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The National Science Foundation Tokyo Regional Office periodically reports on developments in Japan that are related to the Foundation's mission. It also provides occasional reports on developments in other East Asian countries.

Tokyo Office Report Memoranda are intended to provide information for the use of NSF program officers and policy makers; they are not statements of NSF policy.

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Robotics Research in Japan

At their monthly meeting in May 2006, the CSTP (Council for Science and Technology Policy), Japan's highest decision-making body for science and technology policy, made public their projection for Japan's Robot Market in 2025 as Yen 6.2 trillion (about $54 billion) (See Figure 1). On June 1, the NSF Tokyo Regional Office organized a meeting between prominent Japanese professors in Robotics and U.S. Air Force, Army and Navy Office officers to exchange information. The three military Offices made presentations that included opportunities for providing research funds to Japanese university professors. The Japanese professors presented robotics research in Japan to provide an overview of

robotics research in Japan.

Reflecting all of these, this report is to overview robotics research in Japan, focusing on the R&D supported by the government funds in the following order:

1. **Expectation for Robotics Research**
2. **Government-funded Robotics Research Players in Japan**
3. **Robots and Japanese**
4. **"Monozukuri" Concept at Assembly Lines**
5. **Future and Conclusions**

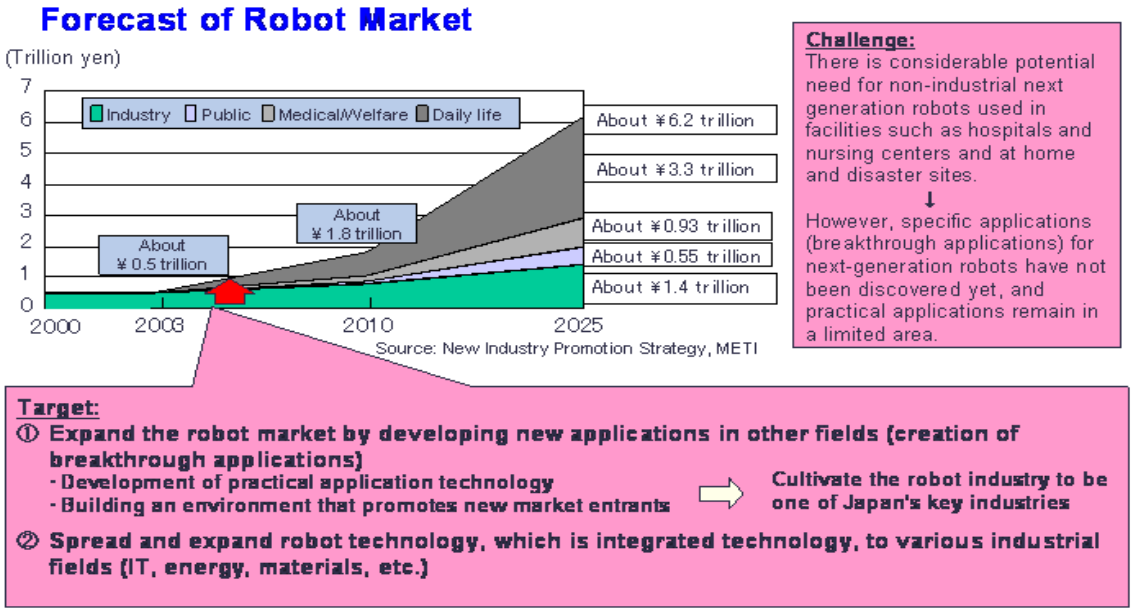


Figure 1: Basic Concept for Robot Technology Development

Source: CSTP Home Page

1. Expectation for Robotics Research

Historically, with the rapid growth of industries in the 1960s and the resulting labor shortage

and the need for improving labor environment in 1970s, industrial robots came to be fully utilized. Since then, Japan's robot technology has reached the world standard. Currently, 40 percent of industrial robots that are now under operation all over the world are in Japan. This fact reinforces that Japan is a "Robot Nation" or "Robot Technology (RT) Nation." Moreover, in recent years, advancement of sensing technologies, including vision sensors and power sensors, and control technologies, as well as element technologies, are prominently utilized in industrial robots. Thus, industrial robots' activities are no longer restricted to transportation and welding/coating, but being expanded to more advanced and complicated processing tasks like assembling/cell production.

