Designing a 'Knowledge Science' Based Graduate MOT Education Course and Its Review of Implementation and Practice

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Abstract--JAIST (Japan Advanced Institute of Science and Technology) established a unique MOT course in 2003 in Tokyo, which framework was structured on the base of "Knowledge Science". The graduate school of knowledge science was established in 1096, by the first dean, Prof. Ikujiro Nonaka, a distinguished leader of knowledge creation management. The JAIST-MOT course focused its goal to innovation management and to educate technology based innovators to be called "Techno-producer" who has capabilities of concept generation, coordination, and project management. This MOT program introduced many new subjects such as strategic roadmapping, concept generation, services sciences that empower the competence of next-generation MOT or next-generation innovation management. This paper reviews the JAIST-MOT concept, characteristics of the programs, implementation process, resulting performance of about three-year practices and the future perspectives.

I. INTRODUCTION

Over the past five years, MOT (management of technology) has been a major focus of Japanese science and technology policy. This is in response to mounting evidence that Japan's innovation system has been struggling to translate the fruits of research and development into radically innovative products and services. Japan's economy has been in the midst of an historic transition from a structure based on technological catch-up to one based on technological innovation at the frontier of knowledge. Whether it succeeds in the paradigm shift from incremental innovation to radical innovation, will depend on the country's capacity to generate and commercialize new knowledge across the economy. The paradigm of MOT in Japan is on the brink of an overall shift. How to create original product targets is now the central issue, which is completely different from the conventional management. It is critically important to establish a new management system that surpasses the conventional style by focusing on new concept creation and rapid and dynamic decision-making to achieve agile management. The linkage of research and technology development (RTD) to the corporate business strategy, RTD networking and outsourcing, and higher integration of industry, academia and government are also important. To close this gap, Japan's government, the Ministry of Economy, Trade, and Industry (METI) started in 2002 to strengthen and expand educational curricula in management of technology; with the cooperation of major business organizations.

Economic success in the 21st century, however, requires more than an ability to produce good science. Equally important is the capacity to translate scientific knowledge into new products and services that satisfy the needs and wants of consumers in global markets. Here, Japanese companies have encountered serious bottlenecks that have undermined industrial competitiveness over the past decade. Although a country's competitiveness depends on many factors, 80 percent of Japanese firms cite the difficulty in translating the results of basic research into new products and services as one of the most critical barriers to growth. Bridging the so-called "death valley" between basic research and commercial operation has thus become a key objective of public policy. The linkage of research and technology development with the corporate business strategy, networking and outsourcing, and higher integration of the industry, academia and government are critically important. In addition, new metrics of measuring the system performance has to be developed to promote the dynamic and high-quality technology and innovation management. How to design the framework, how to motivate the core actors, and how to introduce the interactive cooperation, are to be studied.

II. JAPAN'S INDUSTRIAL COMPETITIVENESS

First, it is necessary to understand the reality of a country by observing objectively where the problems are and what are the strength and weakness. An intensive questionnaire survey of the Japanese industry carried out for two years from 1999 to 2000 compared Japan with the United States, European and Asian countries, with respect to 14 industrial technology fields (290 items) that covers all of whole technologies from materials, devices, software to system engineering as well as production technologies and technology management [1][2]. The respondents were mostly corporate executive technology managers, including some researchers of universities and corporate R&D consultants. The result showed that Japan keeps higher level of industrial technologies than other Asian countries in the most areas and slightly higher than EU and almost even to US in average. Japan is extremely strong in electronics appliance (CE) and strong in production technology (PD) as well, and slightly strong in new materials (NM) and electrical devices (ED), but weak in biotechnology (BI), software (SW), communication system (CS), and medical engineering (ME). The most serious result was its weakness in "Management of technology and human resources etc. (MG)" which includes, for examples, standardization, management of intellectual property, integrated

project management, benchmarking, supply-chain management, knowledge creation, and systems for cooperation among the industries, government, and academic sectors. Among others, it has to be noticed that the critical capabilities like "Management of Technology" and "Corporate Strategy" are pointed out to be problematic in Japan. Accordingly, MOT should be regarded as the most important factor for Japan to restore its world competitiveness.

