THE JAPANESE SOFTWARE INDUSTRY:
A COMPARATIVE ANALYSIS OF SOFTWARE DEVELOPMENT STRATEGY AND TECHNOLOGY OF SELECTED CORPORATIONS

by

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ABSTRACT

This thesis discusses the development of the Japanese
software industry, beginning with corporate group
structures, government support of the computer industry in
general and the more recent specific promotion of the
software industry and software development process
technologies. The SIGMA project is presented in detail
followed by a comparative analysis of major Japanese
computer manufacturer development process R&D efforts. The
current competitive environment is discussed and firms’
strategies are compared. The analysis concludes that
Japanese computer manufacturer’s long term investment in
automating the software development process paces them
ahead of US firms in computer aided software engineering
technologies (CASE). This competitive lead makes it likely
that, as the worldwide industry struggles to meet rapidly
growing demand for software, Japanese firms will leverage
their productivity and quality advantage to capture greater
market share.

Thesis Supervisor:

Michael A. Cusumano
Assistant Professor of Management
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Introduction

The computer industry as a whole has been one of the fastest growing global industry sectors. With dramatic declines in the price/performance ratio of computer hardware, software has emerged as an industry unto itself, representing between 80% and 90% of the cost (software and maintenance) of information technology applications (OECD Report, 1984). The central role of software in information technology became apparent as manufacturers realized that the tremendous advances in hardware capability would only become economically useful when coupled with software that allowed widespread use by non-data processing personnel. As a result, the software industry has grown from a $10 billion industry in 1981 to over $50 billion today and promises continued rapid growth in the future (see figure i).

The Japanese computer and software industries have lagged behind the development of the worldwide industry, but have gained remarkable ground in the last 10 years. Japan's software industry now ranks third in the world. With revenues of $1.5 billion in 1983, it's industry is a tenth the size of the 70% market share held by the U.S. software manufacturers, but is clearly a major player for world market share (Fortune, Oct., 1984). The U.S. continues to be
the technology leader, but under a comprehensive promotion and protection plan, the Japanese government has nurtured its software industry and succeeded in shifting comparative advantage in its direction. Vigorous competition within Japan from industry leaders like IBM and DEC have contained the Japanese industry to its own borders, but with increasing difficulty. The combination of state intervention and competitively driven, but also cooperative Japanese firms, has built an industry which is capable of and beginning to compete effectively in the global market.

This thesis briefly reviews the early development of the software industry in Japan and then discusses the importance of "group relationships" and technology tie-ups with foreign
manufacturers during its infancy. The vital role the
government played in nurturing and directing both the
computer and software industries is explored in-depth. A
chapter is devoted to the SIGMA project, perhaps the most
potentially significant government/industry cooperative R&D
program ever undertaken in the Japanese software industry. A
large portion of this thesis then reviews the evolution of
software development process technology in Japan, compares
the technologies of the major Japanese computer/software
manufacturers and assesses the importance of this technology
in the future. A broader view of the competitive environment
and current major Japanese and foreign equity firms' strategies are presented and the final chapter then draws
some general conclusions on the positioning, technological
capabilities and strategies of the Japanese software industry. As it is often difficult to separate software from
the computer industry in general, much of the discussion
will focus on Japanese computer manufacturers (JCM's) who are also the software industry leaders.

This thesis presents primarily a historical view of the rapid growth and development of the Japanese software industry and provides some implications regarding the health and future potential of this industry. The research is based on available literature, past and current US and Japanese trade press articles, working papers and opinions and
information provided by sources involved in software related activities in IBM Japan. My intent has been to cover a wide range of topics in order to present a composite view of the many factors influencing the past development, current state and future potential of the Japanese software industry. To such an end I have omitted many details on the topics presented, each of which, taken individually, could have represented an entire thesis.
CHAPTER 1

Early Development of the Japanese Software Industry

Local Firm Participation

Traditionally, there has been a strong presence of computer hardware manufacturers in the software market (OECD Report, 1984). Manufacturers supplied systems software bundled with the hardware and applications typically as a part of turnkey contracts. The subordinated status of software evolved considerably in the 1970's after IBM "unbundled" software from hardware sales in 1969 and essentially launched a new industry in the U.S.

Japan followed this pattern of software industry evolution with about a 10 year lag behind the U.S. industry. In 1969 the major hardware manufacturers (e.g. Hitachi, NEC, Fujitsu) began to form software subsidiaries (U.S. Dept of Commerce, 1984). The industry did not begin to really establish itself, however, until the 1970's when the Japanese government began its formal assistance programs and the major firms began cooperating in research and development. In 1970 the leading firms established the Japan
Software Industry Association (JISA) as a collaborative trade and R&D organization. MITI also enacted the Information Technology Promotion Law and created the Information Technology Promotion Agency to promote and assist software development and utilization in Japan (discussed in more detail in Chapter 3).

By 1982 there were over 2000 software vendors producing $1.2 billion in revenue and growing at a 20% compound annual rate (see Figure 1.1).

![1982 Software Industry Revenues](image)

Source: U.S. Dept. of Commerce, '84

Figure 1.1

Of the 2000 plus software vendors, as many as 75% of them were actually subsidiaries or sub-contractors to the major hardware vendors and more than 90% of their output was
custom software as opposed to application packages (Fortune, Oct., 1984). They served primarily the domestic market with exports amounting to less than one percent. The software they produced was generally considered less sophisticated and more expensive to produce than western software. Of the top ten software suppliers in 1982, the first and fourth leading firms were subsidiaries of major hardware manufacturers and many of the others maintained affiliations (see Figure 1.2).

As recently as 1983 the Japanese were considered to be 10-15 years behind the U.S. in software development (Forbes, Aug., 1986). Both the government and major firms realized the importance of software to the health of their computer industry and began increasing their efforts on its improvement. Mamoru Mitsugi, a managing director of Fujitsu, said "Software is very important to getting more market share than we have today" (Fortune, Oct., 1984). The big three firms (Fujitsu, Hitachi and NEC) spent over $500 million in 1984 on software research and development, three quarters of their software revenues. They have 10 "software factories" between them which are making good progress in the quantity and quality of software, while also significantly reducing the development costs. Edward Miller, president of San Francisco based Software Research Associates, estimates that Japan's "factory" approach to
### 1982 Revenues and Programmer Employment of Top Ten Japanese Software Suppliers (1)

<table>
<thead>
<tr>
<th>Company</th>
<th>FY 1982 Revenues ($ millions)</th>
<th>Number of Programmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nippon Electric Software</td>
<td>105</td>
<td>1,065</td>
</tr>
<tr>
<td>Japan Business Consultants</td>
<td>92</td>
<td>1,350</td>
</tr>
<tr>
<td>Computer Services Kaisha</td>
<td>71</td>
<td>3,100</td>
</tr>
<tr>
<td>Hitachi Software Engineering</td>
<td>60</td>
<td>1,450</td>
</tr>
<tr>
<td>Japan Business Automation</td>
<td>37</td>
<td>442</td>
</tr>
<tr>
<td>Central System</td>
<td>32</td>
<td>400</td>
</tr>
<tr>
<td>Japan Electronic Development</td>
<td>26</td>
<td>640</td>
</tr>
<tr>
<td>Mitsubishi Research Institute</td>
<td>22 (E)</td>
<td>416</td>
</tr>
<tr>
<td>Japan Information Industry</td>
<td>17</td>
<td>730</td>
</tr>
<tr>
<td>Software Research Association</td>
<td>17</td>
<td>310</td>
</tr>
</tbody>
</table>

**SUB TOTAL Top Ten Suppliers** 479 9,903

**TOTAL Japanese Suppliers** 1,046 38,152

(1) Includes subsidiaries and affiliates of computer manufacturers and independent software houses. This data understates the actual size of the industry as it does not include the "bundled" software and the total software revenues of major Japanese computer manufacturers which could be as high as 50% of the unbundled and it also does not include the in-house developed software of corporate DP or MIS departments.

