Appendixes

Appendix A
Selected Computer Hardware and Software Initiatives Overseas

Introduction

European producers have long faced competition from U.S. fins; they now face increased competition from Japanese firms positioning themselves in Europe in anticipation of the single European market. At the same time, the European software market is growing rapidly and packaged software+-long a U.S. strength-is becoming more popular. European research in computing is fragmented; market unification is expected to permit more integrated research in information and telecommunication technologies.[1]

Japanese firms are positioning themselves for rapid expansion in the United States, Europe, and Asia; Japanese computing research emphasizes massively parallel and distributed computing, optical computing, neural nets, and applications of fuzzy logic; software areas receiving attention include supercomputer software and graphical-display software for use in simulation and animation, The Japanese approach for "manufacturing' software has received much attention. Custom software currently dominates the Japanese market but some consider that Japanese "software factories' can extend Japan's advantage in quality "embedded" software to packaged software as well.[2]

Taiwan and Singapore are both developing information-technology industries, During the 1980s, a number of government measures facilitated development of Taiwan's microcomputer industry; the government is now focusing on nurturing a software industry. Over the past decade, Singapore has actively pursued a national goal of developing a software and services industry. It is now targeting strategic computing technologies like commercial applications of expert systems, neural nets, and fuzzy logic.

Europe

Computer Hardware

Europe makes up about one-third of the world computer market. In 1989, U.S. firms accounted for more than half of all computer sales in Europe and were even more dominant in the mainframe market; Japan held only about 10 percent of the computer market.[3] According to International Data Corp., the total European mainframe market was valued at $8,440 million in 1989 and $9,069 million in 1990. IBM, which earned 37 percent of its revenues in Europe in 1989, accounted for 52 percent of mainframe sales in 1989 and 61 percent in 1990.[4]

Computer hardware sales are slowing in Europe, due in part to economic conditions. Mainframe and minicomputer sales have slowed the most, despite price discounts, while microcomputer and workstation sales are more robust.[5] The latter reflects a trend in Europe toward smaller computers—annual growth in the microcomputer market is estimated at 25 percent for 1990 and 22 percent for 1991.[6]

During the downturn, European manufacturers like Olivetti and Groupe Bull have been more vulnerable than U.S. firms.[7] But now, in addition to slower sales, U.S. and European manufacturers are facing increasing competition from Japanese manufacturers, especially in the

1 Another expected outcome is more uniformity in European standards. See U.S. Congress, Office of Technology Assessment, Global *Standards: Building Blocks for the Future,* forthcoming 1992.

2 Sometimes a computer, its memory, and often, its programs, are embedded in another device such as an automobile engine, videocassette recorder, microwave oven, or television set. Such a computer is called an embedded computer and its programs are embedded applications programs. Some of the market estimates cited in this chapter may include the value of some embedded software but these were not reported separately.

3 Richard L. Hudson, ''Japanese Set To Do Battle in Europe's Computer Market,' *The Asian Wall Street Journal Weekly,* vol. XII, No. 34, Aug. 20, 1990, p. 1.

4 Data cited in Amiel Kornel, "Fujitsu Move Rattles Europe,' *Computerworld*, vol. 24, No. 32, Aug. 6, 1990, p. 1.

5 Before the slowdown, computer sales in Europe were growing at a rate almost twice that in the United States. The slowdown came after 5 years of heavy computer buying in Europe, reflected in 30-percent growth rates in computer sales in the late 1980s. Growth rates from Jonathan Levine et al., "Europe Ain't No Bonanza Anymore," *Business Week*, Aug. 6, 1990, pp. 26-28.

6 By comparison, growth in the U.S. microcomputer market is estimated at 10 to 15 percent in 1990 and 1991, compared to 50-Percent annual growth rates in the mid-1980s. (Levine et al., op. cit., footnote 5, pp. 27-28.)

7 France's state-owned Groupe Bull's strategy to compete in the market of the 1990s depends in part on "open systems' based on AT&T Unix. Bull had revenues of $6.5 billion in 1989. Bull purchased Zenith Data Systems (laptop and personal computers) in 1988; Bull and NEC bought into Honeywell's computer business in 1987 and Bull took majority control of what is now Bull HN in 1988. Seventy percent of Bull's revenues come from outside France, including 33 percent from the rest of Europe and 30 percent from the United States. (Jonathan Levine and Gary McWilliams, ''Francis Lorentz' Scheme To Get Groupe Bull Charging," *Business Week*, July 16, 1990, pp. 154,156.)

mainframe market. Previously, m mainframes made by Fujitsu, NEC, and Hitachi have been resold by European manufacturers like Siemens A.G. and Comparex.[8] Recently, however, Japanese firms have been establishing European bases of operation in anticipation of 1993's single market. For example, Fujitsu has acquired controlling interest in ICL (Great Britain's largest mainframe manufacturer)[9] and Mitsubishi has acquired Apricot Computers Ltd. (Great Britain's largest personal-computer manufacturer), now called ACT Group P. L.C.[10] Nevertheless, despite slower sales and increasing competition from Japan, the European computer market is still a lucrative and important one for U.S. manufacturers (see table A-l).