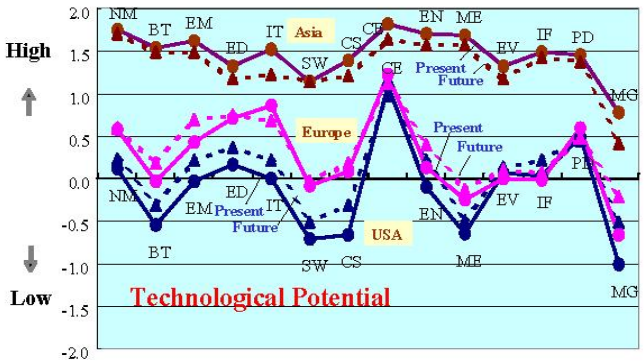


Fig 1. Industrial Competitiveness of Japan-USA-Europe-Asia

III. GOVERNMET POLICY for MOT PROGRAMS IN JAPAN

The core of industrial competitiveness is in the capability of creating new innovation forms, and the most important thing is to recognize the paradigm shift from incremental innovation to radical innovation. This requires MOT professionals with new capabilities, who have to effectively manage the linkage of technology and business. During last five years, METI (Ministry of Economic and Trade Industry) promoted MOT programs, as shown in Fig. 2, by supporting many universities to develop MOT education programs to provide MOT professionals up to a scale of 10,000 students per year in five years. Many universities in Japan have been developing comprehensive programs and some collaborative programs with foreign universities. The METI's MOT programs have been commissioned in more than seventy universities and other public and private educational institutions throughout the country. Partnerships with private companies and foreign universities are also being encouraged.

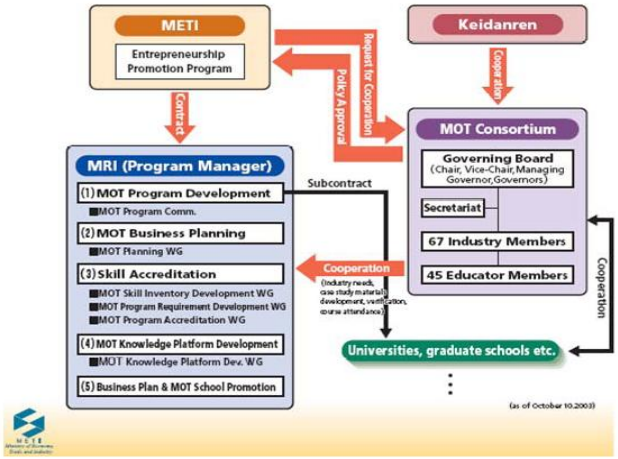


Fig.2. METI's MOT Measures (as of 2003)

IV. 'KNOWLEDGE SCIENCE' for KNOWLEDGE SOCIETY

Our society is now moving from the information society to knowledge-based society and the human society is becoming increasingly complex. If science remains segmented into specialized disciplines, we cannot deal effectively with multi-faceted problems which we now face. Thus, we need a new integrative science that is founded on the deep understanding of humanity and society which concept is shown in Fig 3. In view of this need, the School of Knowledge Science has embarked upon a new initiative that aims to discover both theoretical and practical principles of knowledge management (i.e., management of creating new knowledge and integrating it with existing knowledge), thereby developing new knowledge systems for decision making and problem solving. To that end, the School has enlisted not only natural scientists and engineers but also social scientists and humanities scholars. These faculty members conduct research into:

(a) innovative methods for solving complex problems; and
(b) man-computer systems that support such problem-solving activities.

The School also provides master's and doctoral programs to educate professionals (e.g., project-team leaders and knowledge engineers) and knowledge scientists equipped with such knowledge-creating methods as fieldwork, statistical analysis, simulation, knowledge engineering, etc. They are expected to become pioneers of the knowledge society (http://www.jaist.ac.jp/ks/index-e.html).