(E) Estimate

Source: U.S. Dept. of Commerce, 1984
Figure 1.2
software development makes it possible to write 1000 lines of code at half the cost of traditional approaches and the president of Promod Inc., a maker of computer aided tools for software engineers, believes that the factories are achieving a ten-fold increase in productivity with only one-tenth the defects (Forbes, Aug., 1986).

This push to improve software was also supported by numerous government programs, the net result being a substantial improvement in Japanese produced software. Firms began concentrating in traditional areas of expertise (graphics, CAD, languages, etc.) The focus began shifting to packaged applications with custom software dropping below 60% (Forbes, Aug., 1986). Firms such as Zuken, Hitachi America, Ltd. and Tokyo Stella Systems have begun to export and achieve some success in the American market. Japan’s software industry is also becoming a prime contender in the fast-growing Asia/Pacific market.

Entry of Foreign Firms

In addition to the opportunity provided by the growing Japanese market, many U.S. firms had the foresight to position themselves to compete with the Japanese within their local market. IBM is the clearest example of this
strategy. IBM formed a sales subsidiary in Japan in 1937, but its assets were confiscated during the war (Anchordoguy, 1987). The company was re-established in 1949 as Nihon (Japan) International Business Machines, one year before the Foreign Capital Law was enacted. This enabled IBM Japan to avoid being forced to establish itself through a joint venture as later entrants were required to do. IBM made several unsuccessful attempts over the next decade to obtain permission to import technology and begin manufacturing operations. In 1960 MITI concluded that access to IBM technology was critical to the development of a domestic computer industry. MITI was in a strong bargaining position, able to offer market access, and manufacturing permission, but IBM’s competitive advantage in technology proved to be a stronger lever.

After difficult negotiations IBM Japan was given permission to manufacture limited computer models in exchange for technology licensing agreements, but MITI retained sufficient leverage to delay startup and control production volumes. Japanese firms significantly improved their capability in the wake of MITI’s decision to follow the technological leadership of IBM. Along with hardware technology came access to IBM software, especially operating systems.
Other U.S. firms with less bargaining power like Sperry Rand were able to enter the Japanese market, but only by agreeing to a joint venture relationship with a Japanese firm or technology licensing agreements. Sperry joined with Oki Electric, RCA with Hitachi, GE with Toshiba, TRW with Mitsubishi, and Honeywell with NEC (Anchordoguy, 1987). These tie-ups were typically an exchange of technology for market access and benefited the Japanese firms to a much greater degree than their U.S. partners.

DEC’s first entry in the Japanese market was in 1960 through an arrangement with Rikei, an importer and distributor (Baba, 1985). DEC established a branch sales office in 1968 and later a service center, software services department, product development group, and finally an R&D group in 1982. In 1978 MITI began to liberalize it protectionists policies, thus eliminating most entry barriers for both hardware and software manufacturers.

Japanese firms benefited significantly from the presence of major foreign firms and from the technology they were able to indirectly acquire. IBM, Sperry and DEC not only infused technology into Japan, but also stimulated vigorous competition within the domestic market. Early tie-ups with other U.S. firms provided direct technology transfer which helped the major Japanese firms compete quickly, but later
set them back as the flow of new technology dried up with
the withdrawal of RCA, GE and Honeywell from the mainstream
of the computer industry. This drove most of the Japanese
manufacturers to an IBM compatible strategy so that they
could take advantage of the large amount of software which
existed, and caused them to increase focus on their own
in-house software development efforts. Fujitsu, much like
Toyota in the automobile industry, chose to rely exclusively
on indirect technology transfer and develop its own in-house
capabilities from the beginning. It was not until 1974 when
it saw the opportunity to aid Amdahl, that Fujitsu moved to
an IBM compatible strategy (Cusumano, 1986).
CHAPTER 2

Relationships Between Manufacturers

Corporate Group Relationships

Each of the major Japanese computer manufacturers is a member of one or more "corporate groups" (Keiretsu). The major Keiretsu include Mitsubishi, Mitsui, Sumitomo, Sanwa, Fuyo and Dai-ichi Kangyo Bank (See Appendix A for details on membership structure). The Keiretsu has been the principal non-government cooperative mechanism which helped modernize and expand Japan's economy after World War II. They are large combinations of financial, manufacturing and sales organizations. (IBMa, 1987)

In many cases significant data processing business has been transacted between member companies of a Keiretsu. The Dai-ichi Bank was the main financial concern in the group to which Fujitsu belongs. In the mid 1960's they made a bold decision to be the first bank in Japan to replace an IBM on-line banking system with a Fujitsu system. Kawasaki Steel was the first private customer for Fujitsu's M-780 computer. Hitachi was able to successfully install its HITAC systems at the Sanwa Bank and the Industrial Bank of Japan, both of whom Hitachi has maintained close business relationships.
with over several decades. In the Sumitomo Group there are more NEC customers than in any other group and Oki was able to sell large quantities of terminals within its group to Fuji Bank. In 1985 Mitsubishi Electric abandoned its plan to announce an IBM compatible system in favor of marketing new systems developed by companies within the Mitsubishi Group. (IBMa, 1987)

Group membership, however, does not guarantee business as each company is independent from a P&L standpoint and is driven by its own profit maximization objectives. However, agreements for preferential offerings such as discounts or joint ventures are more easily closed between companies in the same group. Intercompany relationships are also closer within the older Mitsubishi and Sumitomo groups than in the newer groups such as DKB, Fuyo and Sanwa. Group relationships are becoming increasingly complex as illustrated by the subgroup structure which has formed within the DKB group (see figure 2.1).

Numerous relationships have also evolved between companies in different groups. Fujitsu maintains close business relationships with Mitsubishi Trust & Banking and Toyo Trust & Banking for computer trust bank leasing although both are outside of the DBK Group (IBMa, 1987). Mitsubishi Electric has been increasing its ties with Nippon Univac, a joint
venture between Mitsui & Co. and Sperry Corporation. C. Itoh has closer relationships with Hitachi than Fujitsu and with the cooperation of Mitsubishi Corp. (a major trading firm in the Mitsubishi group), Fujitsu succeeded in increasing its

DKB GROUP

Dai-ichi Bank

Furukawa Group
Furukawa Co.
Furukawa Elec.
Fuji Electric
Fujitsu *
Asahi Life, Etc.

