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Trends in Policies for Promoting Converging Technologies Expected to Bring Innovation

YUKO ITO
Life Science Research Unit

1 Introduction

In 2002, the U.S. National Science Foundation (NSF) and the Department of Commerce published the first proposal for the promotion of converging technologies (hereinafter abbreviated as CT(s)) titled "Converging Technologies for Improving Human Performance[2]." Following publication, three annual conferences have been held since 2003, which were summarized by the NSF in a report titled "Managing Nano-Bio-Info-Cogno Innovations: Converging Technology Society" published in 2005[1].

Although they were not clearly defined in the report, CTs are acknowledged as "technologies converging two or more fields of science and technology for achieving specific goals" and "are categorized as 'metatechnologies' that affect other technologies to bring about drastic changes to the entire system."

According to the 2002 report, we are living in the "Age of Transition" and are already experiencing technological innovations brought by computer and information technologies, nanotechnology and biotechnology. From now on, CTs, which are based on these technologies and transcend conventional frameworks in the fields of science and technology, are expected to serve as key technologies that will trigger revolutionary technological and social changes[2].

Regarding NBIC (pronounced enbick or nibick), which stands for the four fields of nanotechnology, biotechnology, information technology and cognitive science, rapid and expansive integration of technologies is observed, and new technologies are continuously being created.

Consequently, the CTs attracting most attention today are "technologies developing from the 'convergence of NBIC'" and "technologies assisting or enhancing the convergence of NBIC" (Figure 1). Such technologies are believed to create sciences and technologies producing paradigm shift or innovation, and the U.S. promotes further convergence of NBIC-based technologies in the Science and Technology Policy[3].

The mission-oriented aspect and the strong need-oriented aspect of CTs enable them to associate social needs or policy issues with specific science or technology. The U.S. expects that promoting CTs will result in drastic improvement of human performance, social innovation and the creation of new business.

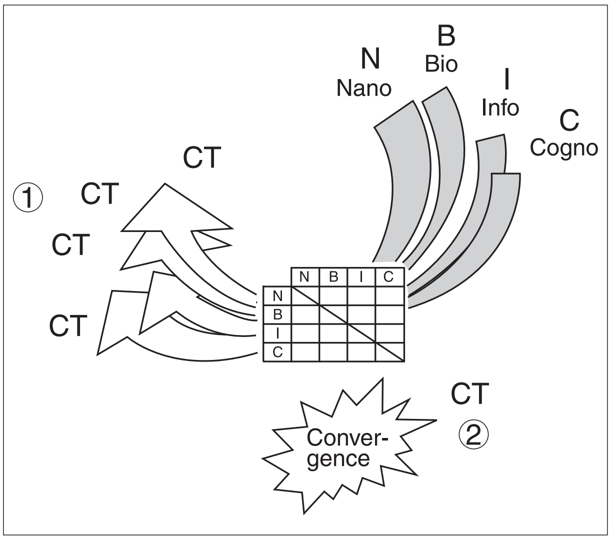

Figure 1 : NBIC and CTs (converging technologies)

(i) Technologies developing from the convergence of NBIC in various combinations
(ii) Technologies assisting or enhancing the convergence of NBIC

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Inspired by the U.S. trend, the European Commission (EC) established an expert group in 2003 to start discussing the European approaches regarding CTs. In 2004, the Commission released a report titled "Converging Technologies - Shaping the Future of European Societies"[4].

Unlike the U.S., the EC has not included "improvement of human performance" in the goals of CTs. Moreover, EC's standpoint slightly differs from that of the U.S., i.e., in addition to the bright future brought by the introduction of CTs, technical limitations or concerns as well as social influences, such as predictable risks, have been brought up for discussion. Nevertheless, the report concluded that "the European societies will be newly shaped by CTs." CTs are expected to contribute to the implementation of the "Lisbon Strategy," which aims at enhancing economic growth and employment by increasing the competitiveness of European economy. The Commission has set the agenda "CTs for the European Knowledge Society (CTEKS)" and proposed to initiate CT research programs. The KNOWLEDGE NBIC Project (2006-2009), funded by the Sixth Framework Programme for Research and Technological Development (FP6) and the following FP7 (2007-2013) by the European Commission, has been implemented to advance research and investigation on the promotion and social application of CTs.