Table A-l —U.S. Computer Manufacturers' Domestic and European Sales (1989)

Company	Revenue ($ billions)	Percentage of sales: United States	Percentage of sales: Europe
IBM	$62.7	41 .0%	37.0%
DEC	12.7	46.0	40.0
Hewlett-Packard	11.9	46.7	34.7
Apple	5.3	64.4	22.9
Compaq	2.9	54.6	41.8
Sun	**1.8**	**57.9**	**24.2**
Tandem	**1.6**	**50.1**	**32.5**

SOURCE: 1989 data from Salomon Brothers, Inc. and company reports, cited in: Jonathan Levine et al., "Europe Ain't No Bonanza Anymore," *Business Week,* **Aug. 6, 1990, p. 27.**

Software

The software market in Europe, valued at $32 billion in 1990, is growing faster than the U.S. market and faster than the European hardware market.[11] At the same time, the composition of the market is shifting. Computer software-and-services companies, producing custom ('‘bespoke' software tailored to clients' operations and needs, are facing growing competition from packaged software. Packaged software's share of the market is increasing, accounting for 29 percent of software sales in 1989, up from 11 percent in 1979.[12]

According to the market research organization Ovum, the top 40 packaged software vendors in Europe (including 21 U. S., 6 French, 5 German, and 4 British companies) accounted for 64 percent of packaged software sales valued at $11 billion in 1989.13 Most of the major European packaged software vendors have been either large hardware manufacturers or systems houses focusing on sales of hardware or computer services, rather than specializing in packaged software (see table 3-3 inch. 3). With sales of both system and applications software, the largest vendor of packaged software overall in Europe is IBM, with 1989 sales worth $2.12 billion. Almost all of the major packaged software vendors that specialize in software are U.S. firms like Microsoft or Computer Associates International.[14]

Research and Technology Initiatives

Historically, research in Europe has been fragmented by company and country. Beginning in 1993, market unification in the European Community (EC)[15] will permit more integration of research in member countries, with the intention of strengthening the technological base of industry in the EC and improving EC industry's global competitiveness. The Research and Development (R&D) Title to the EC Treaty provides a firmer legal basis for cooperation in R&D and calls for the EC to adopt a multiyear framework laying out all its R&D activities. In 1987, the EC adopted the "New Framework Program," after debate concerning content of, and funding for, cooperative R&D, and the relative merits of coordinated research versus competition in stimulating commercially productive innovations.[16]

There have been three Framework Programs, providing R&D funding in overlapping 4-year periods: Framework

[8] Kornel, op. cit., footnote 4.

9 Levine et al., op. cit., footnote 5, and David E. Sanger, "Fujitsu To Buy ICL Stake, " *The New York Times,* July 31, 1990, pp. D1, D6.

10 Richard L. Hudson, ''Japanese Set To DO Battle in Europe's Computer Market,'' The Asian *Wall Street Journal Weekly,* Aug. 20, 1990, pp. 1, *6.*

11 *Estimate from:* 'European Software Industry 1992 Market Changes Response Profile (Executive Summary),' prepared by Ernst& Young on behalf of the Scottish Development Agency (Boston, MA: Clarke & Co., 1990).

12 ''Salvation in Services?'' *The Economist,* Aug. 11, 1990, pp. 70-71.

13 Ralph Bancroft, "Europe Struggling in Software, " *Computerworld,* July 23, 1990, p. 97.

14 Ibid.

15 For a summary of the impacts of the EC92 initiative on science and technology issues, including industry R&D and standards, see Glenn J. McLaughlin (coordinator), "The Europe 1992 Plan: Science and Technology Issues, " Congressional Research Service Report for Congress, revised Aug. 23, 1989.

16 Discussion from Candice Stevens, " 1992: The European Technology ChaUenge,' *Research & Technology Management, vol. 33, No.* 1, January-February 1990, pp. 17-23.