Widely known scholar of knowledge management, Prof. Ikujiro Nonaka, funding dean of the Graduate School of Knowledge Science in JAIST, generated the SECI model for knowledge creation process. The model shown in Fig. 4 emphasizes the conversions of tacit knowledge and explicit knowledge, including four stages; (1) socialization (from tacit

to tacit), (2) externalization (from tacit to explicit), (3) combination (from explicit to explicit, and (4) internalization (from explicit to tacit). How to proceed this knowledge management cycle effectively in the radical innovation process is a new challenge of JAIST-MOT course, to overcome "the valley of death" between the advanced basic research and business development.

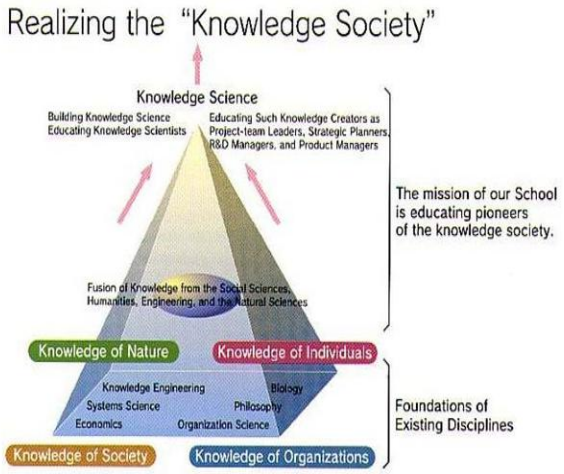


Fig.3 Scheme of Knowledge Science

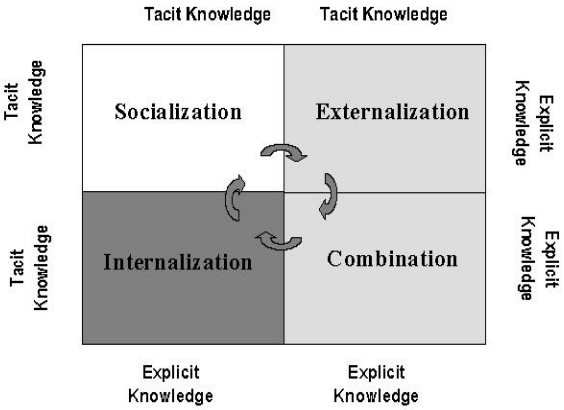


Fig. 4 Nonaka's Knowledge Creation SECI Model

V. PROGRAM DESIGN of JAIST-MOT COURSE

The Japan Advanced Institute of Science and Technology was founded in 1990 in Ishikawa Prefecture as the first national graduate university offering Master's and Doctoral degrees in selected fields of science and technology. Currently, JAIST offers degree programs in materials science, information science, and knowledge science. Since October 2003, JAIST has been offering a new Master's curriculum in Management of Technology through its Graduate School of Knowledge Science, which was the first school of its kind to make the creation and management of knowledge a target of interdisciplinary scientific inquiry. It is being offered as an evening and Saturday program at a new satellite campus conveniently located at Tokyo Station, making it accessible to the large community of technology professionals clustered in the central Tokyo area. Consistent with national policy, JAIST-MOT program aims at the straightforward goal of uniting theory with practice, training managers who understand the technology they are managing and technologists who understand how to manage the technology they are developing.