Meanwhile in Japan, no particular discussion on CTs has occurred.

Chapter 2 of the present report introduces the CTs reviewed in the U.S. and their positioning in U.S. Science and Technology Policy. Chapter 3 attempts to evaluate the international status of progress in CT research through bibliometric analysis. Chapter 4 discusses the incorporation of CTs into Japanese Science and Technology Policy, and Chapter 5 proposes measures to be taken in Japan.

2 Twenty topics for CTs discussed in the U.S.

CTs are potentially involved in critical areas having great impact on human activities. Such areas are (i) revolutionary tools or products, (ii) daily human performance, such as work efficiency, accelerated learning (i.e., learning of new knowledge at a high speed), and increased group performance, (iii) changes in organizations, business models and policies for reestablishing infrastructure and setting priorities for R&D planning and (iv) trends toward a "global information exchange" regarding ideas, models and cultures.

The 2002 report[2] listed 20 specific examples (topics) of CTs with potential contributions to the improvement of human performance, etc. within the next one or two decades. Moreover, the 2005 report presented the results of a survey in which experts from industry, government and academia who participated in the preparation of the report were asked to estimate when each of these 20 CT topics might be accomplished. As described below, the content and results of this survey closely resembled those of the Science and Technology Foresight Survey (Delphi Analysis) performed every five years by the National Institute of Science and Technology Policy in Japan.

2-1 Expected years of accomplishment and ratings of benefit of the 20 CT topics

For the 20 CT topics, 26 experts from industry, government and academia were asked to estimate when each of these 20 CT topics might be accomplished and their ratings of benefit. The expected year of accomplishment is defined as "the breakthrough year" in which each of these technologies will be at least partially accomplished. Medians are presented instead of averages for the expected years of accomplishment and ratings of benefit. The ratings of benefit are expressed on a 1 to 10 scale, in which 10 is the maximum.

As shown in Table 1, the 20 CT topics cover a wide range of areas, including health, information, communication and engineering. The CT topics with the earliest expected year of accomplishment were "(3) comfortable, wearable sensors and computer," "(9) instantaneous access to information from anywhere in the world" and "(13) new organizational structures and management principles," whose expected years of accomplishment were 2015, while the topic with the latest expected year of accomplishment

Table 1 : Expected years of accomplishment and ratings of benefit of 20 representative CT topics