For more discussion on science and technology programs in Western Europe, see Congressional Research Service, Library of Congress, *Transfer of Technology From Publicly Funded Research Institutions to the Private Sector,* prepared for the Subcommmittee on Oversight and Investigations of the Committee on Energy and Commerce, U.S. House of Representatives, Committee Print 102-G, 102d Congress, 1st Sess., July 1991, pp. 51-68.

One (1987-91), Framework Two (1988-92), and Framework Three (1990-94). This is intended to allow continuation of current R&D programs while providing a way to reevaluate them. The Framework Programs provide support for many fields of science and technology; support for R&D in information technology and communication technology is provided through the ESPRIT and RACE programs, respectively .17 Phase I of ESPRIT began in 1984, before the Single European Act, and continued through 1988; it addressed basic technologies and standards in microelectronics and software, as well as computer applications like computer-integrated manufacturing and office systems. Phase II of ESPRIT (1988-92) continues the initiatives begun in phase I and also includes new basic research projects; currently about 3,000 researchers are involved in 200 ESPRIT projects.[18] ESPRIT's software accomplishments to date include development of software for optimizing designs of application-specific integrated circuits (ASICS) and software-development and software-integration tools developed under the Portable Common Tool Environment project.[19] The EC contribution for ESPRIT II during 1988-92 is about 1,600 million European Currency Units (ECUs), nearly $2 billion.[20]

The RACE program includes research and standards projects intended to move the EC toward combined communications (voice, data, video, electronic mail) based on integrated services digital network (ISDN) standards. The EC contribution for RACE during 1987-92 is 550 million ECUs, or $660 million.[21]

Japan

Computer Hardware

Beginning in the mid- 1950s, the Japanese Government, which recognized the strategic importance of the computer industry, used capital, subsidized R&D, and protective regulations and procurement policies to nurture a developing Japanese computer hardware industry.[22] By 1990, these policies had paid off in an industry with compelling strengths in memory chips, flat-panel displays, and optical disks. In 1980, the Japanese industry had a 10 percent share of the world computer market; a decade later, Japan's share of the world computer market was expected to exceed 40 percent by 1992.[23] Japan already dominates the laptop and notebook computer markets.

In 1990, IBM held almost 52 percent of the world mainframe market, followed by Fujitsu (9.5 percent), Hitachi (6.8 percent), Unisys (6.6 percent), Amdahl (4.6 percent), Siemens (2.8 percent), and NEC (2.7 percent) .24 Japanese mainframe computer manufacturers have been positioning themselves via product development, marketing strategies, and acquisitions for rapid expansion in the U. S., Asian, and European markets now dominated by IBM.[25] For example, Fujitsu has acquired ICI P. L.C., Britain's largest mainframe computer manufacturer[26] and the world's ninth-largest producer of mainframe computers. Fujitsu acquired an 80 percent share of ICL for about $1.4 billion and thereby became the world's second-largest computer manufacturer (in terms of sales), behind

17 ESPRIT is the acronym for European Strategic Programme for Research and Development in Information Technologies; RACE is the acronym for R&D in Advanced Communications Technologies in Europe. See Congressional Research Service (July 1991), op. cit., footnote 16, pp. 56-58.

18 Ibid., pp. 57-58.

19 Gadi Kaplan and Alfred Rosenblatt (@.), "The Expanding World of R& D,' *IEEE Spectrum*, *October* 1990, *pp.* 28-33.

20 Congressional *Research* Service (July 1991), op. cit., footnote 16, pp. 57-58.

21 Ibid., pp. 59-60.

22 Marie Anchordoguy, "How Japan Built a Computer Industry, " in Charles H. Ferguson, "Computers and the Coming of the U.S. Keiretsu, " *Harvard Business Review,* July-August 1990, p. 65.

Between 1965 and 1985, Japanese R&D expenditures as a percentage of gross national product (GNP) nearly doubled, from 1.27 percent of GNP in 1965 to 2.53 percent in 1985. Over the same period, the Japanese Government's share of R&D expenditures fell from 31 to 19 percent; although totat government funding increased, industry R&D grew more rapidly. (National Science Foundation and Japan Science and Technology Agency data cited in: Leonard H. Lynn, "Technology Policy in Japan,'' *Forum for Applied Research and Public Policy,* fall 1990, pp. 57-61.)

For a discussion of Japan's basic research initiatives, see "CanJapan Make Einsteins Too?" *The Economist,* Aug. 11, 1990, pp. 81-83. Japan's R&D expenditures now total over 2.9 percent of GNP, with government expenditures amounting to 20 percent of this sum and expected to double during the 1990s (ibid., p. 81).

