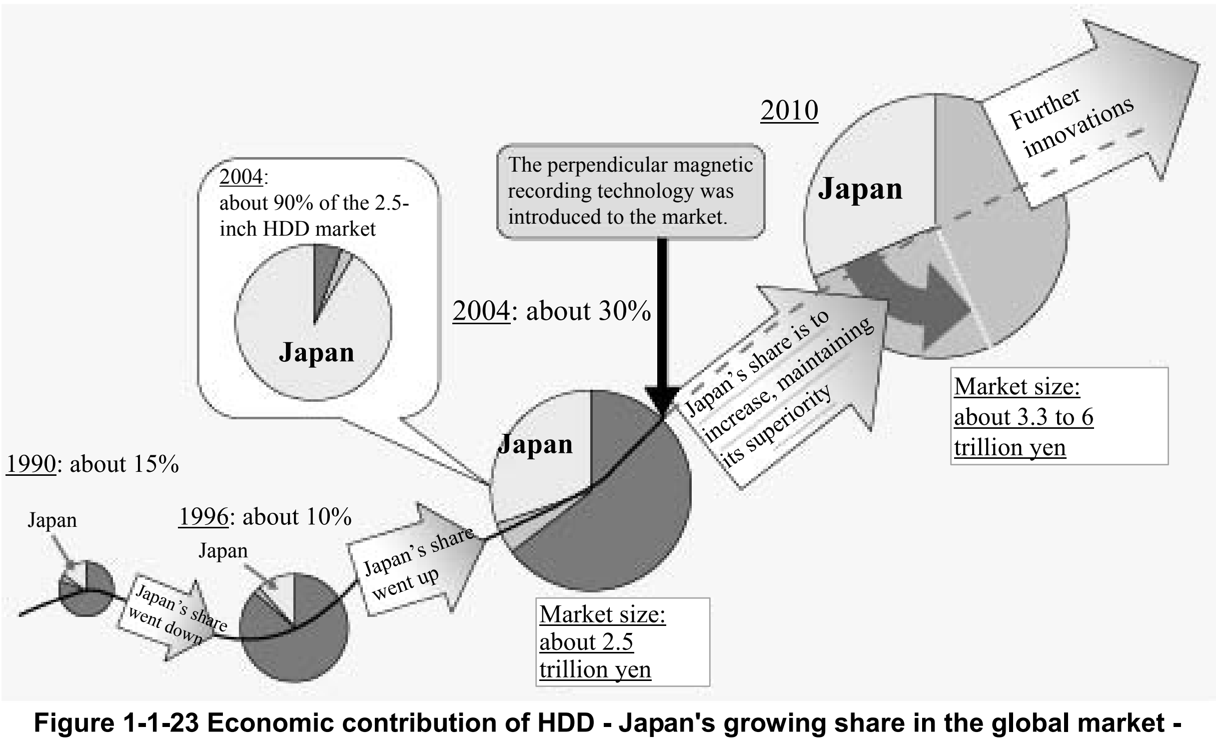


Figure 1-1-23 Economic contribution of HDD - Japan's growing share in the global market -

Prepared by the Council for Science and Technology Policy of the Cabinet Office (47th Council for Science and Technology Policy, June, 2005) based on the following sources:
"Study Report on Patent Application Trend, 2001: High Storage-Density HDD Units," Japan Patent Office; NISTEP Report, No. 89, National Institute of Science and Technology Policy; and Institute of Information Technology, Ltd.; Prof. Yoshihisa Nakamura of Tohoku University.