On the other hand, "Robotics" is presently one of the most highlighted research fields in Japan from the viewpoint that Japan is having more elderly people and the number of young people is decreasing (See Figure 2).

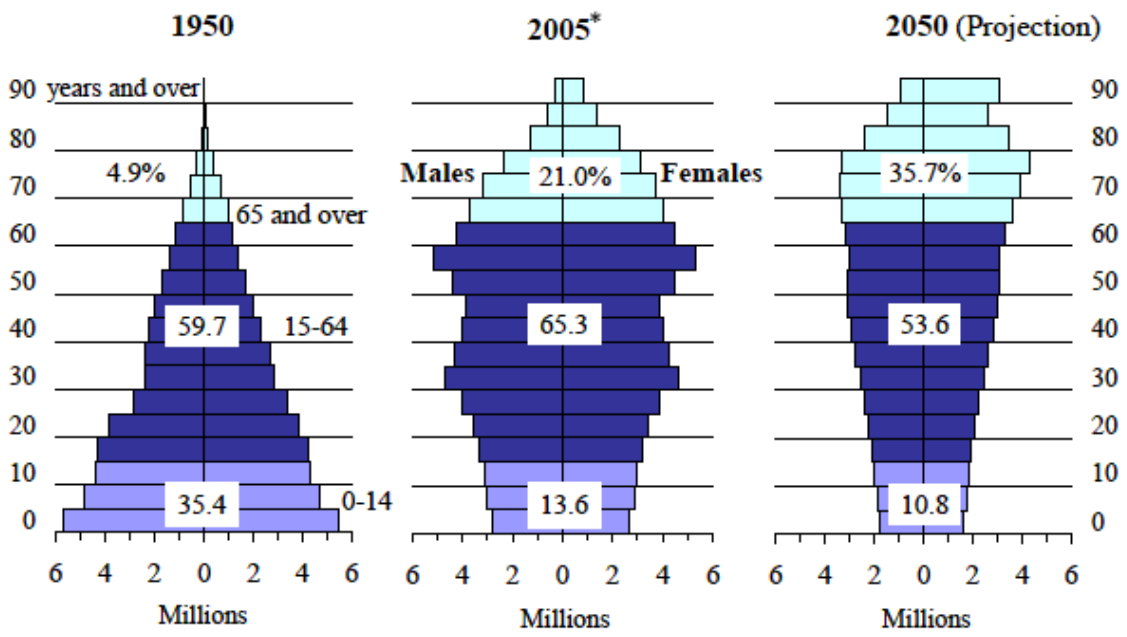


Figure 2: Changes in Population Pyramid

Source: Statistics Bureau, Ministry of Health, Labor and Welfare

Apparently, this will cause shortage in labor force and therefore Japan is going to be more dependent on robots that can handle multi-tasks, including house-keeping, welfare, and rescuing, in addition to tasks at assembly lines. The Aichi EXPO that was held in summer 2005 was a good opportunity for Japan to exhibit to the world Japan's high-level technology in robotics research at industry, government and academia and the variety of tasks that robots perform, outside of assembly lines. The Aichi EXPO showcased fundamental technologies for service robots, such as image recognition, voice recognition, autonomous movement and obstacle and hazard avoidance. In addition, the utility and reliability of service robots were verified at the EXPO site (See Figure 3).