23 ''Computers and Other Targets: How Japan Learns, and Wins, Even by Losing,'' *The New York Times,* May 11, 1990, p. A32 (editorial).

24 Nikkei, IDC data cited in Jean S. Bozman and Lori Valigra, ''Long-Term Global Strategies Unfold," *Computerworld*, *Nov. 26,* 1990, p. 101.

25 For example, in 1989 Hitachi acquired 80 percent of National Advanced Systems, now called Hitachi Data Systems (Electronic Data Systems owns the other *20* percent), and Fujitsu has owned 43 percent of Amdahl since 1984. See Robert D. Hof and John W. Verity, "The Japanese Threat in Mainframes Has Finally Arrived, " *Business Week,* Apr. 9, 1990, p. 24; Jean S. Bozman and Lori Valigra, ''Long-Term Global Strategies Unfold, " *Computerworld*, *Nov. 26,* 1990, pp. 1, 101.

26 Jeff Shear, ''Japan Upsets Computer Applecart,'' *Insight*, Oct. 22, 1990, pp. 44-45. Fujitsu was already manufacturing ICL hardware.

IBM and **just ahead** of Digital Equipment Corp.[27] By the time that Fujitsu acquired ICL, the British firm had grown dependent on Fujitsu for crucial technologies (e.g., computer chips, circuit boards, cooling systems) .28 Fujitsu's acquisition of ICL was of special concern to the European information-technology community because ICL was a partner in about 40 hardware and software projects being conducted under the European ESPRIT prograrn.[29] Fujitsu also has a majority interest in a mainframe computer factory in Spain and an agreement to sell powerful mainframes through Siemens A.G. Coupled with concentration in the European computer industry due to financial pressures, such acquisitions position Japanese firms like Fujitsu or Mitsubishi Electric (which has acquired the manufacturing facilities of Apricot, a British PC company) to participate in the EC's single market after 1992.[30]

At the same time, Japanese investments in computer and software firms in the United States have continued to grow through minority equity positions as well as acquisitions. In 1990, Mitsui & Co. purchased a minority interest in Unisys with $150 million of preferred stock that can be converted into 4.6 percent of Unisys' common stock outstanding. Unisys also arranged a $50-million, 5-year loan from Mitsui.[31] Also in 1990, Mitsubishi Kasei Corp. acquired Verbatim Corp. for $200 million.[32] Canon has invested $100 million in NeXT Computer (multimedia computing), Canon Sales Co. has invested in FPS Computing Inc. (64-bit computers), and Fujitsu has purchased 46 percent of Poqet Computer (notebook computers) .33

Computing Research Focus

Japan's highly publicized Fifth-Generation project (1982-91) was intended to create "intelligent" machines that could support expert systems to emulate human reasoning and could communicate with humans through natural (rather than computer programmingg) languages. **MITI** initiated the Fifth-Generation project in 1982 and anticipated three phases: 1) study of existing knowledge in logic processing and parallel processing and development of prototype hardware and software systems; 2) construction of small-scale subsystems for logic processing and parallel computation; and 3) completion of a full-scale prototype computer implementing inference and knowledge-based functions in hardware (for speed) and using software for knowledge-base acquisition and management, natural-language interfaces, and "intelligent" (user-friendly) programming tools.[34] Today's Japanese artificial intelligence (AD) market reflects industry's commitment to increase the use of AI technology, especially expert systems in the financial and manufacturing industries, in support of the Fifth-Generation project.[35]

Although Japan, along with other countries, made progress in AI research, the Fifth-Generation project fell far short of its original goals. However, the project has had two important consequences. First, it stimulated research in the United States and Europe, as well as Japan, and enabled Japan to build up a basic-research infrastructure in computing, training, and influencing thousands of Japanese computer professionals. Second, it gave credence to, and focused Japanese Government and industry attention on, parallel processing.[36] Emphasis on massively parallel computing, part of what is referred to as the

27"Fuji@u's **Purchase of ICL Illustrates Its Aggressive** Pursuit of Europe **Market,''** *The Asian Wall Street Journal* Weekly, Aug. 6, **1990,** p. 5.

28 **Sanger (July 1990),** op. *Cit.,* fo'emote 9.

29 **Kaplan and Rosenblatt (eds.),** op. cit., footnote 19, pp. 28-33.