CT topics	Expected years of accomplishment	Ratings of benefit of technologies (from 0 to 10, 10 is the maximum)
(1) All kinds of machines and structures, from homes to aircraft, will be constructed of materials having desired properties, including adaptability to changing situations, high energy efficiency and environmental friendliness.	2030	8.9
(2) Individuals or groups of individuals will be able to communicate and cooperate across traditional barriers of culture, language, distance and professional specialization.	2020	8.8
(3) Comfortable, wearable sensors and computers will enhance each individual's access to information of interest, such as his or her health condition, environmental pollution, etc.	2015	8.7
(4) Agriculture and the food industry will increase yields and reduce spoilage through inexpensive networks and smart sensors that constantly monitor the conditions and needs of plants, animals and farm products.	2020	8.7
(5) A combination of technologies and treatments will compensate for many physical and mental disabilities.	2025	8.6
(6) The human body will be more durable, healthier, more energetic, easier to recover and more resistant to various kinds of stress, biological threats and aging.	2025	8.5
(7) The work of scientists will be revolutionized by importing approaches pioneered in other sciences (for example, genetic researchers employ tools or knowledge from natural language processing, and cultural researchers employ tools, etc. from genetics).	2020	8.5
(8) People from all backgrounds and at all levels of ability will gain valuable new knowledge and skills more quickly and reliably at school, job or home.	2020	8.4
(9) Anywhere in the world, an individual will have instantaneous access to information of interest.	2015	8.3
(10) Engineers, artists, architects and designers will experience a dramatic expansion of creative abilities, both with a variety of new tools and through increased understanding of the wellspring of human creativity.	2020	8.3
(11) Average individuals, as well as policymakers, will have an improved awareness of the cognitive, social and biological forces affecting their lives, enabling more adaptive and creative decision making in their daily lives.	2020	8.3
(12) Transportation will be safe, cheap and fast, due to ubiquitous realtime information systems, extremely high-efficiency vehicle designs and the use of synthetic materials and machines fabricated from the nanoscale to achieve optimum performance.	2030	8.3
(13) New organizational structures and management principles based on fast and reliable communication of needed information will drastically increase efficiency for administrators of business, education, and politics.	2015	8.0
(14) Factories in the future will serve as "intelligent environments" that achieve the maximum benefits of both mass production and custom design through systematization of converging technologies and improvement of human-machine capabilities.	2020	7.8
(15) Education will be transformed into a unified but diverse curriculum based on a comprehensive, hierarchical intellectual paradigm for understanding the structure of the physical world from the nanoscale through the cosmic scale.	2030	7.5
(16) Robots and software agents* will be more useful for human beings (* software capable of autonomously adjusting its own action in accordance with change in execution environment or user instructions).	2025	7.2
(17) The potential of the vast universe will be appreciated by means of exploitation of celestial resources such as the moon and Mars, which are near to the earth, efficient landing vehicles and robotic construction of extraterrestrial bases.	2050	6.7
(18) Direct broadband interfaces between the human brain and machines will be introduced into factory work, automobile control, military activities, etc.	2030	6.4
(19) Genetic control of humans, animals and agricultural plants will greatly benefit human welfare (a widespread consensus about ethical, legal and moral issues will be built in the process).	2030	6.2
(20) National security will be reinforced by lightweight, information-rich combat systems e.g., unmanned combat vehicles, smart materials, invulnerable data networks, superior intelligence-gathering systems, effective technologies for detecting and measuring biological, chemical and nuclear attacks.	2020	5.5

Prepared by the STFC referring to Reference[1]

Table 2 : Additional CT topics with high ratings of benefit (8.5 or larger)

CT topics	Expected years of accomplishment	Ratings of benefit of technologies (from 0 to 10, 10 is the maximum)
We will have the technical means to ensure an adequate food supply, clean air and clean water.	2030	9.2
Assistive technologies will overcome disabilities such as blindness, deafness and immobility.	2035	8.8
Computer interface architectures will be changed so that disabled people can access the Internet and other information sources as quickly as other people.	2015	8.8
Free availability of information to disadvantaged people around the world will improve their agricultural production, health, nutrition and economic status.	2015	8.6
A deep understanding of the visual language – communication by pictures, icons and diagrams – will realize more effective interdisciplinary communication, more complex thinking and breakthroughs in education.	2025	8.5

Prepared by the STFC referring to Reference[1]

was "(17) exploitation of celestial resources such as the moon and Mars," which was expected to be accomplished in 2050. The topic with the highest and the lowest ratings of benefit were "(1) machines and structures constructed of new materials" and "(20) reinforcement of combat systems," respectively.

The 2005 report added 56 topics to the above 20 CT topics and discussed 76 topics in total. Among the 56 additional topics, those with ratings of benefit of 8.5 or larger were extracted in Table 2. Among these five highly beneficial CT topics, four aimed directly at human performance improvement. The additional topics included five topics involving performance improvement of soldiers, etc. all of which were given low ratings of benefit. (For reference, see "new realistic training environments revolutionizing training of military personnel, such as virtual-reality battlefields and war-gaming simulations, 2010, rating of benefit 6.2," "soldiers having the ability to control vehicles, weapons and other combat systems instantly, merely by thinking the commands, 2045, rating of benefit 4.5").

2-2 CTs in U.S. Science and Technology Policy

According to the 2005 report, NSF, NASA (National Aeronautics and Space Administration), EPA (Environmental Protection Agency), DOD (Department of Defense) and DOE (Department of Energy) are engaged in research and development projects involving more than one NBIC field. This implies that the U.S. is already implementing national projects related to CTs.

