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——A Japanese Perspective

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Prospect and Role of Science and Technology —A Japanese Perspective

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1927年1月5日生まれ
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1973年以降、通商産業、文部、郵政、運輸等各省の審議会委員を歴任、情報処理学会会長('81)、OECD科学技術政策委員会議長('84)、電子通信学会会長('85)、全米科学アカデミー(NAS)外国人会員('77)、IEEEフェロー('78)、全米工学アカデミー(NAE)外国人会員('85)、日本学術会議会員('85)、スウェーデン王立理工学アカデミー(IVA)外国人会員('88)、大英王立研究所名誉会員('89)、また、マルコニ国際学術賞受賞、日本学士院賞受賞、IEEE国際コミュニケーション賞受賞、文化功労者顕彰等。

1. Introduction

The prosperity which the free world is enjoying today can be attributed to a large extent, to rapid technological innovation and industrial development, and to the ensuing economic growth that has been taking place in Europe, the U.S. and Japan. In order to maintain and develop such mutually beneficial relations, the economy of the world should be full of vitality, and be given a stronger scientific and technological base.

Today unprecedented industrial revolution is in progress centering around information technology. Industrialized nations which have outstanding scientific and technological capabilities should assume responsibility for promoting positive adjustment of industrial structures, improving societal infrastructure and solving environmental and other problems of a global scale. Because nothing is more effective than the overall application of science and technology to solve these enormous problems by making the most effective use of limited financial and human resources.

With the development of science and technology in recent years, knowledge of mankind has expanded to a remarkable extent. Thanks to the progress of space sciences we have come to know much about the macrocosm, and we have obtained a considerable amount of knowledge of our inner microcosm owing to the advancement in life sciences. However, human beings share unending intellectual appetites. In order to meet such appetites, an enormous amount of fund and human resources must be invested further. Industrialized nations can play a leading role in this regard.

Considering this, I believe that whether the 21st century will become an epochal period in the history of civilization will depend heavily on how industrialized nations will be able to cooperate with each other in promoting their scientific and technological capabilities and using these for the good of mankind. There will be no progress without competition. A fierce technological innovation race will unfold at times in this process. However, so long as it is fair, it will contribute to enhance the world economy. Taking into account of the

realization of enormous potential demand on a global scale which will be brought about in due course, I would say that we are going to play a magnificent positive-sum game, rather than a zero-sum game which has often been envisaged. In this regard, cooperation of industrialized countries in particular is indispensable, because any single country no matter how powerful they may be, cannot solely and fully meet the demand and solve problems individually. Such cooperative relationships should be extended further to include work-sharing with the newly industrializing economies which are rapidly improving their scientific and technological capabilities.

Nations around the world are now inseparably linked by an invisible network of interdependence. They should take this into account while strengthening ties with their neighbors so that they are always open to the rest of the world. If powerful areas or nations place too much confidence in their strength and take an exclusive attitude, they will follow the path of decline as past history tells us. Only when areas or nations are open to establish mutually beneficial and cooperative relationships, they will prosper and contribute to the progress of the world. Now ladies and gentlemen, let me tell you my personal views about the prospect and role of science and technology with a particular reference to Japanese issues.

2. Promoting Structural Adjustment

The rapid progress of information technology is exerting an intensive impact on the industrial structure, helping to improve productivity remarkably in existing industrial fields, creating new industries such as computer, telecommunication and robotics, and developing information-oriented service industries. This trend will accelerate in the future, and computerization and software intensiveness will cause remarkable changes in systems and services. The dependence of systems on devices and that of devices on materials will increase.

The change in the industrial structure is inevitable. However, it must be accomplished while maintaining sustained economic growth and without involving negative social effects including unemployment. For this reason, positive structural adjustment is an urgent matter especially for industrialized countries in the world.