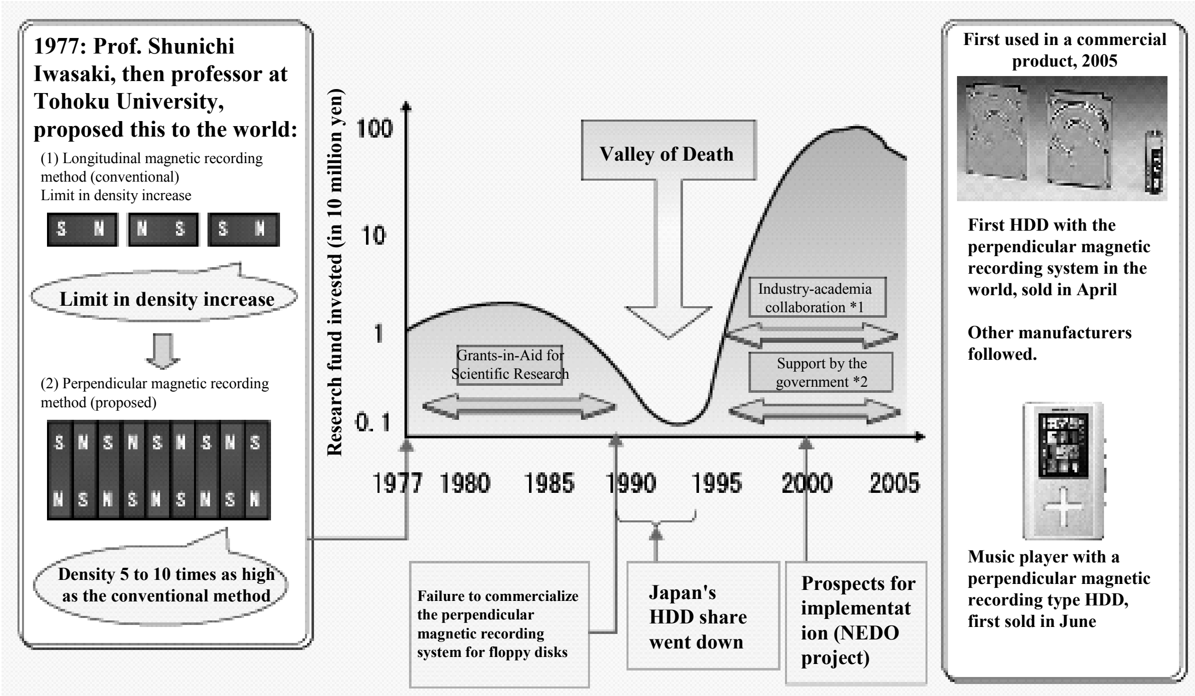


Figure 1-1-24 Public funding that supported the perpendicular magnetic recording method: "through the valley of death"

*1 SRC: Storage Research Consortium (interested parties in the industry and Tohoku University) (1995-)
*2 NEDO (New Energy and Industrial Technology Development Organization) of METI (1996-2002), Japan Society for the Promotion of Science (1999-2003), and MEXT (2002-2007)
Prepared by the Council for Science and Technology Policy of the Cabinet Office (Council for Science and Technology Policy 47th session, June, 2005) based on sources from Prof. Yoshihisa Nakamura of Tohoku University

funding (Figure 1-1-24). During the 1970s and 80s, when Prof. Iwasaki proposed the new method, the little sprout was carefully protected and developed with continual support for basic research by the university and public funding such as Grants-in-Aid for Scientific Research. At some points, the advancement in the longitudinal magnetic recording method questioned the need for implementing the new method, leading even to the opinion that it is unnecessary; however, the basic research funding by the university went on without ceasing, supporting the research. The innovative value of the perpendicular magnetic recording method was still highly recognized even after that time, and the research received support from various sources, including industry-academia-government collaboration, the Japan Society for the Promotion of Science, the New Energy and Industrial Technology Development Organization, and the "IT Program" by MEXT.

When the longitudinal method reached its limits, the need for HDD using the perpendicular magnetic recording method skyrocketed. Finally in 2005, a domestic HDD manufacturer began making products using this technology. One can thus say that this technology saw its fruition because of the significant contribution made by long-term public funding.

(Practical use of blue light-emitting devices)

Looking at traffic lights at crosswalks every day, we notice that bright lights are now used in place of the conventional lights so that the lights can be distinguished even in the late afternoon sun. These lights use LEDs (Light Emitting Diodes), which consume much less power than the conventional lights. LEDs are efficient because they emit only the light of necessary colors. Because of the efficiency, they consume less power, and because of their long life, they do not have to be replaced very often. They can also be mass-produced.

LEDs are also introducing many other new products such as large outdoor color displays, cellular phones with color liquid crystal displays, and illumination lights with sophisticated designs. They continue to cause big ripple effects in our society economically and socially.

