Microsystems in Japan

FEATURE

by Miwako Waga

The Japanese domestic market may jump 11-fold by 2015

Japan was one of the first countries to provide systematic public support for microsystems R&D. In 1991, the Ministry of International Trade and Industry (MITI) launched a 10-year national R&D program called the Micromachine Technology Project (MTP) to develop key technologies that would enable micromachine-based systems to perform advanced tasks in a narrow space.

The MTP, though large in scale, was not the sole spur to microsystem activities in Japan. Several automotive and electronics companies began engaging in silicon micromachining in the early 1980s, and the work that pioneered this innovation dates back to the 1960s. Automotive, electronics, and other companies, either independently or as members of the MTP, continued research internally and in collaboration with universities throughout the 1990s.

The automotive, information-communications, medical, and biotechnology-related market segments have driven the recent expansion of the microsystems field. Backed by industrial, government, and academic research, Japanese companies have brought many innovative microsystem-based products to market that offer advanced and unique features, and this trend is expected to continue. Indeed, a recent market study projected an 11-fold increase in Japanese domestic sales of microsystems within 15 years.

The mid-1990s saw the watershed of public funding for science and technology in Japan. The enactment of the Science and Technology Basic Law in 1995 and the establishment of the Science and Technology Basic Plan in 1996 provided a foundation for greater public financial support. As a result, many public R&D programs and funding schemes emerged in the second half of the 1990s.

Noteworthy in the microsystems field was the decision by the Ministry of Education, Science, Sports, and Culture (Monbusho) to support the creation of the Venture Business Laboratory (VBL) for Development of Sensors and Micromachines at Tohoku University. Another VBL at Kyoto University focuses on nanostructures and next-generation photonic devices. The two VBLs, both established in 1997, provide research facilities that are open to the Japanese microsystems R&D community.

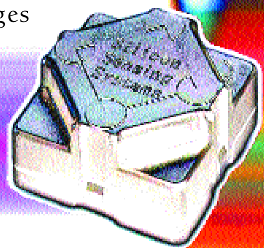
Ministries of the Japanese government sponsor many microsystems research projects. In addition to MITI and Monbusho, the ministries include agriculture, forestry, and fishery; health and welfare; and post and communications. Because microsystems-related R&D is often conducted as part of publicly funded projects with broader research goals, it is difficult to aggregate the Japanese government's total support in this field. However, the government has allocated more than $300 million directly to microsystems research since 1991.

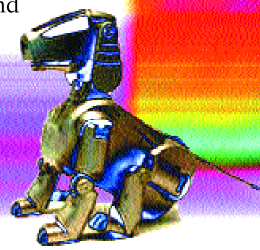
Major players

Industry plays a large role in microsystems R&D in Japan. More than 20 companies have been involved with the MTP. The most active players include Denso, Hitachi, Matsushita Research, Mitsubishi Electric, Olympus, Omron, and Toshiba, as well as NEC, NTT, Sony, and Toyota Central R&D. In total, more than 40 large firms carry out R&D in microsystems.

Academia also plays a significant role. More than 50 national and private universities have groups engaged in innovative research related to microsystems. They include the University of Tokyo, Tohoku University, Tokyo Institute of Technology, and the universities of Nagoya, Kyoto, Tokushima, Waseda, and Ritsumeikan. In the public sector, more than a dozen laboratories carry out such R&D activities. Among the most active are the Mechanical Engineering Laboratory, the National Research Laboratory of Metrology, the Electrotechnical Laboratory, the Technology Research Institute of Osaka Prefecture, and the Institute of Physical and Chemical Research.

Japanese industry is known for its commitment to miniaturization and integration of advanced functions. Sony has recently announced a prototype of the world's





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lightest digital still camera, which weighs only 26 g. Casio has commercialized a wrist camera that takes and stores up to 100 monochrome images and sends the data to a personal computer using an infrared link. Sony's robot AIBO—the first robot meant as a pet—demonstrates the prowess of microsystems. It contains 20 different motors that provide a range of motion for movement and performing tricks.

These examples show Japanese industry's drive to reduce system size, provide novel features, and explore new market opportunities. Other examples of commercialized and prototyped microsystems include:

• the wearable user interface from Olympus, which enables a person to operate a computer sans keyboard and mouse. The device uses sensors attached to the fingertips and back of the hand, and requires only a hand movement for input. Visual output is presented on a display screen worn like eyeglasses.

• silicon-based micro-optical scanners from Nippon Signal. The company brought its first scanner to market in 1998, and has increased both its product variety and production volume since then. The devices control the reflection of incoming light by vibrating a micromirror fabricated with silicon, and use electromagnetic force to actuate the mirror. Nippon Signal produces the silicon micromirrors in Japan and the United States.