Today, Japan is undertaking an enormous task of accomplishing comprehensive structural adjustment of her economy. Her immediate motive is to correct the huge trade imbalances which still exist in spite of her efforts to date. Japan's longer-range objective will be to construct a better future in response to the course of development of high technology. To correct the trade imbalance, first of all, restraint on exports is necessary. To that end, it is necessary to shift the industrial and trade structures from the conventional pursuit of low porfit and high-volume sales to high profits and small-volume sales. This requires a drastic change in Japanese mind because the practice of low profits and high-volume sales has been regarded traditionally as virtuous for consumers. In addition, price competition has been inevitable because Japanese products have been mainly the fruit of application research. In order to shift from this to the practice of high profits and small-volume sales, enhancement of basic research and promotion of originality in science and technology is absolutely indispensable, to be able to come up with high-value-added products capable of leading the international market price by virtue of their unparalleled performance.

The second measure for improving the trade imbalance is to expand imports. Increasing our import of resources may not involve the large-scale import increase of oil and iron ore because of the structure change already undertaken at the time of oil crises to conserve resources and energy. Rather, attempts should be made to use high technologies to create new industries that require imports of rare metals and other high-priced resources. Also, in order to import agricultural product freely from all over the world without any concerns for emergency food supplies, it is necessary to develop technologies that enable us to store foods in large quantities. Japan has less societal infrastructure compared with other industrialized countries. Drastic public investments should be made in housing, transportation and welfare to pass on better national heritage to posterity and thereby stimulate domestic demand for imports. In this case also, promotion of technological innovation in related areas will ensure that these investments are used as efficiently as possible.

The newly industrializing economies share similar problems with Japan, because they have followed to a considerable extent the path the Japanese has taken. Relocation of manufacturing facilities from industrialized countries which has been extensive in recent years, has contributed significantly to their industrial buildup. Continuing technology transfer and capital investment will further strengthen their scientific and technological capabilities. One of the high technology areas which is well suited to the newly industrialized economies is software technology. It is a highly sophisticated technology that requires a very large number of well-educated workforce. It is knowledge intensive and labor intensive but not quite capital intensive. Because of Confucian tradition, the newly industrialized economies esteem education but has been unable to provide sufficient job opportunities for their highly educated people. The unusually large proportion of Americans of Chinese ancestry in the field of software technology in the United States seems to suggest that Chinese people are in some way especially suited to software production. While the introduction of computer hardware plant requires heavy capital investment and will do little to augment employment, software production could create a vast number of jobs for educated people with much less cpaital investment. All these backgrounds may suggest that software is the right technology for the newly industrialized economies. Considering that the mushrooming demand for software products can only be met by an international division of labor, the full-fledged participation of the newly industrialized economies will significantly contribute to overcome the worldwide software crisis. Implication of information technology for industrial structure, if correctly understood, may hasten the arrival of the developing countries among the ranks of the developed. And if the developed countries do not correctly perceive the possibilities, they may join the ranks of the underdeveloped.

3. Strengthening Basic Research

The strengthening of basic research is important to expand the common intellectual assets of mankind and to produce original technological innovation.

Competition in the market-place plays a great role in developing science and technology. However, research and development based on the market forces is susceptible to such limitation or frameworks as usefulness, economy, efficiency and prospects of success,

and may not always be able to attain the original purposes of basic research, including the promotion of free thinking and satisfaction of intellectual appetites. In other words, basic research absolutely requires sufficient public investments to complement the market forces. However, the public sectors in the world are suffering immense budget deficits and have difficulty in drastically and intensively giving larger financial support to basic research. On the other hand, basic research includes the so-called Big Sciences whose scale has been increasing year after year, thus increasingly limiting appropriations for other types of basic research.

Under such circumstances, the public sectors in all countries should review the significance and character of basic research and concentrate their efforts on support for true basic research which are still embryonic and seemingly have no useful purpose, but not adhering only to Big Sciences. At the same time it may be necessary to allow researchers from many countries to participate in precompetitive research projects as well as Big Sciences by encouraging international joint studies.

Particularly Japan should make a determined effort in this aspect. It is true that at the time when Japan was recovering from the ruins of war and was making efforts to attain economic reconstruction, the country took up basic research results which had been left unused in the West and succeeded in developing them into products. Though Japan also had been pursuing basic research at a level that enabled the country to take up research results in Europe and the U.S., the majority of efforts had been aimed at application research. Today when Japan has caught up with Europe and the U.S., the Japanese need to produce, through her own effort, basic research result which will develop into high technology. It is all the more important for Japan to push ahead with broad-based basic research wighout regard to applications and to make efforts to contribute to the improvement of intellectual assets of the world. To sever the "economy first" concept, I have been advocating the establishment of a major research laboratory entitled the Institute for Useless Research.