Regarding to the three primary colors[35], red and green LEDs were already in use in various aspects of our daily lives by inventions of people such as Jun-ichi Nishizawa, then professor at Tohoku University. However, the last of the three colors, blue LEDs, was extremely difficult to produce, and its implementation had long been anticipated. The implementation of blue LEDs faced many challenges, but eventually various researchers and research groups, independently, made progress toward this goal, including a group led by Profs. Isamu Akasaki and Hiroshi Amano (of Nagoya University at the time), Mr. Takashi Matsuoka, a researcher in the private sector (a researcher at the NTT Basic Research Center at the time; now at Tohoku University), and Dr. Shuji Nakamura (of Nichia Corporation, Ltd. at the time). Below, we introduce the research carried out by each of these individuals and groups and track down the process until blue LEDs were implemented and introduced as a product in society.

Two good candidates were known to exist for semiconductors that can emit blue light: zinc selenide (ZnSe) and gallium nitride (GaN). Of these, the former was considered more likely to succeed from the standpoint of crystal growth. It was difficult to let quality crystals of gallium nitride grow, so most researchers seeking for the implementation opted to use zinc selenide.

However, Profs. Akasaki and Amano believed in the possibility of gallium nitride and continued their research. They let aluminum nitride accumulate at a low temperature on a sapphire substrate as a buffer layer formed uniformly even, a thin film of gallium nitride with good film quality, and eventually succeeded in making a prototype of a blue LED. This discovery was the first breakthrough.

Next, they applied electron beam radiation on the film of gallium nitride on which magnesium has been added, obtaining a p-type layer with good conductivity. This turned out to be the second breakthrough. Using this technology, they succeeded in creating a prototype of a pn-junction blue LED in 1989. In addition, they also confirmed sharp and powerful light emitted from a blue laser diode, announcing this result in 1995.

Now, for implementation, there were still many challenges to overcome. If they use gallium nitride as is, the wavelength gets shorter than that of violet, producing high-energy ultraviolet. To produce blue light, a part of gallium atoms must be replaced with indium atoms. It was Mr. Matsuoka who first succeeded in this effort (and this was the third breakthrough). He had been quick in incorporating the results of Prof. Akasaki and others and succeeded, in March 1989, in growing mixed crystals of indium nitrate and gallium nitride.

Meanwhile, Dr. Nakamura too had chosen gallium nitride, developed his own film-forming device using an original method called the two-flow growth system, and obtained film of gallium nitride with good film quality. Then, by heat-processing the thin film of gallium nitride in an environment without hydrogen, he was able to obtain a p-type layer with superior conductivity. In 1993, he developed a high light-intensity blue LED of double hetero-structure using a layer of gallium nitride with indium added to it. He discovered that, with blue laser diodes, as the width of gallium nitride and indium gets smaller, the amount of light emitted increases dramatically if the width of the quantum well is no more than 3 nm (3 nanometers; 3 billionths of a meter); he announced this discovery in January 1996. Based on these results, blue LEDs were commercially produced for the first time in the world in 1994 and blue laser diodes in 1999. Supported by these innovative discoveries, the implementation of blue diodes was a result of the intuition of the researchers that it is gallium nitride that holds the key for making blue LEDs. While many researchers selected zinc selenide, the Akasaki-Amano group, Dr. Matsuoka, and Dr. Nakamura all gambled on the possibility of gallium nitride. Such creation and application of knowledge is ultimately what produced the innovative result. For this accomplishment, Dr. Nakamura won the Millennium Technology Prize (established in 2004, the prize presents 1 million euros, the highest award amount in the world, to an outstanding technical innovation that improves our quality of life, awarded with support of the government of Finland) in 2006.