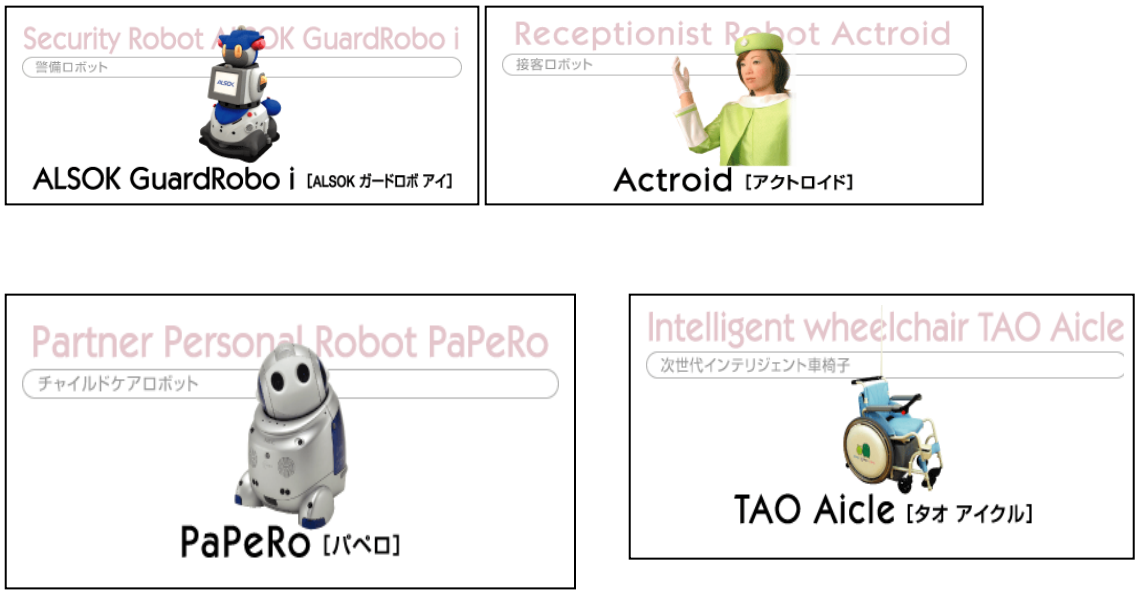


Figure 3: Samples of Robots Shown at the Aichi Expo in 2005

Source: Aichi Expo Homepage

2. Government-funded Robotics Research Players in Japan

Another expectation on robotics research in Japan is that it has potential to create "innovation," the word cited more than 35 times in the Japan's Third Science and Technology Basic Plan that covers Japan's S&T policies during 2006-2010. As a matter of fact, robotics research is one of the CSTP-designated fields that require to be promoted under cross-agency coordination. Major government-funded robotics research players and their projects are summarized in Table 1 (Table 1 was compiled by CSTP's IT

Department). Also, the following are summaries of the major government-funded robotics projects.

MIC (Ministry of Internal Affairs and Communications)

ATR (Advanced Telecommunications Research Institute International)

Their research focuses on “Network Robots,” a combination of robotic and ubiquitous network technologies. It changes the traditional concept of robots that is represented by arm-type robots and humanoid-type robots. Through a network, the application and contents of robots can be distributed. This enables the traditional “visible” robots to far expand their ability in space utilization, continuous movement, information sharing, and remote manipulation. These technologies are essential in supporting life in the future when elderly people constitute one fourth of the Japanese population.

METI (Ministry of Economy, Trade and Industry)

NEDO (New Energy and Industrial Technology Development Organization)

METI’s funding agency

AIST (Agency for Advanced Industrial Science and Technology)

METI’s research implementation agency

AIST focused on Humanoid robotics project from 1998-2002, and Expo 2005 robotics project from 2004-2005. From 2005, they started Welfare robots (2005-2007), Robotic devices project (2005-2007), Service robots project (2006-2007), and Robotics challenges project (2006-2010). METI’s roadmap for robotics research is described as in Figure 4 (I means Industry; II is for establishing system; III for development for future purposes; IV for basic technology development).

MEXT (Ministry of Education, Culture, Sports, Science and Technology)

NIED (National Institute of Environment and Disaster Prevention)

DDT (Dai-Dai-Toku) Project

DDT means Special Project for Earthquake Mitigation in Urban Areas. As one of MEXT’s special projects in Life Science, IT, Environment, Nanotechnology/Materials, and Disaster Prevention, this project was launched in 2002. The DDT project has been conducted at Tokyo University, Kyoto University, NIED, and the International Rescue System Institute (IRSI). IRSI, a non-profit-making organization, focuses on R&D on element technologies

of robot, intelligent sensors, mobile terminals, and human interfaces. Further, IRSI combines these element technologies for active and intelligent collection of information. And they transmit, put together, and summarize the information via a network, so that they can develop a system that supports human activities and decision-making at the time of critical disaster.

MEXT (Ministry of Education, Culture, Sports, Science and Technology)

JST (Japan Science and Technology Agency)

JST is a project-oriented funding agency under the MEXT. The following robotics research projects have been supported by JST.