4. Enhancing Human Resources Development

The progress of science and technology and the success of industrial development depend heavily on the quality and quantity of available human resources. It is education's important mission to capture accurately the course of science and technology and the trend of industrial development, and produce the necessary number of eligible people without delay.

One of the notable changes introduced into Japan in the postwar period had to do with the system of higher education. Under the old system there were several levels of institutions of higher learning. After the war these were integrated into a single level, new-system universities, which incorporated portions of the American curriculum. Universities under the new system proliferated until today to number over four hundred, while junior colleges and technical colleges exceed this number. These educational institutions have managed to supply the large number of personnel needed to support the period of high economic growth and quick industrial buildup. However, it is also true that higher education has become extremely uniform, and the establishment of a large number of universities has reduced the fund and human resources available to each, leading to the deterioration of basic research at universities. As research

projects become larger in scale, a big difference is now found between research investments by universities and those by public and private research centers. This trend is most notable in such high-technology areas as electronic devices, new materials, biotechnology and information science. And although generous support is being extended to such big sciences as high-energy physics, nuclear fusion, space science and marine science, it is a fact that in comparison to prewar levels, basic research at universities overall has declined considerably. Reconstruction of centers of excellence among Japanese universities is urgently called for, because such centers of excellence are absolutely necessary to foster human resources capable of conducting creative basic research.

World population is growing year after year. Because of limited supplies of food and societal infrastructure, the birth of new lives is often considered as a nuisance rather than a gift. However when human beings and computers are compared, human beings are only inferior to computers in information processing speed but far superior in recognition, association, learning and creation. Computers consume more energy in the form of electricity than human beings do in the form of food. And above all, computers become outdated quickly, while human beings do not get outdated and can gain advanced abilities as they get older if they receive proper education. Therefore, it may be more significant to bring up carefully and give better education to newborn babies, rather than to try to produce so-called intelligent computers. Education should be given top-priority for development and I hope the cooperation among nations will be intensified in this regard.

Another problem that needs to be addressed is the rapid rate at which knowledge is becoming obsolete due to the fast pace of scientific and technological progress. Higher education merely provide scientists and engineers with an initial push into the society and do not play a role in refreshing their knowledge thereafter. Today, this is compensated for by self-help efforts as well as corporate in-house educational programs. However for scientists and engineers working in the forefront, finding the time and energy for systematic self-education is extremely difficult. While adequate in-house educational programs are only economically feasible among large enterprises, and even here, such programs are likely to be discontinued at the first sign of a business slowdown. The obvious conclusion is that continuing education should be provided systematically at the public initiative, and universities and other educational institutions should be expanded and reconfigured to accomodate this. And the plrograms of the Broadcasting University or the University on the Air which has been in operation in Japan, for instance, may be more specifically tuned for refreshing knowledge of scientists and engineers, in closer collaboration with major research universities.

5. Improvement in Quality of Life

The rapid development of industry and economies based on the fast progress of science and technology has resulted in consumption of large amounts of energy and raw materials, and mass production and consumption of huge quantities of products, which led to various environmental problems such as air pollution, water pollution, and excessive waste materials. Such problems, which at first affected only local areas, have become global problems including a warming of the earth

caused by carbon dioxide, destruction of the ozone layer by fluorocarbons, acid rain, and radio-active pollution from the accidents of nuclear plants. Contrary to economic prosperity, the living environment of the world has deteriorated. To solve these environmental problems concerted efforts in science and technology are necessary to develop alternative sources of energy and new materials, to prevent pollution by appropriate means including desulfuration, and to improve the safety of nuclear energy. At times, this type of development of technology tended to be acknowledged as an obligation to meet regulations. However, solving environmental problems provides new opportunities for technology and industry. Japan, for example, has strengthened the international competitiveness of automobiles made in Japan by adhering to strict air pollution regulation which called for the development of clean automobile engines. If appropriate and effective regulations were implemented in the future on the basis of sufficient scientific evidence, solution of environmental problems on a global scale would largely contribute not only to the improvement of our living environment but also to the strengthening of the capabilities of science and technology.