Examples of national initiatives (U.S. systems for setting national strategic agendas and implementing them in an integrated manner) related to NBIC are the Information Technology Research (ITR) Initiative announced in 1999, which aims at the promotion of basic and long-term IT research, and the National Nanotechnology Initiative (NNI) announced in 2000, which aims at promoting nanotechnology. The budgets in fiscal year 2005 for these two ongoing initiatives were $2,000 million and $1,200 million, respectively.

The concept of CTs, i.e., the convergence of different fields, originated from NNI that covers the promotion of integration of sciences and technologies at the nanoscale. However, the 2005 report proposes that NNI support the implementation of CTs through cooperation with ITR, as well as with long-term strategic projects related to NBIC other than national initiatives, i.e., projects implemented by individual agencies or national organizations, such as the NIH's Roadmaps implemented by NIH for promoting biomedical research.

2-3 U.S. industries and CTs

To some extent, U.S. industry is already involved in the U.S. Science and Technology Policy regarding CTs. The 2002 report includes a list of participants in the CT expert meeting that served as the source of this report and contributors to the preparation of the report. The list includes 32 members from the government or national research institutes, namely, NSF, DOE, DOC (Department of Commerce), NASA, NIST (National Institute of Standards and Technology), NIH, EPA, Office of Naval Research, U.S. Air Force Research Laboratory, NOAA (National Oceanic and Atmospheric Administration), etc. Twenty eight members were from the academia, namely, Stanford University, Carnegie Mellon University, Massachusetts Institute of Technology, University of California (Berkeley, Los Angeles, San Diego, etc.), and University of Texas, etc. Eighteen members participated from various fields of industry, including companies such as Boeing, HP (Hewlett-Packard) Labs, IBM, Lucent Technologies (business field: network and communication system), TissueInformatics (biomedical tissue screening system), Klein Associates (undersea exploration and security), Institute for Global Futures (think tank) and New England Complex Systems Institute (complex systems).

The promotion of CTs can be categorized as a science and technology policy of a top-down style, but the U.S. government seems to be successfully involving industry. Consequently, future promotion of CTs may realize convergence of NBIC studies conducted in various industrial, governmental and academic organizations and enable laborsaving and acceleration in the series of procedures from basic and applied research to industrialization.

3 Global status of progress in research related to CTs

The U.S. is promoting CTs as a part of a Science and Technology Policy, but what is the actual status of progress in CT research in the U.S.? Is it possible to understand the global status of CTs? Since CTs cover various fields of research, it is very difficult to evaluate the progress of CTs themselves. As an attempt to overcome such difficulty, the author evaluated the progress in CTs by analyzing the number of research papers.

Moreover, this chapter introduces a report by a U.S. think tank, RAND Corporation, which has made a global comparison of capacity to conduct bio/nano/material/information studies, and describes the global status of CT studies based on the report.

3-1 Bibliometric analysis regarding CTs

Using the Web of Science (Thomson) as a research paper database, papers published from 1980 to January 16, 2007 (1,468 papers) were searched by the keywords "converg* AND technolog*." In order to extract papers related to NBIC, a further search was conducted using the keywords "nano* OR bio* OR info* OR cogn*" (* at the end of the string represents any letter(s). For example, "converge," "convergence" and "converging" are simultaneously retrieved by "converg*").

The targets searched were "titles," "keywords set by the author" and "abstracts." The following analyses were performed with the assumption that all retrieved papers were related to CTs. The transition of the number of papers, the number of papers published in individual countries, the study field classification and the number of related papers were analyzed using the Analyze of the Web of Science. The study field classification used here conformed to the Thomson classification.

(1) Transition of the number of papers and breakdown

The search retrieved 452 papers as CT papers related to NBIC. The annual number of papers showed an increasing trend and was particularly large in 2004 (Figure 2).