. R&D for Supporting Humanitarian Demining of Anti-personnel Mines: Professor Katsuhisa Furuta: 2002-

. Interaction and Intelligence: Professor Humio Harashima: 2000-2004

. Creating the Brain: Dr. Shun-ichi Amari: 1999-2006

. Kawato Dynamic Brain: Dr. Mitsuo Kawato: 1996-2001

. Kitano Symbiotic Systems: Dr. Hiroaki Kitano: 1998-2003

MEXT (Ministry of Education, Culture, Sports, Science and Technology)

Grant-in-Aid for Scientific Research

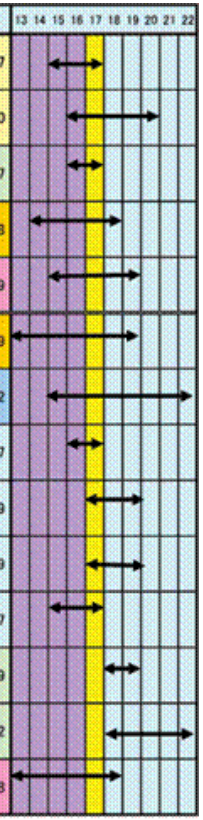
This is a grant funded by MEXT, and the recipients are university professors. Big projects are managed by MEXT and those with smaller-scale funds are managed by JSPS (Japan Society for the Promotion of Science). Examples of the recipients of this grant in robotics field are:

. Mobiligence: Emergence of Adaptive Motor Function through the Interaction among the Body, Brain, and Environment by Professor Hajime Asama, University of Tokyo

. System Cell Engineering by Multi-scale Manipulation by Professor Toshio Fukuda, Nagoya University

Table 1: Japanese Government Robotics Research Players

	Projects	Ministry/Agency	Implementing Organization	HFY2005	JFY2006	Period
1	Network/Human Interface : Language translation	MIC	ATR	121	–	H15～H17
2	Network/Human Interface : Network robot	MIC	ATR	295	300	H16～H20
3	Fire extinction and disaster prevention robot	MIC & Fire Agency	Organizations that belong to "Committee for commercializing search/probing robots at the time of disaster	106	–	H16～H17
4	Rescur robot	MEXT	International Rescur System Institute	Part of 997 (314 was definitely used)	Part of 875	H14～H18
5	IT building systen by robot	MLIT	Public Works Research Institute	156	146	H15～H19
6	Bio-mimetic control	RIKEN	Bio-mimetic Research Institute	417	396	H13～H19
7	Strawberry cropping robot	MAFF	National Agriculture and Food Research Organization	Part of 1,878 (about 32 was definitely used)	Part of 1,886	H15～H22
8	Commercialization of next-gneration robot	NEDO	Commercialization system promotion projects and proto-type development support projects	1,000	–	H16～H17
9	Commercialization of human-aid robot	NEDO	Consortium	900	900	H17～H19
10	R&D on next-generation robot	NEDO	Consortium	400	400	H17～H19
11	Strengthening of strategic basic technology (robot out of all the basic technologies)	METI	Consortium	1,338	–	H15～H17
10	Commercialization of service robot	METI	Consortium	–	420	H18～H19
11	Technology development of strategic frontier robot elements	NEDO	Consortium	–	1,100	H18～H22
12	Underwater robot	MLIT	Port and Airport Research Institute	10	1,391の内数	H13～H18
			Total	4,743* (約5,089)	3,662	



As the amounts used for this purpose at independent administrative organizations are not clear, they are shown as "part of xxx"

MEXT (Ministry of Education, Culture, Sports, Science and Technology)

21st Century COE (Center of Excellence) Program

Based on its June 2001 report, "A Policy for the Structural Reform of Universities," MEXT launched in JFY 2002 a new initiative called the 21st Century Centers of Excellence (COE) Program. The program works to cultivate a competitive academic environment among Japanese universities by providing targeted support to create world-standard research and education centers in a variety of disciplines. These COE raise the standard of both education and research in universities. The Program also seeks to elevate Japanese universities to the world's highest echelons, while fostering talented people with creativity to assume roles as world leaders.

Examples of recipients of this grant in the robotics field are:

. Hyper Human Technology toward the 21st Century Industrial Revolution by Professor Makoto Kaneko, Hiroshima University