C. Itoh

Kawasaki Group
Kawasaki Heavy I
Kawasaki Steel
Kawasaki Kisen (Ocean Trans),
Etc.

Kangyo Bank

Shiseido
Yasukawa Electric
Kanematsu Gosho
Seibu Dept. Store
Fukoku Life
Nippon Express
Etc.

New Group

Hitachi
Shimizu Construction
Asahi Chemical
IHI
Asahi Optical (Pentax)
Etc.

Note: * Fujitsu's relationship with the old Dai-ichi Bank subgroup is still stronger than with the other two subgroups.

Source: IBMa, 1987
Figure 2.1
Current Relationship Between Mitsubishi and Fujitsu

Notes: Mitsubishi Corp. markets FACOM systems jointly with MOM

70% of MOM's revenue was reported to be from FACOM sales in fiscal 1986 and sales from Fujitsu products are about 3 times that of Mitsubishi Electric.

Source: IBMa, 1987
Figure 2.2
customer base in the Mitsubishi group. The two formed a marketing agreement in September of 1972 for sales of Fujitsu’s FACOM computer both in Japan and abroad. By 1979 Fujitsu installations accounted for nearly a quarter of the total systems installed at the Mitsubishi Group companies. The current relationship between Mitsubishi and Fujitsu is depicted in Figure 2.2.

Foreign Computer Manufacturer Relationships

IBM formed a sales subsidiary in Japan in 1937, but its assets were confiscated during the war (Anchordoguy, 1987). The company was re-established in 1949, one year before the Foreign Capital Law was enacted. This enabled IBM Japan to avoid being forced to establish itself through a joint venture as later entrants were required to do. In 1960 MITI concluded that access to IBM technology was critical to the development of a domestic computer industry. The government gave IBM permission to manufacture in Japan in exchange for technology licensing agreements with Japanese computer manufacturers.

Other U.S. firms with less bargaining power were only able to enter the Japanese market by agreeing to a joint venture with a Japanese firm or technology licensing agreements.
Hitachi made an agreement with RCA in 1961, Mitsubishi and TRW in 1962, NEC and Honeywell in 1962, Oki and UNIVAC in 1963, and Toshiba and GE in 1964 (IBM, 1987). These relationships were typically an exchange of technology for market access and they benefited the Japanese firms to a much greater degree than their U.S. partners until the withdrawal of RCA, GE and Honeywell from the mainstream of the computer industry. Fujitsu, however, chose to rely exclusively on indirect technology transfer and focused its efforts on in-house computer and software development.

Current relationships are primarily based on OEM export which has been a basic strategy of JCM’s. Fujitsu and Hitachi have been placing emphasis on OEM export of large and intermediate mainframe computers and NEC has begun OEM mainframe export to Honeywell Bull. However, export growth to the U.S. has been losing significance because of the appreciation of the Japanese yen. Appendix B illustrates the magnitude and complexity of these relationships. Although only hardware relationships are shown, many of these relationships are also the basis for exchange of related software.
CHAPTER 3

Government Intervention and Promotion Strategy

Overview

During the 1960’s Japan’s policy toward the computer industry was one of protection. The government had decided that the development of a Japanese computer industry should be a strategic goal and as such relied on various protectionist instruments to carry out this policy. Among them were raising tariffs from 15-25%, import quotas, foreign exchange control, state procurement preference, and strict control over foreign investment. State protection of the computer industry as a whole was quite extensive and this protection nurtured the development of several major hardware manufacturers who also became the leaders in the development of a Japanese software industry (Anchordoguy, 1987). Without this protection it is questionable as to whether these firms would have had the necessary resources to devote to software development, let alone survive as hardware manufacturers.

A series of laws were enacted and in effect from 1957 to 1985, which empowered the Ministry of International Trade
and Industry (MITI) to carry out a comprehensive set of programs intended to promote and support the computer industry (IBMa, 1987). During the 1960's MITI's policies were primarily directed at protecting Japan's infant computer industry from foreign competition, but in the 1970's MITI's policy shifted from protectionism toward promotion of the industry. By the mid seventies the Japanese computer firms had gained sufficient technological capability to allow the market to be opened to foreign imports and capital.

The key elements in Japan's strategy were 1) early protectionism, 2) government creation of a national computer leasing company, Japan Electronic Computer Company (JECC), 3) government sponsored cooperative R&D projects (see appendix C for summary history), and 4) substantial financial assistance to the industry. The magnitude of the financial assistance is illustrated in figure 3.1 and 3.2. It is significant that government funding accounted for more than 50% of the total investment from 1970-81 and during the critical developmental decade of the seventies it was 170% of the total private sector investment. MITI has consistently underwritten technological development as well as provided loans and subsidies for hardware and software development. MITI's Electrotechnical Lab (ETL) has engaged in significant technological development.
Figure 3.1


Source: Anchordoguy, 1987

Figure 3.2

Source: Anchordoguy, 1987
Government Legislation

In 1957 the Law on Extraordinary Measures for the Promotion of the Electronic Industry (Denshinho) was enacted. The electronic industry was declared strategic and the government was to pay special attention to particular areas of the industry such as computers. This law was succeeded by Kidenho in 1971 and then by Kijoho in 1978. These laws gave MITI the tools to create plans to reorganize and realign the industry and empowered the government to embark on continuing efforts to close the significant technology gap as well as protect local computer manufacturers.

The June, 1957 The Law on Extraordinary Measures for the Promotion of the Electronic Industry (Denshinho) gave MITI the power to: (1) outline programs of R & D planning, (2) to provide financial assistance to manufacturers and (3) formulate plans to reorganize the industry (IBMa, 1987). Subsidy programs to assist the "infant" industry began shortly after the enactment of this law. In 1963 the government decided on a preferential use of Japanese products by the government sector for the purpose of saving foreign exchange reserves. The MITI Minister also sent a letter requesting the business sector to do the same. While this policy included many products, computers were specifically emphasized. This policy lasted until 1972 for
products other than computers. There have been no definite nullification statements for government purchase of computers although MITI began approving the purchase of U.S. made computers in 1977. The significant effects of this policy are demonstrated by the fact that according to a survey made in the summer of 1986, the three major computer manufacturers owned more than 95% of the central government install base (IBMa, 1987).