30 Singer **(July 1990), Op. cit., footnote 9.**

31 **Paul B. Carroll, ''Unisys,** S@=@ **With Big Debt Load, Sells Preferred Stock to Japanese Firm,''** The ***Wall Street Journal,*** June 27, 1990. **Mitsui** and **Unisys** have had long-standing business relations: each owns one-third of **Nihon Unisys** Ltd., a computer marketer that does $2 billion of annual business in **Japan,** and Sperry (which merged with Burroughs to form **Unisys** in 1986) began working with **Mitsui** in the 1950s.

32 **Michael R. Sesit, ''Japanese** Are More Willing To Buy Minority Stakes **in** U.S. **Companies,** " *The Asian Wall Street Journal Weekly,* Aug. 13,1990, p. 21.

33 **NeoConcepts** da@ reported **in: Sheridan Tatsuno,** *''U.S.* Threatened by Rash of **High-Tech** Buyouts," New *Technology Week,* Aug. 6, 1990, p. 7. Fujitsu also owns 44 percent of the **Amdahl** Corp. (mainframes). **(Amiel** Kernel, op. cit., footnote 4.)

34 **See** Michael A. **Cusuman**o, *Japan'* ***s Software*** *Factories: A Challenge to Japanese Management (New York, NY: Oxford* University Press, 1991), pp. 410-417. In addition to describing the Fifth-Generation project and its outcomes, **Cusumano examin**es Japanese approaches to software development in detail.

35 ***An Assessment of*** *the* ***Japanese Artificial*** *Intelligence Market,* U.S. Department of Commerce, **International Trade Administration (Springfield,** VA: National **Technical** Information Service, May 1989), p. xvii. According to **ITA,** most Japanese expert system tools used to build expert systems are less expensive and less complex than U.S. counterparts; Japanese users prefer easy-to-use products with Japanese language capability.

The 1990 market for AI hardware and software was about $2.5 billion but the market is expected to reach $10.6 billion by 1995 (MITI estimates, ibid., p. vii). According to ITA, most Japanese AI software runs only on the hardware for which it was develop@ the eight largest Japanese computer firms (Hitachi, Fujitsu, Toshiba, NEC, Oki, Sharp, Mitsubisbi and Matsushita) control 60 percent of the total Japanese AI hardware and software market (ibid,, pp. xix, 42).

36 see Cusumano, op. cit., foomote 34, and David E. **Sanger,** "Japan Is Planning **To** Challenge U.S. in Computer Field," *The New York Times,* Apr. 30, 1990, pp. Al, D14. The Japanese Government provided about $250 million in funding from 1981 to 1990 and is expected to spend another $40 to $50 million before the project ends in 1992.

Sixth-Generation project, is a change in direction from earlier Japanese efforts to produce very fast supercomputers that relied on speed (rather than parallelism) for computational power.

Parallel processing is thought to hold great promise for applications like picture, sound (voice), and character recognition. To this end, advances in parallel and fault-tolerant architectures, as well as in chip technology, will be required. But, interestingly, the hardware to build massively parallel machines is simpler to design and develop than is the complex software required to coordinate parallel processing and efficiently exploit the capabilities of the hardware. Therefore, MITI has convinced government officials and industry to devote resources to a large effort to develop parallel-processing software.[37]

In April 1990 MITI published a broad outline of how to proceed from the Fifth-Generation project; one of the objectives outlined was a concerted effort to master massively parallel processing. MITI's plans for this New Information Processing Technologies (NIPT) program called for leapfrogging the evolutionary technology-development paths that most U.S. firms and research programs are following, concentrating instead on massively parallel and distributed computing systems, neural nets,[38] optical computing, and applications of fuzzy logic.[39] By spring 1991, the focus of the program appeared to be shifting to a more interdisciplinary, basic research focus that could eventually lead to development of massively parallel, distributed processing systems based on optoelectronics.[40]

Software

According to a 1990 American Electronics Association report, the software market in Japan is only about one-third the size of the U.S. market. However, it is growing much more rapidly-in part, because it is less mature. The Japanese market (for packaged and custom software), estimated at about $18 billion in 1990, is expected to grow to some $33 billion (about 20 percent of the worldwide market for software) by 1995.[41] (In 1986, the Japanese software market was estimated at only about $5.4 billion.[42])

The composition of the Japanese market differs significantly from its United States and European counterparts in that custom software (rather than packaged software) accounts for 80 percent of software sales. By contrast, packaged software is more common in Europe and predominates in the United States, accounting for 75 percent of the U.S. market, according to the American Electronics Association.[43] The prevalence of custom software in Japan accounts for the situation that, although imported software accounted for about half of packaged software sales in Japan in 1988, imports amounted to less than 10 percent of the total market.[44]