The process of the creation and utilization of knowledge is also supported by public funding. Since 1985, Prof. Akasaki's research had been supported by 8 Grants-in-Aid for Scientific Research awarded to the project itself in addition to 21 Grants-in-Aid for Scientific Research awarded to joint researchers. After that, toward implementation, the development was contracted out under the names "Manufacturing technology for gallium nitride (GaN) blue LEDs" from 1987 to 1990 and "Manufacturing technology for GaN-type short wavelength semiconductor lasers" from 1992 to 2000. One can see that seamless investments of public funds supported this innovative technology from basic research to application. Even after Dr. Nakamura achieved the mass production of blue LEDs, he has been producing innovative technologies that will lead to commercializing

[35] The three primary colors for light are red, green, and blue. All colors are combinations of these three. Mixing all of these colors, red, green, and blue results in white (color of solar light and a fluorescent light).

next-generation semiconductor light-emitting devices as the General Director of the "Nakamura Inhomogeneous Crystal Project," an ERATO project of the Japan Science and Technology Agency.

The Japan Science and Technology Agency summarizes the economic ripple effect of the contracted development project "Manufacturing technology for gallium nitride (GaN) blue LEDs" as follows.

During the 9-year period from 1997 to the end of 2005, the total sales of application products using LEDs of Toyoda Gosei Co., Ltd., such as cellular phones and large full-color display units, reached approximately 3.6 trillion yen. As direct results, this has created almost 350 billion yen of add-on value to the industry of Japan and about 32,000 new jobs (Figure 1-1-25). It also brought in royalty revenues of approximately 4.6 billion yen to the government. These figures cover only the economic ripple effect between 1997 and 2005. If we consider the entire lifecycle of the technology, we can expect more economic impact in the future as well.

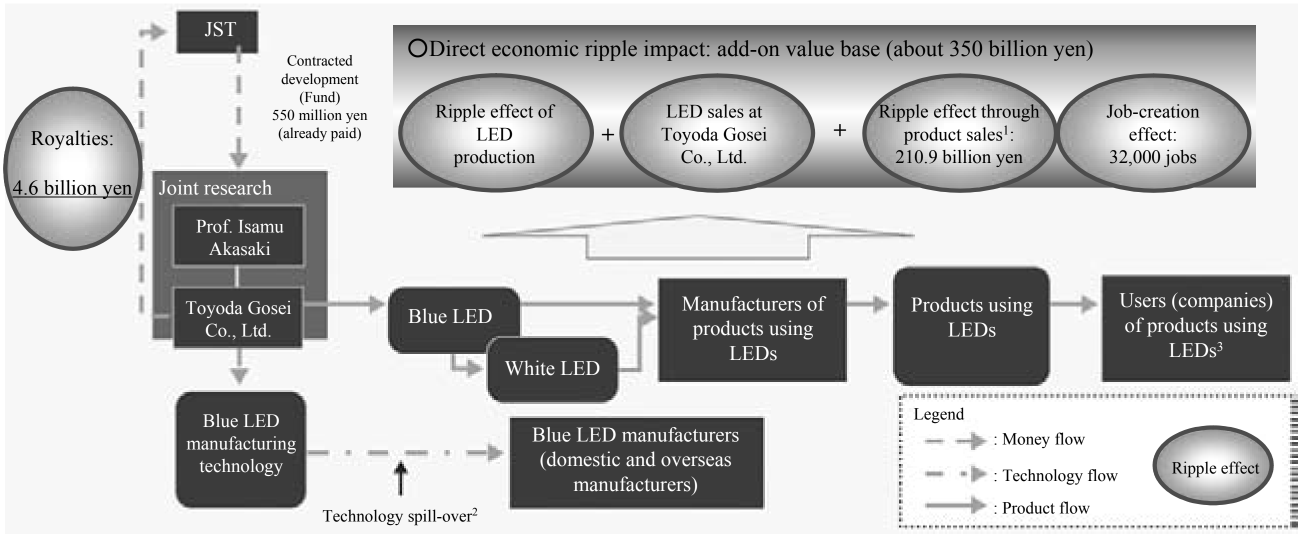


Figure 1-1-25 Economic ripple impact of the contracted development project "Manufacturing technology for gallium nitride (GaN) blue LEDs"

Notes:
1. For "ripple effect through product sales" we calculate the LED contribution, i.e. the part that would have been impossible without LEDs, of the add-on value within the sales of products using LEDs. Products applying LEDs include cellular phones, large outdoor full-color display units, and car accessories (interior lights, etc.).
2. Technology spill-over indicates the impact that the research results of Prof. Akasaki and Toyota Gosei Co., Ltd. had on the entire LED industry and other industries. The blue laser research used in DVD players, etc. is also based on this joint research.
3. The effects of LED-related products to the users (increase in energy saving, low maintenance cost, better design, etc.) are not included in our calculations of the direct economic effect.