• a silicon vibrating-structure gyroscope from Sumitomo Precision Products. The rate gyroscope uses the Coriolis effect to sense angular speed. The ring-shaped, micromachined resonator is resistant to external shocks and vibrations over a wide range of temperature. Silicon Sensing Systems, a joint venture between Sumitomo Precision and British Aerospace, has orders for 1.5 million of the gyroscopes for use in vehicle safety-control systems.

• a fully automatic, optical DNA-assay apparatus for infectious-disease screening tests developed by Olympus. The system incorporates a free-flow electrophoresis module for extracting DNA threads from a sample solution, a micro polymerase-chain-reaction module for making many copies of the DNA threads, and an ellipsometer for optically detecting the presence and amount of a specific DNA or RNA from an infectious agent.

• a quartz-crystal microbalance biosensor from Initium, Inc. (Tokyo). The company's AffinixQ system quantifies biomolecular interactions at nanoscale order through the analysis of frequency change in the quartz-crystal oscillator. The AffinixQ went on sale in Japan last summer.

These devices are the commercial vanguard of the many projects in development at Japanese research institutes and company laboratories.

Market forecast

The Japanese Micromachine Center (Tokyo) began a series of market studies in the mid-1990s that was commissioned by the Japanese Machinery Federation, a large trade group. It is important to note that these studies—which are long-term projections of the micromachine market in various industrial sectors in Japan—address only the domestic market.

The latest study in the series, *Economic Impact of Micromachine Technology on the Creation of New Industries, 1998*, was released in May 1999 and examines the economic impact of micromachine technology on 16 industrial fields. It lists 46 applications that will likely be affected by progress in the technology, including optical disk drives and fiber networks, magnetic heads, micromotors, biosensors, cameras, chromatography, industrial robots, medical monitoring and diagnostic equipment, combinatorial chemistry, intelligent transport systems,

security systems, and home appliances.

In addition, the study investigated six emerging applications that micromachine technology will further enable—smart-card systems, wearable computers, virtual reality equipment, micro-robotics, advanced drug-delivery systems, and greenhouse applications—technologies that increase productivity in farming and fisheries.

The Japanese market study used a three-step procedure to analyze the economic impact of micromachine technology. It first identified the applications, or end products, that advances in micromachine technology will likely affect. It then focused on the subsystems that incorporate modules or components for which micromachined parts are expected to be wholly or partially substituted (called the "component ratio"). Finally, it estimated the micromachine segment of the end-product market (called the "replacement ratio").

The study forecasts that the Japanese domestic micromachine market will grow from more than $4 billion in 1997 to $23 billion in 2010 and to $46 billion in 2015. These projections include the most conservative estimates for the emerging applications.

International comparisons

It is difficult to compare the Japanese micromachine market study with the microelectromechanical systems (MEMS) and microsystems technology (MST) market studies carried out by U.S. and European organizations. First, the Japanese study examines only the domestic market. Second, the forecast time range is significantly different. Third, the use of the component ratio and replacement ratio involves a judgment call that makes a comparison with other studies difficult. Nevertheless, such a comparison is useful—despite the different analytical methods and ranges of forecast times—in understanding the general trends. Particularly pertinent are the similarities and differences between the Japanese market forecast, the SPC MEMS market study covering 1996–2003, and the NEXUS market analysis of microsystems for 1996–2002 (see "For further reading").

All three market studies anticipate significant growth of microsystems for the information–communications, automotive, medical, and biotechnology-related markets. In particular, rapid expansion in market acceptance is projected in the areas of sensors and actuators for automotive safety and comfort, information-communications infrastructure (components for optical-fiber networks), and micro total-analysis systems.

The Japanese market study deals with a wider variety of end products that are generally not regarded as MEMS/MST applications, such as cameras, watches, facsimile machines, and copiers. Otherwise, the Japanese micromachine market in 1997 would not have been larger than the 1996 worldwide sales of MEMS devices estimated by SPC. In addition, the Japanese study takes into account a unique market segment, namely, the microfactory—a concept for desktop production facilities now in development by the Japanese government and industry.

Thus, the Japanese study pushes the overall micromachine market size upward, despite its attempt to rigorously estimate the market segment by setting the component ratio and the replacement ratio for each selected application. Furthermore, the study's time range is too long for business executives to use it as a technology road map for short- to midterm strategic decision-making.

The mismatch between the Japanese micromachine and the other MEMS/MST market studies should not be exaggerated, however, because on the macroscale these studies indicate some common fundamental trends. Micromachining technology, whether it is called MEMS or MST, will find wider acceptance in existing and emerging applications in the years to come.

In Japan, as in the rest of the world, the automotive, information–communications, medical, and biotechnology-related market segments will be the key drivers in the long-term expansion of the microsystems field. The mass end-product markets at home will continue to provide Japanese players with the inspiration and incentives to spur R&D and commercialization of microsystems.

For further reading

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B I O G R A P H Y

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