Much attention has been focused on the Japanese approach to software development through ''information systems" factories bringing manufacturing-style production and quality controls to software development. U.S. observers have raised concern that this approach will extend Japanese productivity and success in embedded software (in electronics) and in custom programming to the packaged software market worldwide.[45]

37 Sanger (April 1990), op. cit., footnote 36.

38 For example, Toshiba Corp. is developing a character-recognition device that uses a neural network to identify both katakana (a Japanese phonetic alphabet) and numerical characters. The system, which will be marketed in 5 years for applications in automatic-teller machines and optical character readers, reportedly has a 95-percent accuracy rate. (''Neural Network Device Can Read Handwriting, ' *The Asian Wall Street Journal Weekly,* Feb. 11, 1991, p. 8.)

39 Richard McCormack, ''Ameri~ Scramble To Figure Out Japan's Next Thrust in Computing, " New *Technology Week,* vol. *4, No. 48,* Dec. *3,* 1990, pp. 1-2.

Fuzzy logic can be used to reduce superfluous software coding in massively parallel computers. A fuzzy-logic chip can be used to reduce the number of conventional logic circuits needed, making it possible to install simpler controllers that require less-complex software to run them.

40 MITI officials seeking U.S. Government support for participation in NIPT by U.S. industry and academic researchers were describing the program as focused on basic research and development, with a special focus on the brain and neural research. (Richard McCormack, ''U.S. Chilly to Japan on 6th Generation Initiative," New *Technology Week,* vol. 5, No. 22, May 28, 1991, pp. 1-4.)

41 Japan Information Service Industry Association estimates cited in: American Electronics Association Industry Committee in Japan, *Soft Landing in Japan,* (Tokyo, Japan: American Electronics Association Japan Office, June 1990), p. 7. *OTA note*: These *figures may* include some ''services' as part of custom software revenues.

42 ADAPSO (The Computer Software and Services Industry Association) estimate in: Jeff Shear, ''Competitive Software Industry Suits Up for Global Hardball," *Insight,* July 10, 1989, p. 39.

43 American Electronics Association, op. cit., footnote 41, pp. 7-8. *OTA note*: These figures may include some "services' as part of custom software.

44 *Japanese Software: The Next Competitive Challenge*, prepared by Dewy, Ballantine, Bushby, Palmer & Wood for ADAPSO's International Marketing Seminar (Arlington, VA: ADAPSO, January 1989), p. vi.

45 See, e.g., Cusumano, op. cit., footnote 34, and Neil Gross, "Now Software Isn't Safe From Japan,'' *Business Week,* Feb. 11, 1991, p. 84; Shlomo Maital, ''Why Not Software Factories,' *Across the Board,* October 1990, pp. 5-6; and Jacob M. Schlesinger, ''Japanese Concept of Software Factory Could Reshape Industry World-Wide,' *The Asian Wall Street Journal Weekly,* Feb. 11, 1991, p. 4.

Moreover, in mid-1991 MITI announced the formation of a new R&D committee to study numerical simulation using supercomputers and high-end workstations. The purpose of this new MITI group, with participants from academia and 20 companies including Fujitsu, Hitachi, IBM Japan, and NEC, is to put together experimental and theoretical underpinninggs for developing advanced supercomputer hardware and software for use in simulation and animation. In concert with other Japanese technology initiatives, such as the Sixth-Generation project and MITIs' new international project on next-generation structural models for large computer systems, the supercomputer simulation initiative may give Japan strong capabilities in supercomputer software, as well as hardware.[46] However, the United States still leads in supercomputers, as well as high-speed networks,[47]

Rapid growth in the Japanese market has led more than 60 U.S. software companies, including Lotus Development Corp., Microsoft, Computer Associates International, and Adobe Systems Inc., to establish subsidiaries or offices in Japan.[48] At the same time, Japanese companies are establishing themselves in the United States. For example, last fall an engineering group in Sony Corp. 's U.S. unit began work developing a new version of Unix as a basis for developing Unix application programs. Sony is one of the first Japanese companies to develop software applications (in this case, with a staff consisting mainly of U.S. software engineers) in the United States.[49] Unix microcomputer and workstation software is expected to grow in importance in Japan during the 1990s.[50]