Anchoring the curriculum are two cores; the Technology Management Core focusing on innovation theory, RTD management, and strategic roadmapping; and the Knowledge Science Core focusing on knowledge management theory and theory of the knowledge society. The features of the JAIST-MOT program in Fig.5 was introduced in the guide book under the title of "A Guide to MOT in Japan" issued by the Academia-Industry Cooperation Division, Ministry of Economy, Trade & Industry in 2004. Among the distinctive aspects of the program is the emphasis on technology roadmapping and the integration of MOT with the interdisciplinary graduate curriculum in Knowledge Science. It is designed to accommodate a cohort of twenty students, all of whom are expected to be experienced, working professionals; upon completion of a minimum of 30 credits and a thesis, students are awarded the Masters of Knowledge Science with a certificate in MOT. For the last three and half years practice, the number of students increased steadily every year, and number of graduates are about 50 as of March, 2007 and total number of students who learned or learning in JAIST-MOT course is about 130 at the beginning of April, 2007. The curriculum was designed under the concept of knowledge creation focusing on technology-based innovation. The number of subjects started from 16 in 2003; technology management core 9 and knowledge science core 7, increased up to 35 in 2007 by introducing new subjects. The JAIST-MOT course was given four "S" especially good marks that prove its experience by the external evaluation committee organized under the METI.

6 MOT Programs in Japan
MOT Degree Programs

Japan Advanced Institute of Science and Technology (JAIST)
School of Knowledge Science
http://www.jaist.ac.jp/ks/index.html

Name

Management of Technology (MOT) Course (Started October 2003)

Qualified applicants

The course is for individuals with work experience of at least three years, including those involved in corporate management planning, technological strategy development, research planning, research and technology development, intellectual property management, industrial, scientific, and technological policy and management, academia-industry collaboration and technology transfer. Also qualified are those who wish to become management and technology development consultants, new industry/business innovators, or entrepreneurs in the advanced technology fields. Such individuals may apply regardless of their specialization, occupation, or age.

Basic information

Course	Enrollment	Duration	Degree	Graduation requirement	Tuition (total)
2-year course *1	20 Applications accepted in Apr. and Oct.	2 years *2	Master's (Knowledge Science) and MOT course certificate of completion	①30 credits or more ②Master's thesis Please refer to our Web site for details	Admission fee: 282,000 yen; Tuition: 521,000 yen/year

*1: Normal duration is two years, but students deemed to have performed outstandingly according to a prescribed assessment may complete the course in one year.
*2: Lectures at the Yaesu campus in Tokyo will be held Monday to Friday (in the evening) and Saturday. (Lectures at the main campus are held on weekday mornings.)

Selection process

Comprehensive assessment based on interview, work experiences, academic records, future plans, etc.

Features of the program

①Management of technology based on knowledge science ②Education and research through international academia-industry collaboration ③Focus on problem solving and the integration of theory and practice ④Interactive lectures with emphasis on discussions ⑤Action research exploiting academia-industry collaboration ⑥Diverse and proactive students with extensive experiences ⑦A knowledge creation platform upon which the small group of students can freely exchange their opinions in a friendly atmosphere ⑧Conveniently located, making self-development possible while continuing to work ⑨World-class course content and instructors ⑩Practical program that can assist people with their work at companies

JAIST-MOT aims to establish a new Management of Technology (MOT) Course based in our pioneering School of Knowledge Science. Japan Advanced Institute of Science and Technology is one of the central constituents of the international collaboration organization GATIC (Global Advanced Technologies Innovation Consortium) along with the Swiss Federal Institution of Technology (ETH) and Northwestern University's Kellogg School of Management. Together, the three schools have initiated joint MOT research projects based on academia-industry collaborations, and have held the GATIC International Workshop in Tokyo in October 2003.

Strategic road mapping course: Professor Farr of University of Cambridge, Professor Coyle of Purdue University and Professor Akio Kameoka of JAIST, and others

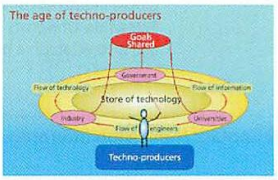
Teaching method

Lectures	Case studies	Seminars	PBL
○	○	◎	◎

Message

MOT is the foundation of business management. Industrial competitiveness springs from the creative power of innovation that generates new industries.