The Law on Extraordinary Measures for the Promotion of Specific Electronic and Machinery Industries (Kidenho) replaced Denshinho in 1971 and was in force through 1977. The law empowered the MITI Minister to direct manufacturers to engage in concerted activities pertinent to industrial standards, technology enhancements, limitation of product types, procurement of components and raw materials, and use of production facilities. It also exempted certain joint activities from application of Japan's anti-trust law (IBMa, 1987). Under this authority MITI organized the six major JCM's into three groups: Fujitsu/Hitachi, NEC/Toshiba, and Mitsubishi Electric/Oki. They received a total of 57.47 billion yen in subsidies between 1972 and 1976 for R & D on the "3.75 generation" systems to compete with the IBM S/370 line. In September 1973, a MITI subcommittee issued a report entitled "The Future of Computerization and the Information Industry in Japan". Referring to the realignment of the
computer industry, the report stated, "It is important to strengthen collaboration within each group without weakening the vitality of the enterprises, but it is not appropriate to force reorganization of the three groups at the present time." It proposed holding off discussion of further integration and specialization until all three groups had announced their new series models. This occurred in 1975, when under pressure from MITI, they decided to reorganize to develop their fourth generation VLC computers as follows (see figure 3.3):

1. Toshiba-NEC group unchanged although Toshiba later withdrew from general purpose mainframe business.
2. Mitsubishi Electric joined the Fujitsu-Hitachi group.
3. Oki split off and was promoted as a specialized terminal manufacturer.

The Law on Extraordinary Measures for the Promoting of the Specific Machinery and Information Industries (Kijoho) took effect in July, 1978, replacing Kidenho as the legal basis of MITI’s promotional programs (IBMa, 1987). The primary difference between Kijoho and Kidenho was the addition of the software industry to the "specific electronic and machinery industries." Kijoho expired in June, 1985 with no new law to succeed it announced. MITI believes that the original objectives of this series of laws has been fulfilled.
The Japan Electronic Computer Co., Ltd.

The Japan Electric Computer Co., Ltd. (JECC) was formed under the guidance of MITI in 1961 (IBMa, 1987). It is a government supported joint venture of seven Japanese computer manufacturers whose major function is to relieve the JCM's from the financial burden of leasing computer equipment to customers. When a customer orders one of the qualifying products, JECC gives the JCM the full purchase
price and then collects the rental revenue from the customer, thereby greatly increasing the present value of the sale to the JCM (see figure 3.4).

JCM's

\[ \text{Sell Return of Install Machines} \]

\[ \text{Rentals Payment} \]

\[ \text{Discontinuance Notice} \]

\[ \text{Buy-Back} \]

JECC Rental

Source: IBMa, 1987

Figure 3.4

Funding is primarily from low interest loans provided by the government owned Japan Development Bank and other private financial institutions. In 1978 JECC also began handling software products. Ownership shares as of 1985 are as follows:

<table>
<thead>
<tr>
<th>Equity %</th>
<th>Purchase % by JECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fujitsu</td>
<td>29.5</td>
</tr>
<tr>
<td>NEC &amp; Toshiba *</td>
<td>40.2</td>
</tr>
<tr>
<td>Hitachi</td>
<td>17.1</td>
</tr>
<tr>
<td>Oki</td>
<td>7.9</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>5.3</td>
</tr>
</tbody>
</table>

* includes NTIS (a joint venture between NEC and Toshiba)

Source: IBMa, 1987
Cooperative R&D Promotion and Support

The Electrotechnical Laboratory (ETL) of the Ministry of International Trade and Industry (MITI) and the Musashino Electrical Communication Laboratory (ECL) of Nippon Telegraph and Telephone Public Corporation (NTT) have played an important role in Japanese computer technology development since the early 1950's. (note: NTT became a private company in April 1985)

In 1956, a decade after ENIAC, the world's first electronic computer, ETL developed Japan's first electronic computer (ETL-MARK III). In March of 1957 NTT and Tokyo University jointly developed Japan's first parametron computer, MUSASHINO I. (IBMa, 1987)

Under the guidance of MITI, Japan's first computer development association was formed in July 1962 between Fujitsu, OKI and NEC to develop a high performance large computer system comparable to the IBM 7040 and 7044. MITI provided a $1 million subsidy which was the largest ever R&D subsidy program at that time. (IBMa, 1987) In November 1964 the three companies developed the FONTAC (Fujitsu-Oki-NEC-Triple-Allied-Computer). Fujitsu was responsible for the main processor and the others provided the subprocessors. The system was not very successful, but
FONTAC became the basis for Fujitsu's first large system, the FACOM 230-50 (May 1964) and Hitachi's HITAC 5020 (April 1964).

In the early 1960's MITI also recommended to the Japanese computer manufacturers that they enter into technical agreements with foreign computer manufacturers. Hitachi and RCA made an agreement in 1961, Mitsubishi Electric and TRW in 1962, NEC and Honeywell in 1962, Oki and Univac in 1963, and Toshiba and GE in 1964 (IBM, 1987). Also under MITI's administrative guidance the seven major computer manufacturers of the time entered into cross-licensing agreements with IBM.

In April of 1964 Japan became a member of the OECD, changing it from an economically intermediate country to an advanced nation with an obligation to open its economy. The government felt it necessary to increase Japan's international competitive power and improve its balance of payments situation. In April of 1965 the Electronic Council (an advisory organ to MITI) made recommendations as to how to enhance competitiveness in the Japanese computer industry. As a result, in 1966, MITI's agency of Industrial Science and Technology started the National Research and Development Programs ("Large Projects"), (IBM, 1987). There have been four large projects including High Performance

Until recently most government promotion of software fell under hardware projects, however, there were several programs during this period that specifically attempted to promote the software industry. MITI’s ETL began the High Performance Computer Development project with an investment of 10 billion yen (IBMa, 1987). The Japan Software Company was formed under MITI’s guidance in 1966 as a joint venture of Hitachi, Fujitsu, NEC and the Industrial Bank of Japan, intending to produce a "common language" software to run on all three’s mainframes (Anchordoguy, 1987). It became Japan’s largest software company with over 200 programmers. Not structured to take advantage of competitive market incentives, like those present in the JECC effort, the company folded six years later.

In 1967 The Japan Information Processing Development Center (JIPDEC) was formed, with the support of MITI and industry organizations, to develop information systems for both government and industry (IBMa, 1987). JIPDEC’s projects have included:
Investigating domestic trends in the information processing industry.

Dispatching survey missions and study groups to the U.S. and Europe.

Conducting software engineering training courses on information processing technology.

Developing software systems using large scale domestic computers.

In April 1976 JIPDEC absorbed two similar MITI managed organizations, the Japan Computer Usage Development Institute and the Japan Institute of Information Technology, and thus becoming a comprehensive software promotion organization (IBMa, 1987). It is charged with the following responsibilities:

- Conduct fact-finding surveys on the status of information processing.
- Perform R&D for information processing.
- Provide DP education.
- Conduct information exchange with foreign organizations.

In 1970 the Information Processing Promotion Agency (IPA) was formed to promote general purpose software (US. Dept of Commerce, 1984). MITI provided $70 million to cover operating expenses between 1970 and 1982 and arranged more than $450 million in loans for software development. The objectives of the agency are (IBMa, 1987):

Development on commission of "specific programs" that have wide application but cannot be easily developed by a private company. "Package programs" were added in 1979.
Buying specified privately developed programs and leasing them.

Guarantee of debts incurred by software houses and data servicers.

Basic research on software engineering.

Surveys of data processing status to enhance management skills of DP operations in Japan.