* The most significant characteristic of LEDs is their long life. This characteristic is widely accepted in society, leading to the popular use of LEDs and producing these ripple effects. Also, the organization shown here does not exhaust all of the ripple effects.

Source provided by Japan Science and Technology Agency

[Column 4]

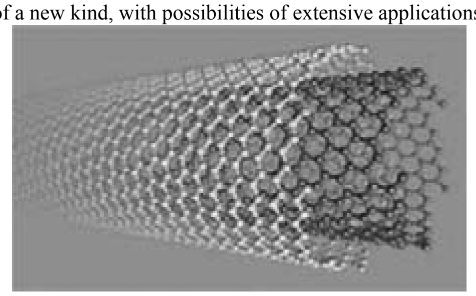
"Carbon Nanotube": A New Material that Will Change the Society

◆ Discoveries of carbon nanotubes and carbon nanohorns

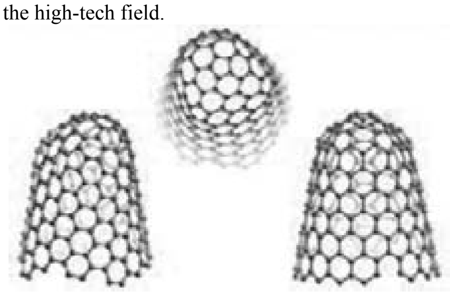
In 1991, Dr. Sumio Iijima (Special Senior Researcher at NEC, Professor in the Faculty of Science and Technology, Meijo University) discovered carbon nanotubes in the soot accumulated at the negative pole during discharge (arc discharge) between two carbon-rod electrodes. Their structures were verified using devices such as electron microscopes. In 1998, through the "Nanotube-type Substance Project," an international joint research project of the Japan Science and Technology Agency, Dr. Iijima, et. al. discovered carbon "nanohorns," the structure of which resembles a bull's horn because one end of the tube is closed.

◆ What is a carbon nanotube?

A carbon nanotube is a substance in which mesh-shaped carbon forms a very small tube with a diameter ranging from 0.4 to 100 nm (nanometer, one billionth of a meter). It is flexible yet has higher tensile strength than iron, with high heat- and electricity-conductivity. It is a dream material of a new kind, with possibilities of extensive applications in the high-tech field.



Carbon nanotube (schematic model)



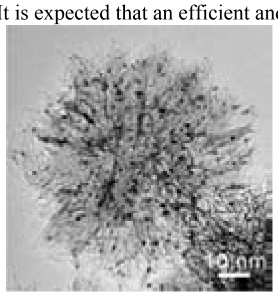
Carbon nanohorns (schematic models)

Source provided by NEC Corporation

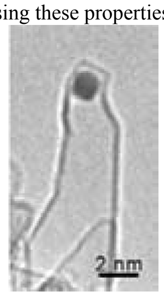
◆ Example of research result: "Drug delivery system (DDS) directly attacking cancer cells"

Anti-cancer drugs could attack not only cancer cells but also normal cells, possibly causing side effects. To overcome this problem, a drug delivery system (DDS) (Note) that attacks only cancer cells is being developed. The possibility of using carbon nanohorns in a DDS was validated by a cell-level experiment carried out under joint research of NEC, Cancer Institute of the Japanese Foundation for Cancer Research, and the Japan Science and Technology Agency.

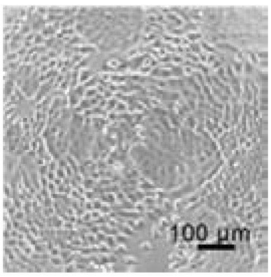
First, an anti-cancer drug "cisplatin" is attached to the interior of a carbon nanohorn, which plays the role of a carrier of the drug and is carried to a cancer cell by body fluid. A cancer cell has coarser gaps in its shape compared to a normal cell, so it easily takes in particles whose sizes are about 100nm (nanometers). The carbon nanohorn, about that size, is thus taken into the cancer cell and releases the anti-cancer drug, directly attacking the cancer cell. It is expected that an efficient and safe cancer treatment can be developed using these properties.