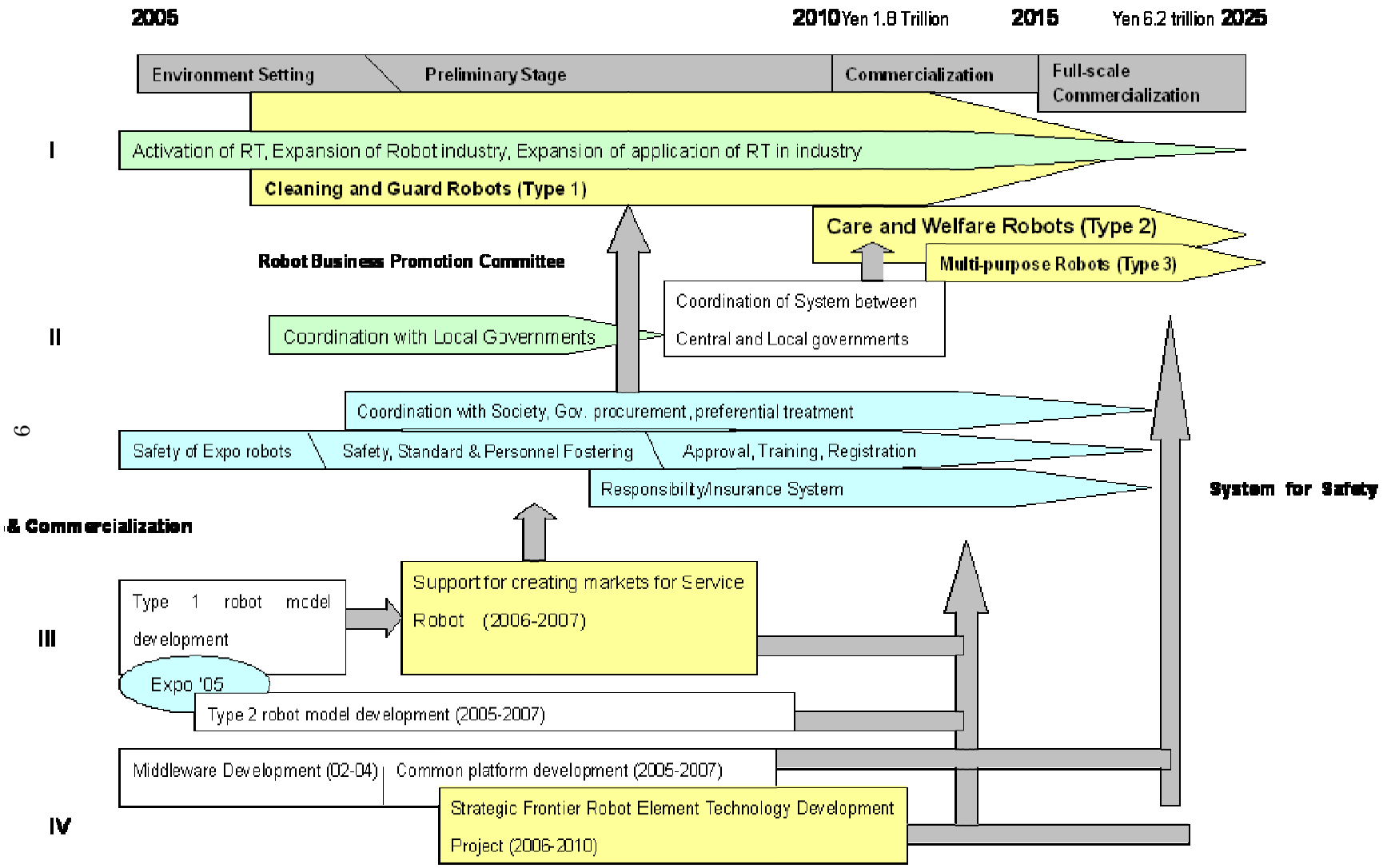
. Innovation of Creative Engineering through the Development of Advanced Robotics by Professor Shigeo Hirose, Tokyo Institute of Technology

. Complex Functional Mechanical Systems by Professor Kazuo Tsuchiya, Kyoto University

. Information Science and Technology Strategic Core by Professor Hidehiko Tanaka, University of Tokyo

. Understanding and Control of Life's Function via System Biology by Professor Hiroshi Yanagawa, Keio University.