IPA can fund up to 100% of the development costs of general interest software and in return shares in the profits if the effort is successful. It essentially provides venture capital for specific projects. In 1984, for example, IPA supported 33 projects with ¥3.5 billion (OECD Report, 1985).

In 1981 the Technical Center was created within the IPA for the promotion of leading-edge information processing technologies. In 1985 the law which chartered the IPA was amended and the agency was given a new job to develop a software production computer system called the "SIGMA System" with a government budget of 25 billion yen (see Chapter 4 for detailed information on the Sigma Project).

The Pattern Information Processing System (PIPS) Development project was launched in 1971 by MITI and funded with $97 million over ten years. This project was central to the development of graphics technology for kanji character processing and the insights gained into artificial intelligence have provided direction for the Fifth Generation Computer Project of the 1980’s. In 1976 MITI
guided the formation of the Joint System Development Center in which seventeen firms participated in a Software Production Technology project to develop software tools and to automate software production process. IPA provided $27 million in R&D funding over five years.

In 1978 MITI launched the Fourth Generation computer project with a software component R&D budget of $74 million (IBM, 1987). Tax incentives were also set up to allow software firms to set aside up to 50% of their income from packaged software sales as a tax free reserve. A software oriented cooperative group, including Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi Electric, CDL and NTIS, was formed to focus R&D on (1) basic technology, (2) network management technology, (3) data base technology, (4) virtual machine technology, (5) super high-level language processor and (6) Japanese information processor. A major emphasis was placed on "Japanese information processing for the Japanese Language". R&D expenditures on software totaled 40 billion yen out of a project total of 47 billion.

IPA established the Software Technology Development Center in 1981 as an R&D laboratory to assist firms in language compilers, CAD/CAM and data base systems and in 1982 MITI launched the Fifth Generation Computer System Project. This project due to complete in 1991 has government funding of
$450 million and is intended to significantly advance and merge hardware and software technology.

The Interoperable Data Base System project was launched in 1985 by the formation of the "Interoperability Technology Association for Information Processing, Japan" (INTAP) with participation from Fujitsu, NEC, Hitachi, Matsushita Electric, Sumitomo Electric, Sharp, Tohiba, Oki, and Mitsubishi Electric (IBMa, 1987). It plans to develop a wide-area network that will link workstations in government and industry through open systems interconnection (OSI) protocols. This program is expected to have significant impact on the highly advanced information societies which MITI intends to help establish in the 1990’s. The R&D effort will last from 1985 to 1991 with a total budget of 15 billion yen. It addresses an area of general concern to the worldwide software industry and if successful could provide JCM’s with an important competitive weapon in the world market.

MITI has also attempted to create a special "program right law" to open up software technology to the Japanese industry and reduce the comparative advantage of foreign firms. In 1983 it proposed that software be protected for 15 years as industrial property and not under copyright law (Japan Economic Journal, Jan. 24, 1984). In return for 15 year
protection firms would have to fully disclose their technology and license it freely. This was seen as a reaction to the Hitachi and Fujitsu settlements with IBM over copyright infringements and was tabled due to intense protest from the U.S. Department of Commerce, IBM and others (Fortune, Oct. 15, 1984).

There were also internal disagreements with the Cultural Affairs Agency which advocated protecting programs in the context of existing copyright law. At issue were the period of protection and the arbitration system which would have enabled software developers to use the software already developed by others. While this would have been a boost to program productivity as reuse of code would have been greatly facilitated, it probably would have limited new product technology infusion by foreign firms as their ability to protect their software assets would have been greatly impaired. In 1985 the Agency of Cultural Affairs prevailed and an amendment to the copyright law was passed to take effect January 1, 1986. The amendment included (1) explicit statement of "software" inclusion, (2) a simple procedure to register developed programs by individuals, and (3) copyright ownership by a corporation when software is developed in a corporation (IBM, 1987).

In 1986 MITI planned to spend almost $700 million promoting
the computer industry, targeting education, software, data base technology and regional computer communication systems (Electronic Business, Jun. 1, 1986). $42.6 million of this is specifically targeted for education of software developers and the Sigma Project. This is in response to a MITI projection of a 600,000 software engineer shortage by 1990 (see figure 3.5).

![Forecast of Japan's SW Supply/Demand Gap](image)

Source: Business Japan, Mar., 1986

Figure 3.5

MITI has developed a comprehensive three point program to address the persistent software gap which is recognized to be limiting the overall growth of the computer industry. This program includes comprehensive education and training, projects to promote efficiency of program utilization (packages) and efforts to mechanize software development (Business Japan, Mar., 1986).
To increase the quality and quantity of software engineers through education and improve the training of able instructors, MITI is promoting the concept of an Information Academy (Business Japan, Mar., 1987). This involves the formation of a Central Information University as the center for the promotion of the information processing industry and local information academies in each district, all part of a nationally coordinated information processing education program.

The high risk of packaged software product development and lack of a venture capital market, combined with a tendency for Japanese firms to view custom software solutions as a competitive advantage, has kept the proportion of packaged software relatively low. Efforts to counter this have been augmented by the explosion of the personal computer market and the shortage of programmers. MITI is placing high expectations on increasing the ratio of packaged software products as PC software gains market acceptance and as firms allocate their development resources more efficiently.

The Sigma project was begun in 1985 as a major effort to build software development automation tools and establish a national data base of these tools for dissemination to software firms. It plans to build libraries of reusable modules to be used as building blocks thus avoiding
duplication of effort and enhancing overall programmer productivity (Japan Economic Journal, 05/02/87). Government sponsorship of the five year project is at 50% and over 100 companies are participating, including at least six foreign-equity and foreign-Japanese joint venture companies.

Conclusions

The comprehensive government policies of the past twenty years with regard to the computer industry in general can certainly be considered successful in promoting a local industry capable of competing extremely well in a vast global market. Much of this can be attributed to MITI's effective combination of protection, financial assistance and cooperative R&D projects combined with an ability to maintain fierce competition among the JCM's and foreign firms outside of the cooperative ventures.

The effectiveness of the recent government promotion efforts in software remains to be seen, but they are clearly oriented toward improving the global competitiveness of their software industry by focusing on the fundamental areas of education, development process productivity and advanced product technologies. The Sigma Project is a critical piece of MITI's strategy and its outcome is likely to have a
significant impact on the future of Japan's software industry.
The SIGMA Project

Project Description

In October 1985 the IPA began the 5-year SIGMA (Software Industrial Generator and Maintenance Aids) project. SIGMA is a major effort to build software development automation tools and establish a national data base of these tools for dissemination to software firms. The project proposal was distributed to most computer manufacturers (including IBM Japan and AT&T) and software houses. The project is expected to cost 25 billion yen ($150M) from 1985 to 1989, and will be funded by both government and industry (IBM, 1988). SIGMA users will be located at approximately 10,000 sites.