Among NBIC, information technology had the largest share (61%) in the gross number of papers, followed by biotechnology (24%),

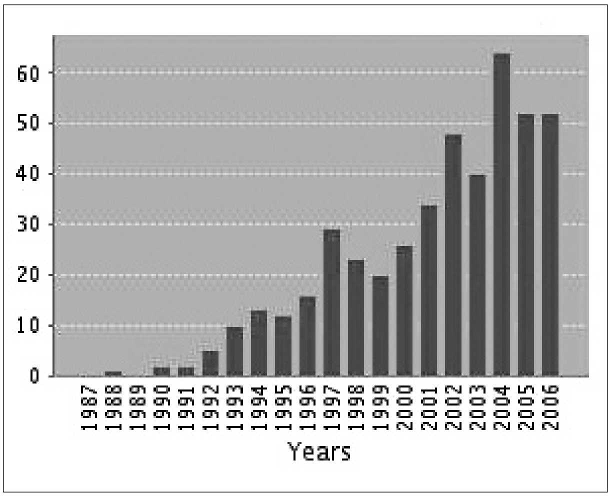

Figure 2 : The transition of the number of papers retrieved by keyword searches

Prepared using a function of Web of Science

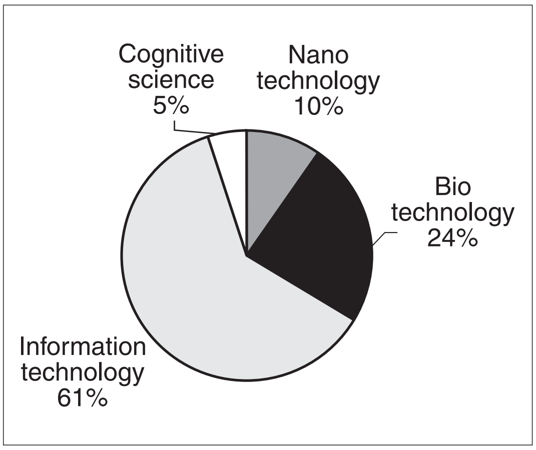

Figure 3 : Breakdown of retrieved papers by NBIC field (gross number of papers)

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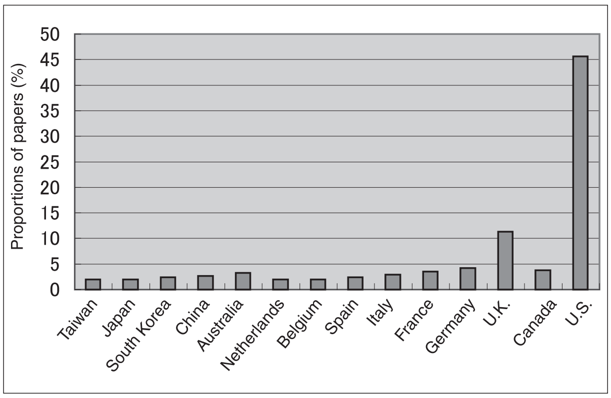

Figure 4 : Country-by-country proportions of papers

Prepared by the STFC

nanotechnology (10%) and cognitive science (5%)(Figure 3). About 2% of the papers were potentially related to all four fields of nanotechnology, biotechnology, information technology and cognitive science. Among the papers related to more than two fields, such as "nanotechnology and biology," "information technology and cognitive science" or "biotechnology, nanotechnology and cognitive science," those related to "biotechnology and information science" were most commonly found, accounting for 7%.

Further analysis of the papers published in 2003 and 2004 revealed that the number of papers drastically increased during this period, not only in the field of nanotechnology but also in the other three fields of NBIC. This increase might be attributed to the enforcement of the U.S. CT promotion policy in 2002.

Table 3 : The study field classification and the number of related papers

Study field classification	Number of papers	Proportion (%)
Engineering, Electrical & Electronic	67	14.8
Telecommunications	67	14.8
Computer Science, Information Systems	64	14.2
Computer Science, Theory & Methods	46	10.2
Information Science & Library Science	39	8.6
Computer Science, Hardware & Architecture	23	5.1
Computer Science, Interdisciplinary Applications	23	5.1
Management	23	5.1
Multidisciplinary Sciences	23	5.1
Computer Science, Software Engineering	20	4.4
Operation Research & Management Science	18	4.0
Chemistry, Multidisciplinary	16	3.5
Engineering, Multidisciplinary	15	3.3
Biochemistry & Molecular Biology	14	3.1
Biotechnology & Applied Microbiology	14	3.1
Pharmacology & Pharmacy	14	3.1

Prepared by the STFC

(2) Number of papers published in individual countries

Figure 4 shows the country-by-country proportion (%) of papers to the total number of papers. The U.S. had the largest share (46%) followed by the U.K. (11%), while the rest of the countries had substantially the same shares (5% or less). The European countries collectively accounted for around 33% of the total, being the second to the U.S.