The fast development of information and communication technology created sophisticated services based on telecommunication and computers. Various socioeconomic activities which were carried out independently before are now closely integrated, despite physical separation, through increasing exchange of information. Large amounts of information are now transmitted, processed, and utilized. Network systems using communication satellites and optical-fiber cables have become popular, and are in use on a global scale. Yet, on the other hand, vulnerability issues in computerized society have arisen, such as infringement of privacy, and concerns on the reliability and safety of services. Further development of technology is necessary in regards to access control to databases, maintenance of integrity of information, improvement of software reliability, establishment of confidentiality of communication including the use of cryptography, and countermeasures for accidents.

While the world population is continuously growing, in contrast to the prosperity of the industrialized countries, many people in the developing areas are still suffering from poverty and starvation. As I have already mentioned, children are the most valuable asset of mankind. If we give them a warm welcome and provide sufficient nourishment, good living environment, and good education, they would be able to create a better future. Consequently, science and technology must be used on a full scale to achieve industrial progress, economic development and an increase of food production.

Prosperity, however, is not the ultimate goal of mankind. What everyone is looking for is a meaningful life and happiness. When the suicides rate is used to measure the degree of unhappiness, the fact that the suicide rate in industrialized countries including Japan is extremely higher than that in developing countries reveals a great irony. Science and technology of today are excessively economy-oriented and efficiency-oriented. Cultural satisfaction, which is the source of meaningful life and happiness, is sometimes forgotten. However, when considering the cultural benefits brought by science and technology throughout our history, the role to be played by science and technology today is stronger by far, compared to that in the past. For example, computer technology has opened new

dimensions that have enabled composers and musicians to create outstanding music using new methods of expression. In March, 1989, I organized an international symposium entitled Music and Information Science which was participated in by outstanding musicians and scientists of Europe and the U.S., resulting in great success. Furthermore, information technology has made it possible to create completely new artificial environments through the use of super-computers and computer graphics, providing opportunities to experience unique sensation. These will greatly help us to expand our sensitivity and feelings, and thereby to create new culture.

6. Formation of International Consensus

It is needless to say that the progress of science and technology is indispensable to the satisfaction of the intellectual desires of mankind and to the growth of the world economy, but the important roles that science and technology play for military purposes must also be mentioned. Recently, the technologies originally and exclusively developed for civil use, have accomplished rapid progress through severe competition in the market place and have become useful also for military purposes. This type of technology is known as "Dual-Use Technology," and since its unlimited availability to the market creates unfavorable influences on the security of the free world, the necessity of restriction has been recognized.

However, the borders between military and civil uses are gradually becoming unclear. Therefore, one extreme view persists that as most high technologies for civil uses are adaptable to military purposes, all these should be subjects to restriction. This calls for careful consideration in selecting what to restrict, because technologies developed for civil use would lose the opportunity to be refined through market competition, once it becomes restricted. Furthermore, it would become impossible for society to take advantage of their benefits. As a result, the researchers in charge of technological development would be discouraged and the basis for technological development would be deteriorated. As Sun-tzu, an ancient Chinese strategist said, "It is best to subdue the enemy without war." The best way of using a weapon is to prevent war by intimidating the enemy rather than killing or injuring the enemy with the weapon. If various dual-use technologies would be restricted as critical technologies for military purposes and preserved for the purpose of intimidating the enemy, it would become obsolete before derestricted for use for civil purposes. When considered in this sense, dual use technology subject to restrictions must be limited as much as possible to that directly used for weapons. At the same time, it is most desirable to establish international consensus to prevent excessive concerns for security that inhibit the future development of science and technology.