The following environmental factors faced by the software industry in Japan have precipitated MITI to launch this project:

1 The majority of information contained in this chapter is derived from interviews conducted via electronic mail (December, 1987 and March, 1988) with Dr. T. Takeshita, Project Planning, Tokyo Research Lab, IBM Japan. Dr. Takeshita follows software engineering developments in Japan through the trade press, attendance at conferences, personal contacts and through his own efforts at the Research Lab. I am deeply indebted to him for this information.
Software crisis: a gap between the supply of programmers and the demand for them will reach 600,000 programmers in 1990.

No common computer network equivalent to ARPANET or CSNET in the U.S. is available.

No software development environment for small and medium size computers has been supplied by JCMs.

A serious technology gap exists between JCMs and independent software houses.

The overall objective is to improve software development productivity by a factor of more than 4. At present, development of computer software is reportedly performed 10% mechanically and 90% manually. SIGMA intends to reduce manual production to 20% (IBM, 1987). The basic approach is to provide a standardized development environment independent from specific manufacturer hardware environments and a common network for exchanging programs and technical information.

The specific goals of the SIGMA Project are (IBMc, 1988):

- Improvement of quality and productivity in
  - Business application area
  - Scientific and process control areas
  - Microprocessor programming area
- Elimination of redundant effort by reuse of software
- Improvement of development environment
- Accumulation of software know-how and technical skills
- Improved efficiency in education of software house programmers
In October, 1985, the SIGMA System Development HQ was established and full-scale R&D activities were begun (IBMa, 1987). System development is divided into two phases encompassing the following major activities:

First Phase (October 1985 - March, 1987)

- Sigma Operating System Version 1 which will be the base for creating a standard development environment.
- A group of tools necessary for the SIGMA system development and the tools that can confirm the effectiveness of the productivity improvement for experimental services.
- The SIGMA Center to manage and operate the total SIGMA System. (The center was established in Harumi in December, 1986.)
- The SIGMA data base which can be accessed for experimental data retrieval.
- The SIGMA Network which is necessary for basic information exchange and to construct the SIGMA System.
- The Management system for project management and data collection.

Second Phase (April, 1987 - March, 1990)

- Functional enhancement and extension of the SIGMA operating system.
- Enhancement of groups of tools and expansion of the scope of their applications.
- Enhancement of the SIGMA Center and the SIGMA Network with focus on security enhancement.

In the first phase of the SIGMA workstation development project, prototypes will be developed. In the second phase they will be evaluated by actual use at the participating software houses. The SIGMA System Development Headquarters at IPA planned to introduce trial machines made by
manufacturers who have finished development of SIGMA workstations by December 1986, and will start the first stage comprehensive tests.

The requirements to be met by the operating system to be used on SIGMA workstations are as follows (IBMc, 1987):

- A clear external specification (h/w independent)
- Multi-tasking
- Graphics for software design
- Interactive with multi-windows, etc.
- Easy to create tools
- Message and file transfer
- Security
- Virtual memory
- Accumulation of tools
- High transportability

In order to satisfy these requirements, it was decided to modify UNIX to include the following capabilities:

- Japanese language processing
  - Japanese word processor
  - Kanji support for variables, literals, and file names
- Graphics processing
  - Diagram processing for software design
  - Image (non-coded information) processing for documentation
- Window management -- multi-windows, color
Communication management
- Japanese file and message transfer
- Digital communication (i.e. X.25)
- Local area network (e.g. Ethernet)

File management
- Improved efficiency in file processing
- File access protection

A modified version of AT&T Bell Laboratories UNIX System V will be used for distributed processing and to build the large central system with data bases for common tools and software parts and to be shared with connected node systems at local centers. For the Japanese language capability, it is planned to make it compatible with AT&T’s international version UNIX. Software developers will have access via communication lines. The SIGMA Operating System and the C language will be used on users’ workstations. Object code which may run on IBM architecture machines will also be generated.

An agreement document specifies that Japanese language processing should conform to the Japanese language code developed at the end of 1985 by the Japanese UNIX System Advisory Committee, comprising Tokyo University and six Japanese computer manufacturers.

The following kinds of tools are planned to be developed for
use on the SIGMA workstations (see figure 4.1):

Basic Tools
- Office automation (OA) tools -- documentation, project control, schedule control, etc.
- Network tools -- message communication, file transfer, RJE, conversational virtual terminal, etc.
- Resource management tools -- local database/library by project, version control, etc.

Business Application Tools
- Support for total life cycle from requirement definition/design through maintenance
- The main language will be COBOL
- Reuse support tools

Scientific Application Tools
- Support for total life cycle from requirement definition/design through maintenance
- The main languages will be FORTRAN 77, and C (for micro-computers)
- Reuse support tools
- Cross compiler for micro-computers
- Debugging tools -- including source level debugging

The SIGMA Center is located in downtown Tokyo and administered by IPA. The facilities at user sites will be connected to the network and are supposed to run under a standard operating system (SIGMA OS). Also a SIGMA gateway will be provided to jobs using operating systems other than SIGMA OS.
Source: IBMc, 1988

Figure 4.1 - Organization of SIGMA System Tools
The SIGMA Center will offer network and database services and consists of five sub-systems:

- Network (NW) -- NTT
- Database (DB) -- Hitachi
- Demonstration (DEMO) -- Fujitsu
- Development environment (KK) -- Fujitsu
- EDP -- NEC

At the user sites the following facilities will be installed:

- Software development computer
- Database which may be connected to SIGMA network
- To provide software and technical information to other users
- Test purpose computer
- For testing software which requires non-SIGMA OS
- System services

SIGMA Workstations

The minimum SIGMA workstation configuration is as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>SIGMA OS</td>
</tr>
<tr>
<td>CPU</td>
<td>1 MIPS</td>
</tr>
<tr>
<td>Main Memory</td>
<td>4 MB</td>
</tr>
<tr>
<td>Hard disk</td>
<td>50 MB</td>
</tr>
<tr>
<td>Display</td>
<td>Bitmap (1000 x 1000) with color option</td>
</tr>
<tr>
<td>Others</td>
<td>Mouse and/or tablet</td>
</tr>
<tr>
<td></td>
<td>Communication interface (Ethernet, X.25)</td>
</tr>
</tbody>
</table>

The two main database services that will be provided are:

- Retrieval of tools and programs in database
- IPA programs (mainly tools) accessed via this service

Registration services for user programs

Three kinds of programs will be handled by this service:

IPA programs
User programs submitted to IPA for distribution
User programs located at user sites

- Information on efficiency, supplier, cost, etc. available through the network

The Network Service will provide the following:

Electronic mail in Japanese text
Electronic bulletin-board (in Japanese)
Electronic newsletters (text and NCI)
File transfer of tools and programs
Access to networks other than SIGMA
- e.g., CSNET, USENET
Remote logon for testing at remote sites
Trial use of IPA tools
Access to SIGMA user information

Software engineering education will be provided to the users of the SIGMA System:

Guidance for SIGMA -- users will be guided on the services via help menus

Development methodology education will be conducted by using CAI-like packages
Project Progress and Status

In April 1985, Fujitsu announced a plan to set up a project team for positive involvement in SIGMA. According to a February 1986 newspaper report, Hitachi’s SDL/PAD can work on its 2050’s UNIX System V-compatible OS so that it can qualify as a SIGMA Project tool.