Taiwan

In Taiwan, government measures, including research funding and tax advantages, spurred development of Taiwan's computer-hardware industries during the 1980s. At present, Taiwan has relatively strong microcomputer and semiconductor chip industries made up of domestic manufacturers as well as original equipment manufacturers (OEMS) from the United States and Japan.[51] In 1990, revenues for these industries amounted to $1,566 million for microcomputers and $450 million for semiconductor chips.[52]

For the long term, however, Taiwan faces a transition from a manufacturing to a service and knowledge-based economy.[53] Accordingly, interest in the domestic and global software markets has increased sharply, and industry leaders called for the government to institute policies and programs to assist the software industry, as it did for the hardware industry. To this end, the government of Taiwan has provided research funding and, in some cases, investment and tax incentives for software developers.[54] This software activity takes place in a larger context of increasing total R&D expenditures as a percentage of gross national product (GNP), increasing business expenditures for R&D; and emphasis on target industries including microelectronics, computers, computer peripherals, materials, automation and robotics, as well as software and information science.[55]

By the mid-1980s, according to the U.S. Department of Commerce, such government efforts had given rise to over 100 small software houses in Taiwan, most with fewer than 20 employees. These software houses were

46 Sheridan Tatsuno, "The Latest MITI Thrust: Supercomputer Simulation Hardware and Software," New *Technology Week,* June 10, 1991, p. 3.

47 See U.S. Congress, Office of Technology Assessment, *Seeking Solutions: High-Performance computing for Science*, OTA-BP-TCT-77 (Washington DC: U.S. Government Printing Office, April 1991); and U.S. Congress, Office of Technology Assessment, *Networking the Nation: The National Research and Education Network,* forthcoming 1992.

48 Gross and Schwartz, op. cit., pp. 56-57.

For case studies of six U.S. software firms in Japan (Autodesk, Lotus, Comshare, Ingres, Oracle, and SDC), see American Electronics Association, op. cit., footnote 41, pp. 77-89.

49 "Engineering Group Set Up To Work on UNIX Software," *The Asian Wall Street Journal Weekly,* Aug. 20, 1990.

50 American Electronics Association, op. cit., footnote 41, pp. 10-11. IDC data cited by the American Electronics Association indicate that while MS/DOS *will* continue to dominate microcomputer operating systems in the early 1990s, use of Unix systems is expected to grow at a compound annual growth rate of 140 percent during this period, compared to 25 percent annually for MS/DOS.

51 Paul C.B. Liu, "Computer Software and Intellectual property Law in the Pacific Rim counties, ' contractor report prepared for the Office of Technology Assessment, March 1991, p. 4.

52 Jullian Wu, Market Intelligence Center, Institute fo, Information Industry, personal communication (letter), June 13, 1991.

53 According t. Taiwan's Council of Economic Plarming and Development, 50 percent of Taiwan's GNP will come from services by the year 2000. Chris Brown, "Taiwan Software Firms Ponder World Market," *Computerworld*, vol. 24, No. 29, July 16, 1990, pp. 110-111.

54 According t. the Institute for Information Industry's Market Intelligence Center, conditions under which software firms may receive investment and tax incentives are strict; from 1985 to 1989 only 15 software companies qualified for the tax incentive. (Jullian Wu, Market Intelligence Center, Institute for Information Industry, personal communication (letter), June 14, 1991.)

55 Dennis Fred Simon, "Technology Policy on the Pacific Rim," *Forum for Applied Research and Public Policy,* fall 1990, pp. 67-72. In 1978, total R&D expenditures in Taiwan amounted to 0.5 percent of GNP ($1 11 million); by 1987, R&D spending had increased to 1.2 percent of GNP; Taiwan's 10-Year Science and Technology Development Plan projects R&D expenditures of 2 percent of GNP by 1995.

primarily developing application-software packages; by contrast, systems-software development in Taiwan was mostly being done in publicly supported research institutes like the Institute for Information Industry (III). Tax incentives and the availability of skilled, lower-cost labor led major U.S. corporations like Hewlett Packard, IBM, and Wang to establish software-development groups in Taiwan .56 Computerization of whole industries in Taiwan contributed to the rapid growth of Taiwan's software industry. By 1990, it had grown to about 300 software firms; 1990 revenues from sales of Taiwanese application-software packages amounted to $149.5 million.[57]

The government-sponsored III has been charged with promoting progress in the software industry through a variety of technical and institutional means. These include development of Chinese versions of Unix and the X Windows interface for use in workstations[58] and educational efforts to promote intellectual property concepts to the public,[59] as well as market-intelligence, economic, and legal research for the industry.[60] III has also signed a cooperation agreement with the Justice Yuan for information exchanges and joint research in computer law.[61]

