Japan's Technology Development — Strategies for the Future

By Matsui Konomu

Three Innovations Strengthened Japan's International Competitiveness in Technology

Tremendous external stimuli in the 1970's, 80's and 90's brought about three structural reforms to Japan's system of technology development. These three innovations enabled the rapid enhancement of Japan's international competitiveness in technology.

The first innovation was triggered by *Indicators of International Trends in Technological Innovation* (PB-263-738), released in 1976 by the U.S. National Science Foundation (NSF). According to this international comparative analysis, 46% of all technological breakthroughs were made by the U.S. and 2% by Japan. This data sparked Japan bashing worldwide owing to the view that Japan was enjoying a free ride in the scientific field, and pressed the Japanese government to change its policies on science and technology, and domestic industry to improve its basic research and development capabilities. Under the influence of a buoyant Japanese economy, more than 200 basic research institutes were established over the five years from 1980 to 1985, causing a kind of boom in basic research institutes and bringing to an end Japan's "free ride" in science.

The second innovation was triggered by the publishing of two book-length *Japan Study Reports* in the late 1980's. The first one, titled *The Positive Sum Strategy*, was issued by a group of Stanford University scholars in 1986. This report attracted attention throughout Japan, as it reported the actual status and outlook of the United States facing high-tech competition with Japan. A conference was held concerning this book in the Ministry of International Trade and Industry's international economics section, in which all managers in the section took part. The second book was *Made in America*, published by a group of scholars at the Massachusetts Institute of Technology. The report stated that the U.S. had lost its dominance in the high-tech race because it had become complacent, relying on the superiority it had enjoyed in the past, and allowing its strategy to become outdated. The honest reflection of this report taught the Japanese a good lesson.

The Japanese gleaned two strategic suggestions from the analyses of these two books. The first one led to the conviction that they could not win the high-tech race by sticking to a linear R&D model of basic research followed by applications, followed in turn by development. They concluded that the non-linear R&D model was indispensable, where basic study, application, and development were conducted in parallel and in response to market needs.

The other suggestion brought about the conviction that Japanese and U.S. research and development each complemented the other's strengths and weaknesses, urging both parties to work together through a strategic alliance.

The third innovation was triggered by a common interest brought about by the booming U.S. economy and the depressed Japanese economy of the 1990's. This innovation was the recognition that in order to increase the success of technological innovation, the study of new innovative processes such as the non-linear R&D model and research on MOT (Management of Technology) were important, with Japan superior in the former and the U.S. in the latter.

Through these three stages of technological innovation, Japan was able to maintain its competitive edge in technology despite the country's grave economic situation, while at the same time continuing to move forward through the development of its so-called "Hyper System" in the 1990's, a synergetic fusion of the waste-cutting "Lean System" of the 1970's and the speed-increasing "Agile System" of the 1980's.

New Technology Development through Cooperation among Industry, Government and Universities

While inconsistencies surfaced in Japan's economic and financial policies in the 1990's, no particularly grave problems surfaced in its policies on science and technology. The basis of Japan's scientific and technological policies can be summed up by the ERATO (The Japanese Exploratory Research for Advanced Technology) Program, which assists in the transfer of research from universities to industry, and by the Science and Technology Basic Plan.

The ERATO Program supports the development of commercial applications for university research by supplying publicly subsidized grants and contract research. The NSF's Industrial Research Program is said to be modeled after this system. The essence of this is reported in detail in the NSF's Japanese Technology Evaluation Program (JTECH Panel Report, 1988).

A significant early achievement of the ERATO Program was the development of a commercial application for an aluminum-based amorphous magnetic light alloy. Basic research in this field was begun in Japan ten years after the discovery of the principle behind the technology. Five years later, ERATO invested

¥1.5 billion in the development of a commercial application for this technology over the ensuing five years, culminating in success for the project. The acceleration in the development of a commercial application caused by the ERATO Program's funding heightened industry's interest. As a result, more than 10 companies, including YKK, Honda and Toyota, applied to participate in joint research at the Tohoku University Metallic Material Research Institute's Masumoto Tsuyoshi Laboratory, which was advancing commercial applications. At first glance, this may seem to be a case of the kind of excessive competition for technological development often seen in Japan. Careful analysis, however, will show this competition to be quite sound.

For example, there are three significant uses for aluminum-based amorphous magnetic alloy wire, namely magnetic field devices, magnetostrictive devices, and pulse generating devices, each thought to have five to six highly independent uses as sensor devices. Consequently, it is not illogical for many companies to compete in this area.