As of February 1986, the SIGMA Project had 135 companies, consisting of computer manufacturers and software houses, participating. A July 7, 1986 newspaper report says that the project has been promoted by some 250 companies including seven foreign capital-affiliated manufacturers, which will bear some of the total development cost of 25 billion yen (approximately 150 million dollars). As of the fall of 1986, approximately 560M yen ($3.5M) had been collected.

The names of the participating organizations are as follows:

JCMs, NTT
UNIVAC-J, DEC-J, Burroughs-J; Fuji Xerox
Sumitomo Electric Industry
Matsushita Electric Industry
Ricoh, Sharp, Sanyo, Tateishi
Hitachi SK, Toshiba Engineering
JBA, CSK, TIS, SRA, MRI, etc.
AT&T (note: IBM Japan declined to participate)
According to a news article which appeared in the July 7, 1986 issue of Nikkan Kogyo Shimbun (Daily Industry Newspaper) the SIGMA Project had taken a step forward towards practical operation in 1990:

1. The definition has been agreed for the "VO" which defines the SIGMA's OS and which has been reviewed by 59 companies, including Omron Tateishi and Sumitomo Electric Industries, to ensure compatibility of SIGMA OS

   - Basic control functions
   - Multi-windowing
   - Graphic capabilities

2. NTT, Hitachi, Fujitsu, and NEC will each participate in development of the system at the SIGMA center.

3. Based on this, IPA will begin monitoring tests from the second half of fiscal 1987

As of the fall of 1986 approximately 40 developers had been assigned to IPA project office from the industry and prototype workstations were being developed by 15 companies.

According to the 9/12/87 issue of Nihon Keizai, Fujitsu and PFU started to market the FACOM Sigma Station 200. It is equipped with the Sigma OS based on UNIX. More than 50 software development tools are available. The price is 3M to 3.8M yen (approximately $20K to $27K) and it is expected to sell 5,000 units in three years.

According to Nikkei Computer, 10/12/87, Oki and Sharp delivered their SIGMA workstation prototypes to the SIGMA System Development Office, following 9 other manufacturers.
who had already brought in their prototypes for SIGMA. Both of them use 68020 for their CPUs, and SIGMA V0R0 as OS. Their commercial versions will be marketed beginning in the spring of 1988.

According to Nikkan Kogyo Shimbun, 11/05/87, NEC has announced a Sigma-compliant EWS4800/10/50 offering twice the price performance of their existing EWS4800. The 4800/10 is a desk-top size, capable of 2.3 MIPS, offering a maximum 16M byte main storage, while the 68020 (20M Hz) based 4800/50 is capable of 3.2 MIPS, offering 32M byte main storage and a 32K byte cache memory. Both can be used as Sigma workstations, as well. Together with the ACOS Series machines, SX systems, PCs, etc., they can be used to construct a vertical/horizontal distributed system. The prices range from 1,900K yen to 5,450K yen and up. Sales objectives over the next two years are for 5000.

The Daily Network News, 3/23/87, carried a status report as of 1986 fiscal year end by the SIGMA Development office. Each activity seems to have been carried out as planned:

1. SIGMA Center hardware installation

   NTT’s CCP-IIE, Hitachi’s M260D, Fujitsu’s M360R, and NEC’s ACOS 630/10 have been additionally installed on top of the currently installed Data General Japan’s DG1000SX and DEC Japan’s VAX-11/785.
2. SIGMA workstation development

Digital Computer, Hitachi and Ricoh have been additionally approved on top of the already approved Sumitomo Electric Industry, OMRON, Toshiba, NEC, Fujitsu and Mitsubishi Electric Industries, totaling 9 suppliers.

3. SIGMA software

Six SIGMA Center hardware suppliers and Kohzo Keikaku Kenkyusho have completed each component, such as, network service, database service, development assist, user service and demonstration. In April, combined tests will start.

4. SIGMA tools

Prototyping system has entered into implementation.

Common tools have almost completed detailed design and will enter implementation in April.

Specific area tools:

- Scientific and process control - being implemented and enter testing

- Business processing - almost completed detailed design and to enter implementation by April

According to the 8/11/87 issue of Nihon Keizai Shimbun, in October MITI will start a trial use service of SIGMA for the companies who have developed OS and workstations for SIGMA. Actual application development will be done to find technical problems. In January, 1988, the trial use will be expanded to computer-related companies who are not participating in the project; and in April, it will be provided to general users in order to hear opinions and comments as to the charges for the use of the system which will officially start its service in 1990.
According to The Daily Network News, 11/24/87, MITI is planning to start establishing several regional SIGMA subcenters in Osaka, Hokaido, Kyushu, etc. in 1988 and to complete the on-line networks connecting to the SIGMA Center in Tokyo. Different application information data bases by region will be built and provided, and also will serve as access points to the data bases in the Tokyo Center.

According to Nikkei Computer, 10/12/87, the SIGMA System Development reorganized itself by splitting the 2nd Development Department into the SIGMA OS Development Department and the Common Environment Development Department. The former is starting the development of SIGMA OS VOR2 (Version 0, Release 2) as VOR0 had been completed and installed on various SIGMA workstations and VOR1 which has multi-media window capabilities is being implemented. VOR2 will have distributed file capabilities, most likely RFS (Remote File System) which has been developed by AT&T. Its specifications will be completed within 1987 and its development and transportation to various workstations will be completed by the end of 1988.

The latter department will integrate four common tools such as a documentation support tool, a project management tool, etc., and develop leading-edge tools such as requirement analysis/definition tools and others which utilize
artificial intelligence functions.

According to the Daily Network News, 11/5/87, following the experimental use by the companies developing SIGMA tools, the SIGMA Project has started accepting about 50 companies as monitors to use SIGMA workstations from 1/88 through 3/88 before the general use of the SIGMA tools begins in 4/88. The SIGMA tools are to be evaluated by actually using them for production works in the following categories:

- Tools required in common
- Tools for scientific and engineering, and process control software
- Tools for micro-computer software

According to Nikkei Computer, 10/26/87, Oki Electric will converge three UNIX-based OS's into a SIGMA OS by 1989. (note: Oki developed the SIGMA OS Prototype (VORO)).

Nihon Keizai Shimbun, 11/27/87, reported that a tutorial (in a comic-book style edited by IPA) on the SIGMA Project had been published by a publishing company in Tokyo. The project is now being supported by 177 companies with total funding of 25,000,000,000 yen (approximately 170M dollars).

According to Nikkei Computer, 12/21/87, was decided to support a DBMS to allow the use of SQL on SIGMA workstations.
According to Nikkei Computer, 12/21/87, the SIGMA Project HQ has decided on the procedures for release and distribution of software development tools.

1. SIGMA products are grouped into two classes: object code only and source code, for which different rules are defined for release and distribution.