(3) Study field classification and number of elated papers

Table 3 shows the study field classification and the number and proportion (%) of related papers. Papers related to "Engineering, Electrical & Electronic" and "Telecommunications" had the largest shares (15%), followed by "Computer Science" and "Information Science." Papers related to "Management" and "Operation Research" came next, followed by "Chemistry" and "Biotechnology."

The above results demonstrated that, as

Table 4 : The top 16 technologies related to bio/nano/materials/information having potential impact on society

1. Cheap solar energy
2. Rural wireless communications
3. Communication devices for ubiquitous information access anywhere, anytime
4. Genetically modified (GM) crops
5. Rapid bioassays
6. Filters and catalysts for water purification and decontamination
7. Targeted drug delivery
8. Cheap autonomous housing
9. Green manufacturing
10. Ubiquitous RFID tagging of commercial products and individuals
11. Hybrid vehicles
12. Pervasive sensors
13. Tissue engineering
14. Improved diagnostic and surgical methods
15. Wearable computers
16. Quantum cryptography

From Reference[5]

expected, the U.S. has published the largest number of NBIC-related CT papers, followed by European countries as a whole.

Moreover, although Tables 1 and 2 included many CT topics related to biotechnology, Table 3 showing the study field classification and the number of related papers demonstrated that research papers related to biotechnology were still few. CT studies are currently focused on information science and perhaps will be gradually shifted to biotechnology and nanotechnology. In practice, we still seem to have a long way to the realization of CTs based on NBIC.

3-2 Global comparison of capacity to implement bio/nano/material/information studies

In 2006, a U.S. think tank, RAND Corporation, published a report titled "The Global Technology Revolution 2020, In-Depth Analyses: Bio/Nano/Materials/Information Trends, Drivers, Barriers, and Social Implications,"[5] which evaluated the capacity of 29 countries to implement 16 advanced technologies related to bio/nano/mate rials/information by 2020. Cognitive science was not included in the scope of the evaluation.

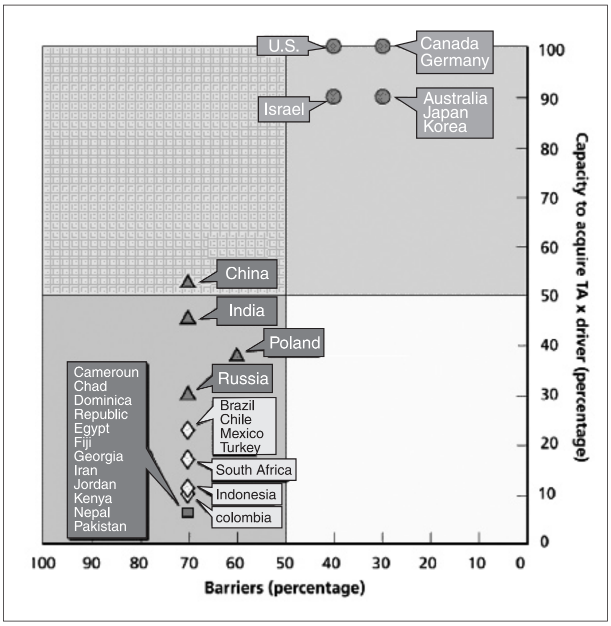

Figure 5 : International comparison in capacity to implement the top 16 technologies related to bio/nano/materials/information

From Reference[5]

The evaluation was performed on the "top 16 technologies related to bio/nano/materials/infor mation having potential impact on society (Table 4)." The "top 16 technologies" were selected based on technological forecasting papers (scenarios) regarding individual fields of bio/n ano/materials/information by 2020 and factors such as "technical feasibility," "social feasibility (nontechnical barriers such as market demand, cost, infrastructure, policies and regulations)" and "global diffusion" by 2020.