Under the ERATO Program, commercial applications for more than 30 new technologies have already been developed, providing the opportunity for significant innovation in many industries and enterprises. At present, Japan is the world leader in the field of new technological development for sensor devices. New material research for sensor devices may exert an extremely significant influence in this field. For instance, the successful deployment of a commercial remote automated diagnosis service for purchased CT scanners will undoubtedly depend on the development speed and quality of the sensor device in question.

Let us now turn our attention to the Science and Technology Basic Plan. Under the current situation of economic recession, enterprises are placing emphasis on development which is directly linked to demand, causing a hollowing effect in basic research. The R&D operated by the Science and Technology Basic Plan's fund complement this tendency, supporting the technological bases necessary to maintain international competitiveness.

This fund directly assists the research and development programs of national laboratories, providing at the same time indirect aid for joint research programs between universities and national research institutes, between enterprises and national research institutes, and among universities, enterprises and national research institutes. It is particularly expected that long-term research and development programs can be promoted by furnishing thereto ¥17 trillion in total over the period between 1996 and 2000. Industry has been slow in taking up such programs.

In the U.S., the activities of all research programs to which even a dollar of government funding is supplied are disclosed to the public, with the exception of important military research programs. The same is true in the case of Japan. Some would say that the level of disclosure in Japan is higher than in the U.S., because in Japan the evaluation process is also disclosed.

By way of example, some of the strategic programs pursuing the highest development targets in the world (in terms of novelty and technological level) are synergy ceramics for higher-order structure control, time-machine biostructure technology, propulsion systems for supersonic transport planes of the mach three to five class, applied technologies for human sensory measurement, solid electrolyte-type fuel cells, new refrigerant development technologies to prevent global warming, and combustion control techniques

At Super Photon ring-8, the number one superconductive magnet in the world is being developed for high-performance industrial furnaces used to keep up with global environmental measures. All of these will soon be core technologies for strategic industries.

From the standpoint of international contribution, the construction of enormous, cutting-edge research facilities should be the focus of the Science and Technology Basic Plan. Although these facilities do not directly serve industry, their size and level of technology is beyond the reach of any single enterprise. The cosmic ray observation facility constructed on the ruins of the Kamioka mine; the Super Photon ring-8, which was jointly constructed by the Japan Atomic Energy Research Institute and the Institute of Physical and Chemical Research at Nishiharima Technopolis; and the Japan Marine Science and Technology Center's deep-sea submarine, established at Yokosuka by the Science and Technology Agency: these and others all deserve the distinction of being called number one in the world.

While research making use of these facilities has yet to show results, many new technologies on the international cutting edge have been developed by related enterprises in the process of their construction. A photomultiplier cosmic ray observation device, the most advanced of its kind in the world, is currently being developed. At Super Photon ring-8, the number one superconductive magnet in the world is being developed. In addition, a deep-sea submarine, now capable of deep-sea observation at the deepest point ever reached in the world, can be used to observe and collect deep-sea creatures and minerals, or examine the structure of the deep.

Japanese Technologies Indispensable for the World

Recently, a demonstration titled "Japanese Technologies Indispensable for the World" attracted attention at an exhibition of new technologies organized by the TEPIA Foundation.

Items displayed were selected by the about 20 planning committee members, each selecting within his or her area of expertise. What led to this planning was the report that semiconductor manufacturers all over the world were thrown into utter confusion when an accidental explosion occurred in the early morning of July 4, 1993 at the epoxy resin plant of Sumitomo Chemical Co. Ltd., halting the supply of high-performance, high-quality epoxy resin used for sealing semiconductors produced by that company.

Analysis of electrolytic capacitor paper at Nippon Kodoshi

Sumitomo Chemical produces as much as 60% of the world's supply of high-quality epoxy resin for sealing semiconductors. The cause of confusion was that the production of this company, with its high technical level, could not be replaced by other companies, and that crisis management was insufficient due to lack of recognition that semiconductor manufacturers around the world were dependent on this company alone for 60% of a material used in parts vital to their operation. Fortunately, production was resumed after a short period, ending this confusion.

Japan has many high-tech products like this one that the world could not do without. These products support Japan's international competitive advantage. Below are a few examples. Mabuchi Motor Co. Ltd.'s direct-current micro-motors for precision machinery (world's highest market share)

●Advantest Corporation's semiconductor testers (world's highest market share; about ¥200 million per unit; 62% share of the world market for memory testers)

●YKK Corporation's high-quality zippers (100% share of domestic market; world's highest market share; virtually monopolizes the market in the area of airtight and watertight types used for space suits, diving suits, suits used for undersea tunnel construction, etc.)