Nurturing MOT professionals is an urgent task for Japan, because Japan must convert to a front-runner-type innovation management model and create new concepts. This is a big jump, comparable to a train operator becoming an aircraft pilot. We have set the new strategic goal for next-generation MOT as "just-in-time innovation," and aim to present "dynamic management" that flexibly integrates all the steps involved in taking advanced basic research to market. We aim to foster "techno-producers," a new type of engineer who would accelerate this process.



Vice President Professor Akio Kameoka

Professor Shuji Kondo

●Contact (Admission information etc.): 1-1 Asahidai, Tatsunokuchi-cho, Nomi-gun, Ishikawa 923-1292
For the MOT course: (Academic Affairs, Division of Student Affairs)tel: +81-761-51-1936 fax:+81-761-51-1959 e-mail:kyoumu@jaist.ac.jp
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Fig. 5 Features of JAIST-MOT Program

VI. GOAL OF JAIST-MOT EDUCATION: ERA OF "TECHNO-PRODUCER"

The key to success in this stage is the ability to generate new concepts and coordinate the task of identifying and harnessing the relevant resources both inside and outside the firm. This next generation of innovation requires a new type of technologist, who can lead the activities needed for market experiments and market creation. As a technology based innovator, here is proposed a new type pf technologist to be called a "techno-producer" who creates a creative objectives and coordinates the practical program to achieve the objective. As illustrated in Fig.6, the techno-producer is a new type of technologist who promotes radical innovation process to generate a new business and industry. The principal role of techno-producer is to set up a strategic objective goal to create new innovation, like a composer/conductor of an orchestra. He/she must not only generate new concepts and formulate strategies, but also lead innovation process. At the same time, he/she does not only play a key role in firm, but also across corporate boundaries to promote cooperation among industry, academia, government, and act worldwide. To facilitate activities of techno-producers, it is necessary to build a sophisticated infrastructure to enhance the flow of technological knowledge across organizational and national borders, so a 'highly advanced techno-flow market should be established, as the social infrastructure to enhance technology transfer on the basis of the market mechanism.

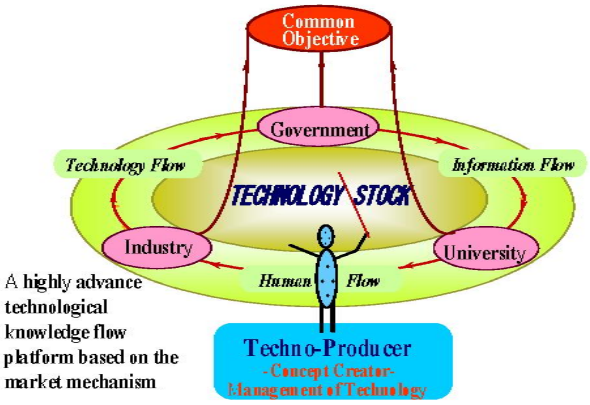

Fig. 6 Era of "Techno-producers"

Techno-producers set the strategic and creative goals needed to create new markets and industries, playing a role similar to that of a composer or conductor in an orchestra; they not only must generate new concepts and construct new strategies, they must also lead the process of innovation. They play their part both inside their corporate organizations and across organizational boundaries to promote cooperation among the industrial, government, and academic sectors worldwide. Examples include Ken Kutaragi, father of the Sony Play station game console, whose strategy of using low-margin hardware as a platform for marketing high margin software powered catapulted Sony to the forefront of consumer electronics in the 1990s. Takeshi Uchiyamada, chief engineer on the Prius hybrid car, played a similar role. If Japan's industries are to remain competitive, they must have managers and technologists adept at working within the cross-generational model. No single, specialized set of skills will suffice. Rather managers must be technologically and scientifically literate, technologists managerially savvy. Since techno-producers will form the vanguard of this new elite, developing the requisite expertise must be a goal of the new MOT curricula in the nation's universities.

Any country will be able to improve the innovation performance if such talent producers are well trained and provided with such advanced techno-flow infrastructure where they can play their role in a way open to not only to the people of a country but also to all the people in the world.