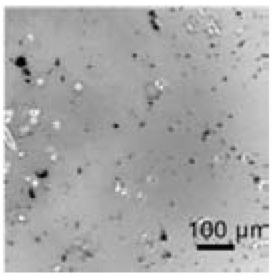
(Left) a group of nanohorns containing cisplatin



(Right) The black particle is cisplatin



(Left) Cancer cell 74 hours after cultivation



(Right) Nanohorns containing cisplatin are inserted. Most cancer cells have disappeared.

(Note) Drug Delivery System: technique of wrapping a drug with a chemical substance to send the drug to the target parts effectively and intensively without the drug being decomposed or absorbed in the body

1.1.3.2 Industry-Academia-Government Collaboration: A Key to Application of Science and Technology Results

For outstanding results of science and technology to return to society, not only is it important to have creative researchers and their spirit of relentless intellectual pursuit, but it is also critical to create an environment in which the results obtained in basic research can organically lead to application.

In the 21st century, sometimes referred to as the "century of knowledge," with the recognition that a continuous, progressive industry-academia-government collaboration system is extremely important, Japan has taken comprehensive measures.

Here, we look back at the framework concerning the industry-academia-government collaboration promoted in this country, focusing on and introducing some actual examples of particularly remarkable results.

(1) Industry-academia-government collaboration steadfastly planted

According to the Third Science and Technology Basic Plan, there has been sure and solid progress as the number of industry-academy-government collaborative research projects, the number of technology licensing cases by the Technology Licensing Office (TLO), and the number of university-originated entrepreneurial companies are all on the rise, supported by the promotion of policies regarding industry-academia-government collaboration based on the Second Science and Technology Basic Plan.

More specifically, accomplishments of joint research by universities and companies have drastically increased; the number of joint research projects at national universities, etc. in 2005 exceeded 10,000, and the number exceeds 13,000 if all national, public, and private universities are combined. The numbers have continued to rise even after the national universities were incorporated. The total amount of research funds given to universities, etc. by research institutions was 32.3 billion yen in 2005, the highest amount ever.

The number of contract research projects at national, public, and private universities, etc. was 16,960, with 126.5 billion yen in contract research project fees, both numbers being highest in history. Meanwhile, looking at the transition in the number of patent applications submitted by national universities, etc. during the 5-year period covered in the Second Basic Plan, the number grew to about 10 times the number at the beginning of the period, indicating a remarkable accomplishment. In regard to inventions, all the related numbers-number of deliberations, number of patent applications, number of implemented cases, and royalty revenues-show growing tendencies, suggesting that industry-academia-government collaboration has indeed been firmly planted in Japan.

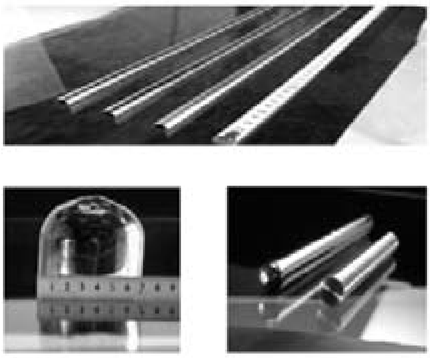
(2) Examples of results of industry-academia-government collaborative research (Metallic glass)

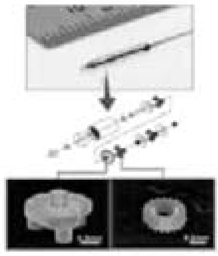
Metallic glass is a metallic material created in Japan; its research has rapidly advanced since 1988. Metallic glass is different from metal, which has a crystal structure (atoms are configured in a fixed way), in that the atomic configuration is "random and dense"; it is a revolutionary metallic material which is strong, flexible, rust-resistant, smooth-faced, and easy to fabricate.