●Nippon Kodoshi Corporation's electrolytic capacitor paper (world's highest market share)

●Toyo Tanso Co. Ltd.'s heat and chemical-resistant isotropic high-density graphite (approx. 50% share of world market; also used as reactor core material for nuclear reactors and for rocket discharge nozzle throats)

●Ujiden Chemical Industry Co. Ltd.'s artificial polisher (100% share of domestic market; 80% share of world market; this is the first artificial polisher to be developed in the world. The name of the product is Tosaemery Extra)

●Semiconductor silicon wafers of Shin-Etsu Handotai Co. Ltd., subsidiary of Shin-Etsu Chemical Co. Ltd. (approximately 25% share; world's highest market share)

●Shinko Co. Ltd.'s cargo oil pump and turbine (pump and drive steam turbine for transportation of crude oil from oil tankers to refineries; world's highest market share)

●Nihon Almit Co. Ltd.'s non-chlorine system resin-cored solder KR-19RMA (Traditionally, the effect of solder was enhanced by rubbing the soldered face with pine resin to remove oxidized film on the surface. Complaints persisted, however, regarding corrosion caused by chlorine contained in the activator added to pine resin to raise productivity. While eight companies which successfully developed non-chlorine resin-cored solders obtained RMA approval based on U.S. Federal Government specifications, Nihon Almit is the only one whose product has been adopted for use on such projects as the NASA space shuttle)

●Disco Corporation's semiconductor cutting and grinding technologies (dicing saw; approx. 80% of world market share)

●Kyocera Corporation commands approximately 60% of the world market share for ceramic packages for ICs used as parts for telecommunication machinery and equipment. In addition, it commands more than 50% of the world market share for dielectric filters, synthesizer blocks, audio blocks, etc.

Strengths of Japan and the U.S.'s R&D

Japan	The United States
(1) Applied research and development	(1') Basic research
(2) Incremental improvements	(2') Breakthroughs and inventions
(3) Commercial applications	(3') Military applications
(4) Process and Production technology	(4') New-product design
(5) Components	(5') Systems integration
(6) Hardware	(6') Software
(7) Predictable technologies	(7') Less predictable trajectories
(8) Quality control	(8') New functionalities
(9) Miniaturization	(9') New architectural designs
(10) Standardized, mass volumes	(10') Customization and semicustomization

Source: *The Japanese Challenge in High Technology, The Positive Sum Strategy*, R. Landan and N. Rosenberg, National Academy Press, 1986, pp.564

Outlook of Japanese Competitiveness in Technology

Japan, though poor in industrial raw materials, has retained its high level of international competitiveness by pursuing a strategy of enhancing its technology development capability and developing an advanced processing trade-style economy, a strategy it has followed consistently since the Meiji Restoration of the 19th century. The following three points are considered important for accomplishing this strategy.

(a) Attach more importance to market-driven style than to discovery-driven style
(b) Set a high value on technology forecasting, and invest in technological development in line with the direction of technological progress
(c) Place high value on developing scientists and engineers, and endeavor to utilize them effectively.

(1) Laying Stress on Market-driven Style

Made in Japan was an attempt modeled after the analysis of industrial performance conducted in the U.S. book *Made in America*. The English edition of this report was published by MIT Press in 1997. The writer was in charge of *Management of Research and Development* (Chapter 10) in this report, and, after comparing the R&D styles of Japan and the U.S., pointed out that Japan's market-driven style commercial applications are developed more quickly and it is easier to establish a competitive advantage than with the discovery-driven style of the United States. This observation was based on the fact that it has been demonstrated in many instances that it is easier to overcome obstacles of organization and specialization by conducting basic research, application study and commercialization as required all at once within a project, using market needs as the driving force, rather than proceeding with research and development step-by-step from basic research through application study to development of commercial applications, using discovery as the driving force.

In my personal opinion, this was proven during the period of Japan-U.S. semiconductor friction of the 1980's by the difficulties faced by Intel, a company which held basic patents, when it competed on the international level with Japanese enterprises which held none. This competitive advantage may be considered universal, as we see many U.S. corporations change the direction of their R&D styles in the 1990's, attaching more emphasis to a market-driven style in the manner of Japanese companies.