Notice that it is important for a country to develop an innovation platform, which provide many techno-producers who create their strategic concepts and participate in sharing with strategic goals as much as possible [13]. Techno-producers are asked to play their part not only inside their organization but also outside across corporate and national boundaries and to promote cooperation among the industrial, governmental, and academic sectors worldwide.

Establishment of such social infrastructure for research and technology innovation management including these elements is politically important for a country like Japan having a national goal to build a science and technology based nation, as committed in the basic science and technology law established in 1999. This is an effective way to get out of its economic stagnation and to contribute more to the world, by refraining from the homogeneous and sometimes excessive competition, in the knowledge incentive information industry as well as manufacturing industry. In order to promote university-industry linkage, here proposed the third mode of collaboration that is more normative way of organizing innovation projects by creating new concept to share as the common goal and autonomous participations. It is quite different from the conventional modes of the first cooperation mode and the second coordination mode, with respect to the fist objective goal setting by a techno-producer and autonomous participation.

VII. JAIST-MOT FOCUSING on NEXT-GENERATION MOT

MOT has advanced by expanding its domain from RTD management, to technology transfer, technological innovation, technology strategy and planning, corporate venturing, and the integrated strategic roadmapping, which is closely linked with corporate business management. Professor Teruo Yamanouchi defined MOT from three different aspects as follows, (1) promote corporate technology strategy based on the corporate mission and objective, from the viewpoint of innovation management, (2) proceed dynamic process to create innovation and an effective management to achieve new technological knowledge and to accumulate technology assets,

and transform the knowledge to products, (3) transform technological knowledge system to a new knowledge system, in order to create new value by the reformation.

Advanced technologies, for example, NBIC (nano- and bio-technologies, information technology and cognitive sciences) and other science-driven technologies, are transforming the basic structure of product development, operations, planning and regulation across a wide range of industries. The pace of change is fast and growing faster, testing the managerial capabilities of even the most successful firms. Existing tools and practices are inadequate to cope with the challenges managers face in planning, managing, assessing, and deploying these new technologies, and linking them successfully to commercial opportunities. New methodologies and processes that combine academic and practice-centered knowledge are thus needed to prepare today's managers for tomorrow's technologies. Professor Michael Radnor says, it is about revolution of science and technology, and vividly illustrates the convergence of science and technology, in Figure 4. Now, the advanced technology convergence is coming on the new horizon and it is already evident that the greatest value and disruption will come from the convergence of these technologies - with each other, resulting in opportunities and threats for many manufacturing industries and long-held assumptions may hinder the ability of companies to capitalize on the converging technologies.

Next-generation MOT requires new methodologies for managing knowledge that will empower tomorrow's emerging science-driven innovation be organized and managed to maximize value creation. Success in such a dynamic environment requires responsive organizational structures and processes, and the focused use of new foresight, planning/ management systems and tools attuned to the emerging phenomena. These need to draw on appropriate models, insights, competencies and real-time experience from a wide range of specialized sources. No single consulting firm, university, agency or operating firm can today provide such help. In order to challenge this goal, the international university-industry MOT research collaboration organization; GATIC (Global Advanced Technology Innovation Consortium), initiated by ETH (Zurich - Europe), JAIST (Japan) and Northwestern University (US), formally was launched in September 2002.

VIII. JAIST-MOT: GLOBAL COLLABORATION by ESTABLISHING "GATIC" (Global Advanced Technology Innovation Consortium)

To ensure that the best possible new MOT content from around the world is incorporated in its curriculum, Three university professors of US, Europe and Japan have organized an international consortium aimed at developing and diffusing best practice in MOT education. Established in 2002, the Global Advanced Technologies Innovation Consortium (GATIC) brings together experts from the Swiss Federal Institute of Technology (EHT) in Switzerland, the Kellogg School of Management at Northwestern University in the US, and JAIST in Japan, in collaboration with top firms and other stakeholders spanning three continents. Its goal is to provide the necessary infrastructure that will support the development of creative solutions to the problems of managing technology in high-growth, science-driven sectors in volatile global markets. GATIC provides a forum for sharing knowledge, practice and insights through regional and global meetings. It will be an important resource for sharing and diffusing new knowledge in managing technology.