Singapore

Over the past decade, Singapore has actively pursued a national goal of developing a vital software and services industry. This has largely been done under the auspices of the National Computer Board (NCB), established in 1981.[62] According to the U.S. Department of Commerce, in 1982 the government of Singapore initiated a 5-year, *$80-million* program under the direction of NCB to train computer specialists and provide financial incentives for local software development.[63] Three government-run training institutes were established under this program; of the three, one was a joint venture with IBM, and another was provided with significant funding and equipment from the Nippon Electric Co. (NEC) of Japan.[64] By late 1984, Singapore's financial incentive packages resulted in the establishment of software centers by Nixdorf, the Digital Equipment Corp., Hewlett Packard, and Sperry .65

In 1983, the revenues for Singapore's software industry amounted to $24 million; about $4 million came from exports.[66] AS of 1990, according to the U.S. International Trade Administration (ITA), software and services were a billion-dollar industry in Singapore.[67]

According to the ITA, having accomplished its initial objectives, the NCB is now *using* its applied-research arm, the Information Technology Institute (ITI) to strategically target R&D and commercial uses of emerging technologies like AI and fuzzy logic. 68 At the Nanyang Technical Institute, collaborative R&D by government and industry targets computer integrated manufacturing,

56 U.S. Department of Commerce, office of Computers and Business Equipment/Science and Electronics, *A Competitive Assessment of the United States Software Industry* (Washington, DC: U.S. Government Printing Office, December 1984), p. D-2.

57 Jullian WU, Market Intelligence Center, Institute for Information Industry, personal communication (letters), June 13 and 14, 1991.

58 Chris Brown, op. cit., footnote 53.

59 Carol K.N. Chang, Planning Engineer, Market Intelligence center, Institute for Information Industry, personal communication (meeting), Nov. 9, 1990.

60 Jullian S.L. Wu, Project Manager, and Josephine L.L. Houng, Legal Research Fellow, Market Intelligence Center, Institute fOr Information Industry, personat communication (meeting), Apr. 23, 1991.

61 Under the terns of the agreement, III will provide the Yuan with computer law and market information and the Yuan will provide the III with court decisions related to intellectual property. The Justice Yuan and III held their first legal research meeting in June 1991. Jullian Wu, op. cit., footnote 57, June 1991.

62 The National Computer Board was established with three principal objectives: 1) to computerize the gov ernmental services and departments, 2) to train software professionals in sufficient numbers to meet Singapore's needs, and 3) to develop the software and services industry. For more information see Victoria Kader, Office of Computers and Business Equipment, International Trade Administration, "Singapore Moves Into the Advanced Information Age," *Business America,* Aug. 13, 1990, p. 9.

63 See U.S. Department of Commerce, op. cit., footnote 56, p. D-1.

Government assistance for Singapore software development gave rise to controversy in 1989-90, when the U.S. Department of Commerce investigated whether a Singapore firm's software product (being marketed in the United States) was an "unfair" competitor in that the Singapore Government had subsidized the development of a commercial software product. In March 1990 the Department of Commerce's ITA reversed its original ruling that the product, a computer-aided software engineering tool, had been subsidized. The ITA ruled that software on a disk or tape, including software on a master disk, can be subject to import duties. (David A. Ludlum, "Commerce Department Revokes Singapore Ruling, " *Computerworld, vol. 24, No. 14,* Apr. 2, 1990, p. 119.)

64 Department of Commerce, op. cit., footnote 56, pp. D-1, D-2.

65 Ibid.

66 Department of Commerce, op. cit., footnote 56, p. D-2.

67 Kader, op. cit., footnote 62, p. 9.

68 Ibid. According to ITA, NCB accomplished its goal Of@aining 8,000 new software professionals (Singapore started with 1,800 in 1982) in 1990, 2 years ahead of schedule. ITA also reports that computerization in the government resulted in cost savings amounting to 1.7 times the investment in information technology.

often using U.S. expert system development tools.[69] With industry partnership, the Institute of Systems Science (ISI) at the National Institute of Singapore is working on AI and fuzzy-logic applications, including a neural network for foreign-exchange trading and a logistics system incorporating fuzzy-logic principles for the Singapore seaport.[70]

@Ibid., p. 9.

70 Ibid., p. 10. According to ITA, the 1S1 is active in training programs, such as a degree program in knowledge engineering, that are tailored to meet the needs of industry. The NCB also finances training programs in information technology and provides assistance programs for computerization of company business operations.