Figure 4: METI's Roadmap for Robotics Research

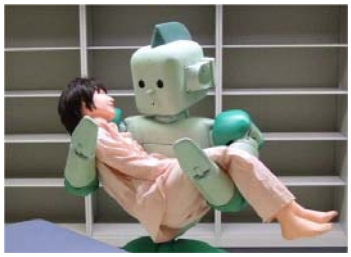


MEXT (Ministry of Education, Culture, Sports, Science and Technology)

RIKEN

Bio-Mimetic Control Research Center

Most of the research budgets at RIKEN come from MEXT. The Center aims to mimic the highly sophisticated control functions of living systems to create flexible, precise and reliable engineering systems. Established in 1993, the Center consists of four laboratories: biological control systems laboratory, motor systems control theory laboratory, biologically integrative sensors laboratory, and environment adaptive robot systems laboratory. Since 2001, the Center has entered its second term of research. They focus on promoting research work from system control theory, robotics, biological control to sensory mechanisms. Their research result can be seen in RI-MAN, which can be used as a partner robot in human care and welfare. The unique feature of RI-MAN is that it is equipped with four senses: visual, hearing, smelling, and touching; its major difference from previous robots is that it can perform jobs that require muscle power. It is 158cm tall and weighs 100Kg, and the surface is made of soft silicon material. It also has five touch sensors in its arms and breast, and can control the movement of its body and arms by sensing the strength of pressure. A camera, two microphones, and a smell sensor are built in. It moves by its wheel legs. When requested by a human via voice commands, RI-MAN walks to the person in a bed and lifts the person with its arms.



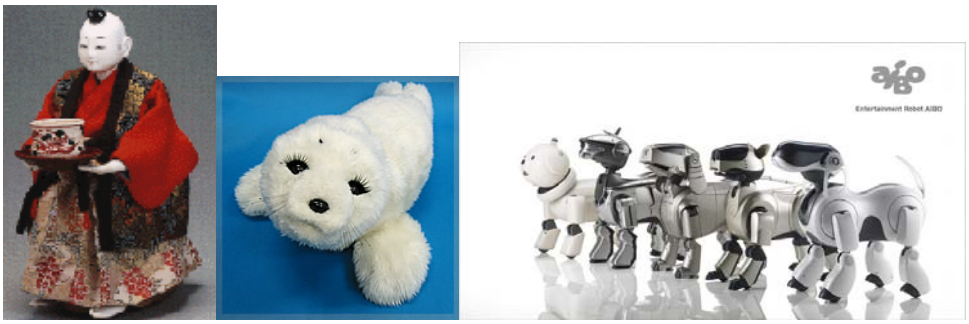
MLIT (Ministry of Land Infrastructure and Transport)

In carrying out civil engineering works at a site of disaster, construction, tunnels, underground space, cliff, and soil contamination, dangerous and painful work by humans is required. In addition, with more senior workers and a smaller number of young people, more safety and security as well as labor shortage are critical issues. MLIT research focuses on synergistic integration of IT and RT, using 3D information. In addition, Port and Airport Research Institute under MLIT conducts underwater robotics research.

3. Robots and Japanese

Robotics research in Japan is unique from the following viewpoints. Traditionally, robotics

technology in Japan has been evaluated very high. Historically, the traditional Japanese doll named “Karakuri Doll” is said to be the origin of robot (See Figure 5). A Karakuri doll that was manufactured and was selling well 400 years ago moves by a combination of gears when its spring is winded. This fact indicates that Japan has a very long history in manufacturing robots. A seal-like robot, called “Paro,” manufactured by AIST is very popular among those who are hospitalized long-term or among elderly people as it has proved to have mental “healing” effects on humans. “Paro” was recently filmed in Denmark, and the theme of the movie shows the difference of viewpoint on robots between westerners and Japanese. Sony’s dog-like robot named AIBO was also a best seller, although they stopped the production of it in 2005 (See Figure 5). These are the examples that Japanese people regard robots more than something that work hard at assembly lines or doing routine tasks. Rather, they deal with these robots as pets and friends. Thus, whereas robots are seen as “labor source” in the western world, in Japan they are being treated like living things with which humans work or live together.



Karakuri Doll Paro Aibo

Figure 5: A Karakuri doll, AIST’s Paro, and Sony’s AIBO

Sources: Homepages for Karakuri, AIST, and SONY

4. “Monozukuri” Concept at Assembly Lines

At the beginning of this report, it was pointed out that multi-task robots are more in demand these days not only those at assembly lines. Actually, the paradigm for economic development that focuses on mass production, mass consumption, and mass waste is getting more difficult to develop these days, with a shrinking and aging population. On the

other hand, among industries, the manufacturing industry is still making great contributions to the Japanese economy. The manufacturing industry shows the highest growth among all industries and is rated fairly high at the world standard (See Figures 6 and 7). Robotics is a major factor in assembly lines.