IX. JUST-IN-TIME INNOVATION

Now, it is critically important to review why Japanese manufacturing industries were so strong in 1970s and suddenly became week since 1990s, from the basic viewpoint. What had happened during the time was the change of the industrial structure and the innovation process model. The most important thing is to recognize the paradigm shift from the *"incremental innovation model"* to the *"radical innovation model"* in Japan. The incremental innovation model worked very well in 1970s and 1980s, but when it moves from follower to front-runner position, or from incremental innovation to the radical innovation process, the conventional innovation management model does not work well enough to keep the competitiveness. What Japan really has to improve is accordingly how to create new product, new businesses and new industries by creating new concepts. This paradigm shift requires management people with new capabilities of MOT and TIM (Technology Innovation management) professionals, who have to manage not only manufacturing but also the whole process of innovation, from technology knowledge creation, technology marketing, product production, business process and others. Accordingly, the span and skill of technology management became much broader to cover whole those processes by strategic linkage of technology and business.

The Just-in-Time production system is a very powerful manufacturing management technology, as it is widely well known. The basic principle of Just-in-time production is rational; and the system has been developed by steadily pursuing the orthodox way of production management. Consequently, the next challenge of next generation MOT is to establish a new sophisticated innovation management methodology suited for whole radical innovation process, by expanding its scope of management from *Just-in-Time production* to *Just-in-Time Innovation*. The "Just-in-Time Innovation" has to cover wide domains from basic and advanced research, applied research and development, technology marketing, manufacturing, business development, corporate management, as well as external resources and alliances, including university-industry collaborations. The concept of this "Just-in-Time Innovation" shown in Fig.7 could be a good strategic objective of the next generation MOT to be shared among people from academia, industry, government and many others to improve the total performance of innovation.

X. SYMBIOTIC COMPETITIVENESS

Take a close look at what competitiveness is for and what it should be like from a philosophical viewpoint. What is competitiveness? The late Hiroshi Inose implied a significant point that explained the concept of competitiveness. He said, "The word 'compete' derives from a Latin word 'competere'. The prefix 'com' means 'together' and 'petere' means 'pursue.' Consequently, 'competere' means to 'pursue together' [5]. But, what is to pursue? The answer is human ideals. When people pursue ideals, they help each other and strive together. In correcting each errors and compensating each other's weakness, and in acknowledging each other's insight and strength, they see the true competitiveness. Competitiveness, thus, should come from the power for self-discipline and not from the motive force to be superior by commanding power, tricks, or fraud tactics, because their purpose is to pursue human ideals." He explained a new idea of "comprehensive competitiveness" by integrating the human and social sciences and the natural sciences, and proposed that this new concept of competitiveness, based on oriental thought would help us more beyond the current western concept of competition. He said that Japan, from this time on, should always keep this new idea in mind and work to make this understood by people all over the world for their happiness in the 21st century.

XI. CONCLUSIONS

Future MOT faces challenges. It has to bring in new fields of management domain including science driven innovations, science and technology fusions, advanced technologies convergence, and technology-service convergence, which have very different factors from the past and conventional innovation process. Consequently, the new methodology for the next generation innovation management should integrate those various aspects so as to achieve comprehensive understanding of the emerging technologies and their social and business impacts. Such an integrated strategic planning and dynamic innovation management of technology is to be focused on "Just-in-Time Innovation" by expanding its scope of integration domain and time horizon to see the future, by developing an advanced technology roadmapping methodology that fits to the demand of corporate practices. At the same time, the next generation innovation model should be considered from global point of views, including international collaboration, global alliances, and competition.

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