This field of research was initiated by a group led by Dr. Akihisa Inoue, then director of Tohoku University's Institute for Materials Research and currently president of Tohoku University. Through basic research supported by Grant-in-Aid for Scientific Research in the 1980s, many metallic glass materials, completely new types of metals, were discovered. In the 1990s, by the ERATO system of the Japan Science and Technology Agency and the basic research program, researchers found the conditions under which metals change to glass, the structure of metallic glass, and its properties. Many original papers were published during this period, and a large number of basic patents involving metallic glass were obtained. Furthermore, many excellent researchers gathered together, providing ideal opportunities for young researchers. This environment contributed to nurturing new leaders in this research field.

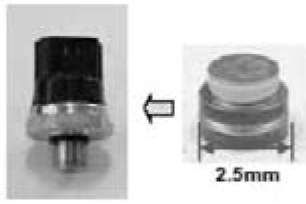
This research topic was selected as the project "Processing technology for metallic glasses" of the New Energy and Industrial Technology Development Organization from 2002 to 2006, evolving to industry-academia-government collaborative research. A space called "main research" was set up within the Institute for Materials Research, where researchers from industry and academia gathered together to do research. As a result, a metallic micro-geared motor and a compact, highly-sensitive pressure sensor (Figure 1-1-26) were developed.

The micro-geared motor is the world's smallest motor and uses extremely small gears made of metallic glass, with superior rigidity and wear-resistance. This is the





The world’s smallest geared motor, with a diameter of 1.5mm, using gears made of metallic glass



The world’s smallest and highly sensitive pressure sensor for automobiles, with a diaphragm made of metallic glass

Figure 1-1-26 Metallic glass

Sources provided by the Institute for Materials Research at Tohoku University, project "Processing technology for metallic glasses" of the New Energy and Industrial Technology Development Organization

result of a joint development project of the Institute for Materials Research at Tohoku University, R&D Institute of Metals and Composites for Future Industries (RIMCOF), Namiki Precision Jewel Co., Ltd., and YKK Corporation. It is hoped that this motor will be used as a device that operates medical machines such as endoscopes and medical pumps.

The pressure sensor takes advantage of the flexibility of metallic glass; its sensitivity is more than 4 times that of the conventional, stainless-steel sensor but has the rigidity to withstand a pressure 3,000 times the pressure on the ground. It is the result of a joint development project of the Institute for Materials Research at Tohoku University, RIMCOF, Nagano Keiki Co., Ltd., and YKK Corporation. This is expected to be applied in diesel engines and hydraulic brake control; a prototype is already made.

(Development of intelligent emission catalyst for automobiles)

Automotive exhaust catalysts have been improved since the 1970s, but the emission standards all over the world have become much more restrictive since the 1990s. This caused the demands for precious metals used as catalysts, especially palladium, to increase drastically, shooting the price up at an alarming rate. For this reason, reducing the use of palladium in automobiles became a huge challenge.

An "intelligent catalyst" self-regenerates palladium, a catalyst for gasoline-operated automobiles, as the vehicle is driven. The depletion of palladium is extremely small, and the performance in purifying the exhaust gas does not deteriorate, thus greatly reducing the amount of palladium used (Figure 1-1-27).

The self-regenerating function of an intelligent catalyst was discovered by Dr. Hirohisa Tanaka, et. al. of Daihatsu Motor Co., Ltd. in the 1990s. Together with Dr. Yasuo Nishihata of the National Institute of Japan Atomic Energy Development, they explained the principle of the self-regenerating mechanism using a large synchrotron radiation facility called SPring-8.

SPring-8 was built in the Harima Science Garden City in Hyogo Prefecture by the National Institute of Japan Atomic Energy Development and the RIKEN; it began its operation in 1997. Not only is SPring-8 used for basic research in life science and materials science, but it can also be used for industry such as in this joint research work. The results of this research concerning catalysts were also published in the English science journal *Nature* (the July 11, 2002, issue).

Research in the self-regenerating mechanism of automotive emission catalysts was carried out from 2003 to 2005, having been chosen to receive Grant-in-Aid for Scientific Research. SPring-8 continued to be used; as the result of discussing its mechanism, progress in research showed that platinum and rhodium also provide the self-regenerating mechanism, leading to the development of "super-intelligent catalysts." Trial calculations showed that over 100 tons of precious metals for automotive catalysts can be saved per year, so the prices of precious metals are expected to stabilize.