Individual countries were evaluated on "cost/financing," "laws/policies," "social values, public opinions and politics," "infrastructure," "privacy concerns," "resource use and environmental health," "investment in R&D," "education and literacy," "population and demographics" and "governance and stability."

As shown in Figure 5, along with the U.S., Canada, Germany, South Korea, Australia and Israel, Japan appears in the upper right section, indicating that the country has a high level of science and technology capability and many drivers and few barriers to technology implementation. The barriers in Japan were assumed to be "laws/policies," "social values, public opinions and politics" and "governance and stability," which were also pointed out as barriers in South Korea.

Combining the results of this global comparison with the country-by-country proportion of research papers on CTs shown in Figure 4, the U.S. indeed has an advantage over other countries, but its technological capability is not much different from those of other countries. China has a high level of science and technology capacity and many drivers of technology implementation but faces many nontechnical barriers to the implementation. Compared to China, India has a lower science and technology capacity and fewer drivers of technology implementation.

As can be seen, the U.S. views Japan as one of the countries capable of implementing bio/nano/materials/information studies. However, countries such as South Korea, China and India, are rapidly developing their science and technology capacities and shifting their social systems and environments towards research promotion. Thus, there is no guarantee that Japan can keep its current global position in the next decade. There is no need to copy U.S. or European policies, but it is important that we adopt policies enabling efficient implementation of science and technology through further development of science and technology capacity, promotion of convergence between different fields of science and technology, removal of conventional barriers and shortening of the process to technology accomplishment.

4 Status of country-level policies for promoting CTs in Japan

Although Japan has no specific country-level policy regarding CT promotion, the concept of CTs may be added to the existing national policies regarding science and technology. As an example of such approach, this chapter discusses the “Coordination Program of Science and Technology Projects,” which is a national policy for collectively promoting similar research projects conducted among different ministries.

The Coordination Program of Science and Technology Projects was adopted by the Council for Science and Technology Policy in 2004 and launched in July 2005. About a year later, in November 2006, the Council for Science and Technology Policy announced “Achievements and future topics and plans of the Coordination Program of Science and Technology Projects (interim report)[6].”

The purpose of the Coordination Program of Science and Technology Projects is that “the Council for Science and Technology Policy will establish important national and social themes to be promoted through collaboration among various government ministries concerned, eliminate unnecessary redundancies among policies related to each theme and strengthen collaboration, with an eye to linking together the vertically arranged policies of individual

Table 5 : Themes and research topics of the Coordination Program of Science and Technology Projects corresponding to U.S. CT topics

Themes and research topics	Goals
Ubiquitous networks – development of electronic tag technology, etc. – “Demonstration experiment for the application of electronic tags in the medical field (from 2005)” “Research and demonstration of innovative application of ubiquitous networks (from 2006)”	Establishment of core technology platforms for realizing ubiquitous network society
Next-generation robots – establishment of common technology platforms – “R&D of basic models of environmental information structuring platforms (from 2005)” “Establishment of robot software platforms that can be accumulated and reused (from 2005)” “Project for delivering structured environmental information services to people traveling indoors and outdoors (from 2006)” “Project for structuring environmental information for handling objects in workspace (from 2006)”	Establishment of common technology platforms covering various application fields of next-generation robots
Nanobiotechnology “Aid for nano-drug delivery systems based on molecular imaging (from 2005) (from 2006)” “Nanobiosensors (from 2005) (from 2006)”	Realization of good health, longevity and a safe and secure society through research that integrates nanotechnology and biotechnology

Prepared by the STFC referring to Reference[6] ministries. This should create synergistic and integrated effects to bring an excellent outcome as a whole.[6]" (The underlined part was added by the author.)

The expected outcomes are maximizing research results and generating innovation. Table 5 shows the themes, targets and related fields of the Coordination Program of Science and Technology Projects. Some of the CT topics presented in Table 1, such as ubiquitous systems and robots, also appear as themes for the Coordination Program of Science and Technology Projects. The original purpose of the program is to "collaborate among ministries," and to "create synergistic and integrated effects to bring an excellent outcome as a whole," which is claimed in the underlined part of the purpose, overlaps with the effects expected from CT promotion. Therefore, regarding these themes, the Coordination Program potentially brings more than just the collaboration among ministries by taking advantage of the strong mission-oriented nature of CTs and strategically integrating multiple research topics.