To accomplish successfully the technological innovation processes that include research, development, design, manufacturing, marketing, distribution, and consumption, all these processes must efficiently function through various feedback loops. To maintain the vitality of the whole system of innovation, it is necessary to appropriately return the rewards to each stage of the processes. The reward for research and development is the recognition of ideas. The protection of intellectual property right in this regard has an utmost significance. At the same time, by providing public protection for the disclosure of ideas, it also has a great meaning for social development in avoiding unnecessary duplication of

research and development efforts, and in providing opportunities to utilize the invention to everyone who are willing to pay appropriate compensations. In other words, the protection of intellectual property right is a rule needed not only for protecting ideas but also for promoting diffusion of ideas. Reflecting different historical background, however, the rule has not yet been concerted among industrialized countries, and there has been delays in developing countries. This calls for an international agreements to be established at an early stage.

To promote a free international trade in products and services, international standardization of technology is indispensable. Despite two world wars and other major international conflicts, international standardization has been carried out continuously for the past century with good results. International standardization, however, is a difficult task. The first reason is that the pace of technological development is very fast so that, if standardization comes too early, it disturbs the development of technology, and if it comes too late, its effectiveness is lost. The second reason is the long time required for adjusting the conflict of interest among private enterprises, since the development of technology is mainly carried out by private sectors who are under severe competition. The third reason is the necessity of standardizing software in addition to hardware, which require the standardization of voluminous amounts of programs in response to the sophistication of functions. Recently, facsimile has become very popular as one of the methods of international communication. Behind this success, there was a generosity of related Japanese enterprises who gave up their proprietary right of inventions which were internationally standardized. In regards to the promotion of international standardization, we need to establish an international agreement that includes at least provisions for nonexclusive usage of inventions standardized internationally.

Various types of services which have been thought to be separate are gradually increasing in similarity, in accordance with the development of technology. This is especially true in information and communication services. The convergence of service modes is observed between computers and communication, broadcasting and communication, postal services and communication, and libraries and databases. From the view of guarding public benefit, various regulations up to this time have been enforced to these information services. In response to these convergence services modes, however, derestriction and drastic reconsiderations of regulations have been underway mainly in the industrialized countries. If the international feature of information services are considered, international coordination must be carried out to ensure concerted revision of regulations so as not to hamper the benefits of enterprises and individuals who are developing their activities in a global scale.

7. Promoting International Exchange of Science and Technology

The open and free exchange of knowledge of science and technology in the free world has done much to avoid duplication of research and development investments and to restrain diversification of industrial standards, and has helped to establish the economic and technological advantage of the free world.

In the future, industrialized nations will gain more scientific and technological powers. However, taking into consideration the tendency of science and technology to become

bigger and more diverse, it seems impossible for any single industrialized nation to pursue research and development independently and individually in every field of science and technology. And in view of the rapid rise of newly industrializing economies, it may be crucial for industrialized nations to establish closer scientific and technological ties with them. In other words, international exchange of researchers and international flow of information in all fields should be encouraged.

The Fulbright Program of the U.S., the Humboldt Foundation of West Germany, and the British Council of the U.K. have invited many Japanese researchers for joint research and have made significant contributions to the progress of Japan's science and technology. Japan, which has made remarkable progress both in science and technology and in economy, should reciprocate and offer similar opportunities to foreign researchers. In Japan, various scholarships have been offered to students from abroad, and researchers have been invited to universities and research institutes. While I was the dean of the Faculty of Engineering at the University of Tokyo, I also made efforts by establishing the Research Center for Advanced Science and Technology and opening it to international participation, setting up four endowed chairs for professors from overseas. In 1988, programs to invite many more non-Japanese researchers to universities and national and private research institutes have been created. Such efforts should be enhanced on a larger scale. The language is the biggest barrier to researchers from abroad. The number of Japanese language teaching programs is rapidly increasing for non-Japanese students in Japan. It is Japan's responsibility to offer education in the Japanese language to researchers in major cities abroad following the case of the Goethe Institute of Federal Republic of Germany. It is also necessary to develop infrastructure such as comfortable housing for non-Japanese researchers.