(3) Project to create knowledge clusters

A "knowledge cluster" refers to a technology-innovation system directed under a regional initiative, centered on a public research institution such as a

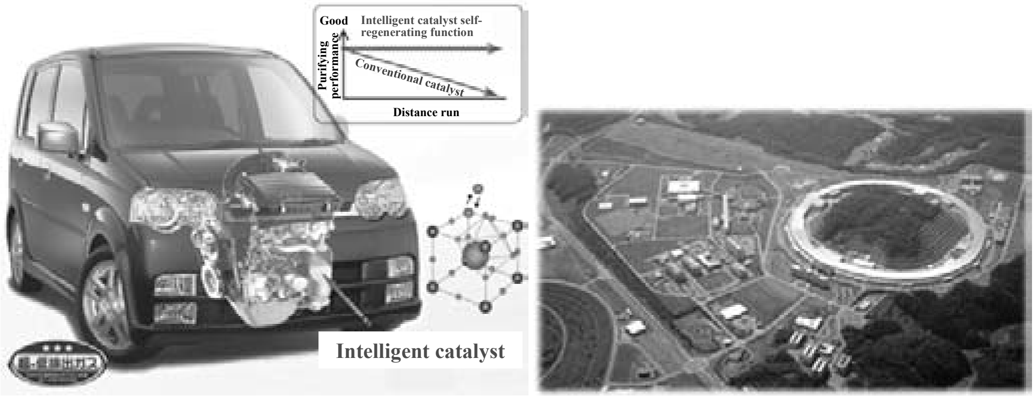


Figure 1-1-27 Intelligent catalyst (left) and large synchrotron radiation facility (right)

university with its own research development theme and potential in that region, with participants coming from in and out of the region, including companies. Here, through human networks and collaborative research, the creative, technological seeds of the public research institution and the companies' need for implementation are organically joined, enabling new industries to be created. A project to create these knowledge clusters was carried out in 18 regions across the nation as a five-year project of MEXT from 2002 to 2006 (12 regions in 2002 when it began).

(Involvement in regional science and technology promotion in the Hamamatsu area)

The Hamamatsu area was one of the highest ranked regions in the country at the mid-term evaluation of the "knowledge clusters creation project," in which 12 regions across the nation were evaluated in 2004. In the industry-academia-government collaboration in the Hamamatsu area, the Organization for Hamamatsu Technopolis plays a very important role as the core institution. In any industry-academia-government collaboration, an extremely important point is how the technological seeds of the "academia" are matched with the needs of the "industry."

In the Hamamatsu region, active efforts are made to train coordinating human resources, led by the Organization for Hamamatsu Technopolis. Science and technology coordinators, well familiar with the regional collaboration situations, and use their information and human networks in "imaging technology project research consortium" that are held to provide an organic meeting place of the industry, academia, and government. This type of coordination of a structure necessary for the project's collaboration and thorough progress management are bringing forth solid advancement in the collaboration. Through human-resource training that promotes the region, for instance, by involving the region's technical high schools (not just universities), the project is having extensive influence on the greater Hamamatsu area.

(Detailed inspection of metal materials by X-ray)

The first result of the industry-academia-government collaboration under the knowledge clusters creation project in the Hamamatsu area was the "X-ray imaging device equipped with the energy-identification function," a result by an industry-academia collaborative project by Dr. Yoshinori Hatanaka of the Research Institute of Electronics, Shizuoka University (at the time), Dr. Toru Aoki, and Hamamatsu Photonics K.K.

This research group developed their basic research, which they had been undertaking for several years by Grants-in-Aid for Scientific Research, the Industrial Technology Research Grant Program of the New Energy and Industrial Technology Development Organization, etc. into a project under the knowledge clusters creation project in 2004 and ultimately achieved implementation.

By counting photons, one can detect the difference in the X-ray energy going through an object or a material. This allows one to identify very small bumps and dents on the metal surface and in the internal structure for each material, thus contributing to increased reliability and accuracy in non-destructive inspection. In addition, Hamamatsu Photonics K.K. commercially developed an imaging device that measures the wavelength difference of the penetrating X-ray and indicates it using colors.