	All Industries Sales (Yen Billion)	Growth from the previous year (%)	Manufacturing Industry Sales (Yen Billion)	Growth from the previous year (%)
1998	25,232	−26.4	10,463	−32.6
1999	29,688	17.7	11,493	9.8
2000	39,696	33.7	16,845	46.6
2001	33,533	−15.5	12,130	−28.0
2002	33,298	−0.7	12,404	2.3
2003	37,482	12.6	14,934	20.4
2004	47,848	27.7	19,489	30.5

Figure 6: Sales: All Industries vs. Manufacturing Industry

Source: Ministry of Finance Quarterly Report on Company Statistics

	Manufacturing Industry (%)			All Industries
	1990−1995	1995−2000	2000−2003	1996−2003
Japan	3.3	4.1	4.3	1.4
United States	3.7	5.7	6.9	2.3
United Kingdom	3.3	2.6	3.7	1.4
Germany	3.3	2.7	1.7	1.1
France	4	4.5	3.5	1.4

Figure 7: Industrial Productivity Growth Rate by Country

Source: U.S. Ministry of Labor "Labor Statistics" and METI's White Paper on Trade-2004

The important factor here is to maintain an efficient manufacturing with high performance by the manufacturing industry, which is different from the days when mass production was

flourishing. Here, the concept of “Monozukuri” plays an important role. Simply interpreted, it could be said as management of skill, technology and human resources. This concept is typically seen in a Toyota production system. Toyota manufactures automobiles based on the “just-in-time” concept. It means “all about producing only what’s needed and transferring only what’s needed.” It stopped the factory from producing unnecessary items.

Another example is FANUC’s (company) receipt of “Monozukuri” award from Nikkei Newspaper Company. Faced with ever-intensifying global competition, the Japanese manufacturing industry needs to strengthen its winning edges. The manufacturing industry must make their products more competitive by reducing their production costs. As a solution, FANUC has proposed and realized an unmanned production system with its intelligent robots. In 2002, FANUC introduced to its factory an unmanned machining system, using its intelligent robots, to machine unattended for long hours. FANUC developed its advanced ‘Assembly Robot Cell,’ a full-scale assembly system using the latest intelligent robots, and installed the system to begin assembly of FANUC’s Mini Robots in June 2004. The ‘Assembly Robot Cell’ is a state-of-the-art assembly system. It uses intelligent robots, especially its latest vision and force sensors, to retrieve randomly piled parts and perform micro-meter-precision assembly at the skilled worker’s level, unattended, for extended periods of time. The Assembly Robot Cell will expand industrial robot applications beyond the traditional material handling and spot welding applications to general machine assembly. FANUC is committed to achieving the winning edge in the manufacturing industry by successfully implementing automatic assembly on the factory floor.

Thus, the robotics technology at assembly lines is required to develop with the “monozukuri” concept in mind.

5. Future and Conclusions

The robotics research in Japan maintains its high level of standard. To meet the societal needs, it is expected to play more practical roles in welfare, search and rescue in disaster sites, and security. Figure 8 shows the dominance of robotics technology and market by

major countries.

	Japan	Korea	EU	US
Industrial robotics	++++	+/-	+++	+/-
Humanoid robots	++++	+++	+/-	+/-
Personal/family robotics	++++	+++	+/-	+/-
Service robotics	++	+++	++	++
Biology/Medical applications	+/-	+/-	+++	+++
Defense/space development robotics	+/-	-	++	++++

Figure 8 : Dominance of Robotics Technology and Market by Major Countries

++++: Outstanding

+++: Very Good

++: Good

+/-: Ordinary

-: N/A

Source: NISTEP (National Institute of S&T Policy) ISSN 1349-3663

To cope with the ever-escalating international competition in robotics, more unique and enabling technologies and manufacturing systems are expected to emerge. In Japan, the first stage -- the body (structure), actuator and computing part of humanoid robots -- has been completed. Presently, hardware for humanoid robots is widely used as a platform for developing software (cognitive structure of robots). In the future, it will be essential to advance “cognitive functions” of robots in developing practical robots. It requires knowledge from biology, neuro-science, cognitive science, psychology, behavioral science, human science, economics, social science, philosophy, computational neuro-science,

mathematics, theoretical physics, information science, control engineering, mechanical engineering, and materials. The future of Science and Technology is said to depend on proper integration of scientific fields. Without such synergistic integration, there will be no future for robotics.