The second measure to be taken in promoting international exchange in science and technology is to strengthen international flow of scientific and technological information. In Japan, various actions were taken to the flow of information, resulting in the deployment of a first-rate information and communication network. However, interest has been low regarding the stock of information, and the serious delay in developing information stock is becoming a matter of concern, especially given the importance of databases. While there has been increasing demand from abroad to have access to Japanese science and technology information. Clearly, along with the construction of databases, measures should be taken to provide broader international access to them in earliest possible date. As the Director-General of the National Center for Science Information System, I have been promoting the development of a union catalog database to promote utilization of the enormous volume of books and magazines held by Japanese university libraries, along with the development of secondary information databases, covering many specialized scientific fields. I have been also working for the deployment of a nation-wide digital information network to support exchange of information among researchers. In January 1989, a satellite communication circuit was set up to link North America, and it is our plan to initiate similar measure with Europe, and Asia, thus offering international access.

What we would like to ask other nations to do in promoting international exchange of science and technology is to stimulate their researchers' interest in Japanese science and

technology. Japanese universities and research institutes already have facilities for inviting non-Japanese researchers. However, only a limited number of Americans and Europeans have shown interest in utilizing it and making a long stay for joint research, leaving quite a few vacancies remain unfilled. There is scant interest in Japanese science and technology information and a very limited number of subscriptions have been received to Japanese scientific magazines published in international languages. To put it differently, there is a large gap in interest in Japanese science and technology between foreign administrators and researchers. Not only Japan but also other nations should make an effort to narrow the gap.

8. Concluding Remarks

Promotion of structural adjustment, strengthening of basic research, enhancement of human resources development, improvement in quality of life, formation of international consensus and promotion of international exchange of science and technology, which I have touched upon today, may be only a few out of many diversified measures for utilizing sience and technology to bring a new age of the world.

Promotion of science and technology for extending human knowledge and utilization of scientific and technological achievement for the good of humanity, require sustained efforts based upon very long term perspectives. Although such short term issues as trade, national security, etc. require immediate attention, in the course of finding ways and means of solving these short term issues, cares have to be taken not to humper the long-term progress of science and technology.

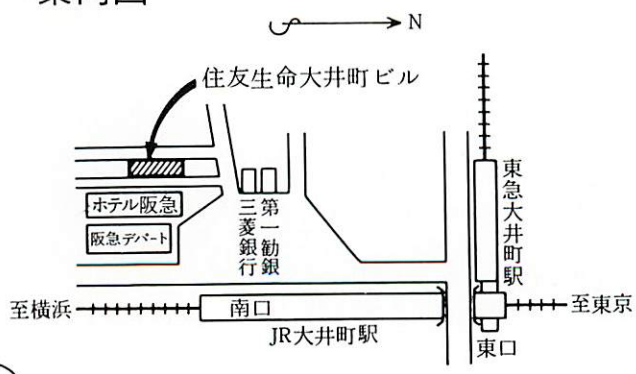
Chuang Tzu, an ancient Chinese philosopher, is said to have remarked that, "Gentlemen's association is as plain as clear water, whereas small-fry's association is as sticky as honey". I quoted this a few years ago at an international symposium on U.S. Japan cooperation by saying that, "to follow this Taoist Principle, Japan should reduce its excessive export dependence on U.S. market and perhaps the U.S. should reduce its excessive dependence on Japanese money flows, if we really want to establish a long-lasting cooperative relation." And my U.S. counterpart who was a renowned scientist and top executive, responded to this by saying that, "What you have said is also true between a married couple, if they don't want to divorce very soon." I believe science and technology is one of the typical areas that require "Gentlemens's association" among world nations.

At the end of the 15th Century, European navigators courageously sailed across the Atlantic and found not only the Americas but also another ocean beyond the new continent, and named it the Pacific. Unfortunately, a long period of colonialism followed thereafter. However, after the Second World War, these colonized areas gained independence and started on a course of self-support, with generous economic assistance from industrialized countries and their own determined endogenous efforts. Especially in Pacific, countries and areas now known as newly industrialized economies have been acquiring the economic and technological powers comparable to those of some advanced countries.

The last years of the 20th Century will represent another age of great navigation, a new age for the world nations to cooperate and compete each other so as to positively contribute to strengthen world economy, to improve quality of life and to dispel poverty

and hunger. Such cumulative efforts will no doubt help world market to make an epoch-making expansion, and a magnificent positive sum game will unfold through the appropriate mix of cooperation and competition. I believe that cooperation and competition in science and technology above all, will play a decisive role for the success of such undertakings.

案内図



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