The interim report suggested that the future topics would be "consistent strengthening of collaboration, from basic research and R&D through application," "information sharing among ministries as well as the private sector" and "further exploitation of the Coordination Program of Science and Technology Projects." Future plans suggested in the report included "the expansion of the scope of the Coordination Program to the Strategic Prioritized Science and Technology for effective implementation of the promotion strategies for prioritized areas of the Third Science and Technology Basic Plan." Regarding the expansion of the scope of the Coordination Program, the report suggests that the plan is to "select and intensively promote the target Strategic Prioritized Science and Technology from the standpoint of collaboration promotion, innovation creation, etc." Since the scope of the Coordination Program will be expanded in hope of generating innovation, it is strongly suggested that the Program will be implemented by setting specific agendas and actively incorporating concepts such as CTs.

5 Measures to be taken in Japan

CTs differ from the so-called integration technologies or fusion technologies in the following three aspects: (i) CTs are mission-oriented and strongly needs-oriented, (ii) CTs are truly (both technologically and socially) revolutionary and (iii) CTs are interdisciplinary technologies based on NBIC.

Japan has recently become aware of the importance of integration and fusion of technologies, and implementation measures have been proposed by government, industry and academia. Yet, none of these measures has covered all the above three aspects. Vertical driving powers within individual science and technology fields are strong in the Japanese government-industry-academia systems, which are said to be hindering the creation of interdisciplinary technologies. However, interdisciplinary technologies based on NBIC are potentially important technologies (CTs) having a great impact on society, so these Japanese systems need to be modified to enhance creation of interdisciplinary technologies. It might be effective to establish, for example, a government-industry-academia platform that links the NBIC fields together.

In order to create many CTs and consequently accomplish the targeted topics, management systems and methodologies for performing the topics need to be established, which should accelerate technology development and shorten the time for accomplishment. Research and technology development should be conducted by analyzing the current status and prospects for science and technology development, predicting the future market scales from social needs (personal concerns, etc.) and social changes (population composition, disasters, crime, employment, medical care, etc.), incorporating science and technology forecasts and technology roadmaps in the early stages of technology development and analyzing them through an integrated approach to obtain results that serve as the basis for research and technology development. By combining these approaches, we should be able to specify which science or technology in the NBIC fields is effective for accomplishing the topics at a certain time point. Under the current circumstances in which science and technology seeds are created everyday, these approaches should serve as a compass for reaching the island of innovation in the ocean of science and technology.

The following country-level activities regarding CTs are considered to be effective for Japan in the future:

(i) Holding of workshops on CTs regarding specific themes by government-industry-academia groups concerned with common missions and topics, where participants can exchange opinions and share knowledge on CTs.
(ii) Reconsideration of the Strategic Prioritized Science and Technology areas of the Third Science and Technology Basic Plan for individual purposes from the viewpoint of CTs, and collective promotion of those expected to be effective in developing innovation through interdisciplinary implementation.
(iii) Government-industry-academia collaboration in the selection of topics that are considered to be important in the future Japanese society and can be accomplished by science and technology, the investigation of their status of progress and the formulation of promotion policies.

In addition to field-specific promotion policies, which have already been adopted in the current Third Science and Technology Basic Plan, policies for promoting the construction of "bridges" between different fields need to be formulated in the Fourth Science and Technology Basic Plan, probably launched in 2011. Whether or not CTs would be the "bridges," it should be meaningful to discuss country-level promotion based on such viewpoint.

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Yuko ITO, PhD
Head, Life Science Research Unit

Ph.D. in Pharmaceutical Sciences. Formerly engaged in experimental research about structural and functional analysis on human chromosomes. Currently specializing in science and technology policy. Interested in the trend of advanced life sciences, competitive research funding systems for young researchers, and process of social application of scientific findings.

(Original Japanese version: published in February 2007)