Although space constraints preclude expansion upon this point, Japan's technology will in the future shift to a new R&D style, uniting the strong points of both the discovery-driven R&D style of the U.S. and the market-driven R&D style of Japan. The writer calls this new style vision-driven R&D.

(2) Strategic Operation of Investment in Technological Development Linked with Technology Forecasting

Japan's accumulation of technology forecasts is deemed to be an untapped resource for strengthening its international competitiveness. The Japanese government has conducted six technology forecasts, once every five years, using the Delphi Method developed by the Rand Institute of the U.S. The forecasts employed the tendency extrapolation method in expectation of achieving long-term forecasts. Full advantage has not yet been taken of this 30-year accumulation of technology forecasts in the process of policy development.

However, Dr. Olaf Helmer, one of the developers of the Delphi Method, says the direction of development can be strategically guided by technology forecasting. Improved investment efficiency can be anticipated by investing in technology development more effectively.

For corporations, it has become increasingly important to raise the operational efficiency of investment in technology development, as they have less funds for investment in technology development due to declining profitability. Although they have so far been able to select target areas of high investment efficiency by working to grasp market needs, efficiency like that of the past cannot be expected any longer owing to more finely divided and diversified market needs. Consequently, they are now more interested in technology forecasting as a supplementary means to learn market needs.

In this regard, they also tend to be more concerned with such methods as frequency analysis of patent and thesis references (quantitative analysis of document citations). Engineers are paying more attention to these methods as complementary instruments for technology forecasting, while they hardly showed any interest in them in the past. For example, in the field of superconductivity engineering, a strategic issue in the area of industrial materials engineering generating enthusiastic interest, an attempt by the research and planning section of MITI's Superconductivity Engineering Institute to conduct a systematic analysis in this connection was the focus of much attention.

(3) Place High Value on Developing and Effectively Utilizing Scientists and Engineers

It goes without saying that the key to improving a competitive edge in technology lies in the creative training and good use of scientists and engineers. In Japan, 40.6% of all technical personnel work for universities and national institutes, while 59.4% of them work in industry. In contrast, 21.2% and 78.7% of research expenses were spent in the public and private sectors, respectively. The decreasing amount of personnel and declining R&D budgets of the private sector has changed the previous conditions whereby Japan's competitive edge was strengthened by making effective use of abundant personnel and research budgets in the private sector. Japan is now being pressed to fundamentally restructure its method of training and utilizing scientific and engineering personnel.

Whether or not this issue can be successfully resolved will undoubtedly determine the future of Japan's competitive advantage. Universities are implementing innovative changes based mainly on the improvement of graduate schools and the promotion of cooperation with industry; public research institutes are implementing innovations centered around technology management and the technology evaluation system; and private research institutes are implementing innovative changes concentrating mainly on strengthening cooperation between industry, the government and universities. All these changes have been started in parallel.

Japan's technology has not yet lost the competitive edge it demonstrated in the process of the high-tech race of the 1980's. Nevertheless, other countries have nearly caught up to Japan as a result of their "Japan Studies" in the 1990's. Each year for the past 15 years, while serving as a coordinator for the International Forum for Management of Technology, sponsored jointly by the Japan Socioeconomic Productivity Center (JPC) and the Industrial Research Institute (IRI) of the United States, the writer has seen experts from other countries more and more firmly recognize the decline in Japan's integral competitive advantage, including technology management, while recognizing that it has retained its technological competitiveness.

If Japan can successfully resolve the three above-mentioned issues, it will certainly be able to again pull away from the rest of the world in terms of technology. Japan must not rest on its laurels, allowing strategies and systems to become outdated and delaying the restructuring of its management system.

References:

(1) Matsui Konomu: 'Management of Research and Development,' *Made in Japan: Revitalizing Japanese Manufacturing for Economic Growth,* The MIT Press, 1997, pp.225-251

(2) Japan Socioeconomic Productivity Center: *Report on International Forum for Management of Research and Development*, 1987-98 Editions

(3) Landau and Rosenberg: *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, The National Academy Press, 1986

(4) MIT Commission of Industrial Productivity: *Made in America*, MIT Press, 1989

(5) *Yume to senryaku no aru sisutemu wo mezasite* (Aiming at Research and Development System with Dream and Strategy), Conference organized by Science and Technology Agency for Research and Development System, 1998

JJTI

Matsui Konomu is a professor at the Industrial Relations Laboratory, St. Paul's (RIKKYO) University and is the author of many books on technological development. He has also served on various MITI's councils and committees.