2. An arbitration organization is to be set up for solving copyright violation problems.

3. The copyright of a modification to a SIGMA program belongs to the company who has modified it.

SIGMA products will be marketed by the manufacturers of SIGMA workstations. For those tools which are released in object code and which require workload to transfer (convert) to another kind of workstation, the workstation manufacturer pays the developer for acquisition of the sales right and the cost for transfer. In the case of tools to be released in source code, the transfer (conversion) is to be done by the workstation manufacturer, who will pay only for the acquisition of the sales right. The prices of these products to the end users will be based on the prices recommended by SIGMA Project HQ.

According to Nikkei Computer, 1/18/88, some 20 companies have started using preliminary SIGMA workstations as designated monitors in the scientific and engineering area. The designated monitors in the commercial area will be selected in 3/88 or 4/88. The trial use by general monitor users will be started in the scientific and engineering area.
in 6/88 and in the commercial area in 9/88.

On 12/21/87, several JCM's announced the schedule for releasing software products to connect Sigma workstations to host systems for TSS and file transfers.

Fujitsu: preliminary 2/88, official version 8/88
  TSS and file transfer
  OS IV/F4 MSP
  OS IV/X8 FSP

Hitachi: preliminary TSS 6/88, official version TBD
  file transfer 9/88
  VOS3

NEC: TSS, data entry, file transfer 4/88
  A COS-2/4/6

According to Nihon Keizai Shimbun, 1/25/88, MITI is also planning to introduce SIGMA into Asian countries, first into Sri Lanka and Singapore. Within 1988, it will send a study team to Asian countries, thereby promoting the advancement of the software industry in these countries and leading to overseas vendorization of software development. The study team will consider requirements for modification of the system to meet local needs and for connection to the center in Japan. Starting in 1989, MITI will begin dispatching specialists.

Nikkei Computer, 2/29/88, reported that the outline of SIGMA OS VOR2 specifications had been finalized and was to be made available to the manufacturers of workstations and vendors of tools. It includes distributed file functions based on
two different architectures:

NFS (Network File System) developed by Sun Microsystems

RFS (Remote File Sharing) developed by AT&T

It is expected that SIGMA OS V1, to be completed in 1990, will have a single distributed file system as the two file systems will be merged by then.

According to the Daily Network News, 2/25/88, 14 private companies involved in the project are experimentally using the SIGMA tools for evaluation. 40 more will start to use the tools at the end of February 1988.

Conclusions

MITI’s IPA has sponsored software engineering related projects in the past with mixed results.

Software Technology Project (1975 – 81) by JSD (Joint System Development) Corp.

Software Maintenance Engineering Facility Project (1981 – 85) by JSD

The leader of these projects, Mr. Kishida is now the chief architect of the SIGMA Project. Professor Ohno of Kyoto University, the chairman of the SIGMA System Advisory Committee, has also been involved in software engineering projects. Their experience appears to be paying off as SIGMA has managed to meet its interim targets. According to Dr.
Takeshita of IBM Japan (IBMc, 1988) "progress to date seems to represent significant effort in terms of the number of presented/published papers, the number of people involved, and/or some reported success in practical use, but does not necessarily mean remarkable innovative or creative progress."

Assuming that SIGMA meets all of its targets for the second phase, the impact on the Japanese software industry of the productivity improvements it will provide is likely to be determined by the world market’s acceptance of UNIX as a preferred operating environment. Recent literature suggests that UNIX is growing rapidly in popularity and may occupy as much as 25% of the market by 1990. AT&T is also showing signs of mounting a major push behind UNIX and is gaining support for an international standard version. If these things all come together, SIGMA may very well complete just as the industry begins jumping on the UNIX bandwagon. It may not be a major innovation, but it could well be a highly practical mechanism for leveraging scarce software development resources into large numbers of application products that operate independent of proprietary operating systems and across the microcomputer to mainframe spectrum.
CHAPTER 5

Software Development Process Technology

Early Development

Since the beginning of the 1970’s there has been an increasing demand for software development as well as a worsening shortage of programming manpower. The growing impact of software quality, not only on the industry and economy, but also on consumers’ daily lives, began to be recognized. By the middle of the 1970’s most of the Japanese computer manufacturers (JCM’s) began to make serious efforts to improve programming quality and productivity by an order of magnitude.

The Information Processing Society of Japan (IPSJ) published a special issue dedicated to Software Engineering in 1977, organized the Software Engineering Study Group in 1978, and held the first symposium in Software Engineering in the following year. Three years later, Japan hosted the 6th International Conference on Software Engineering (ICSE) in Tokyo. This conference gave more impetus to research and development in the field. In October 1983, the Japan Society of Software Science and Technology was established and the first issue of its journal, "Computer Software" was
The papers on software engineering presented in the semi-annual national conferences of IPSJ steadily increased from 51 at its 21st Conference in October 1981 to 205 at its 33rd Conference in October 1986. These numbers do not include those papers on operating systems, data bases, and expert systems (see appendix D).

Initially, Japanese computer manufacturers followed basic software engineering methodologies; top-down structured programming and design review. They then refined their development processes. They prepared detailed guidelines including not only 'what to do', but also 'how to do' using standardized report formats, lists of hints, checklists, etc.

Test coverage measurement tools became mandatory in many of JCMs' projects, including those performed by their vendors, several years ago. In the meantime, most of the software development organizations had developed product control systems to be used in-house by the beginning of this decade.

The majority of information contained in this chapter is derived from interviews conducted via electronic mail (December, 1987 and March, 1988) with Dr. T. Takeshita, Project Planning, Tokyo Research Lab, IBM Japan. Dr. Takeshita follows software engineering developments in Japan through the trade press, attendance at conferences, personal contacts and through his own efforts at the Research Lab. I am deeply indebted to him for this information.
The need to formalize requirement and design specifications, which would allow higher quality and would permit machine processing, was recognized in the second half of the last decade. Hitachi, NEC, and Toshiba developed their own design languages and started using them in 1981.

**Software Engineering Organizations**

Hitachi, NEC, and NTT have laboratories dedicated to software engineering:

- **Hitachi** - System Development Laboratory
- **NEC** - Software Product Engineering Laboratory
- **NTT** - Software Production Engineering Laboratory

Hitachi’s System Development Laboratory, located at Kawasaki City, had nearly 500 employees as of October 1986. Hitachi has other people involved in software engineering and tools development in Hitachi Central Research Center, software plants located at Totsuka and Ohmika, Hitachi Software Engineering Co., etc. Ohmika Plant has a Software Production Technology Department, and it is likely that a similar or larger organization exists to promote software engineering at Totsuka Plant.

In July 1987, NTT’s Software Production Engineering Laboratory became the Software Laboratory which has two organizations:
Software Basic Technology Lab

Software Production Engineering Lab

NTT also has a Software Development Center Organization working on projects to promote modularization, production systems, development support, and development planning.

Fujitsu does not have a laboratory dedicated to software engineering. Judging from the papers submitted to technical journals and conferences, software engineering related projects are conducted at Software Development Planning Group (a HQ organization), Research and Planning Division, Software Factory at Numazu, Systems Laboratory at Kamata, and at the International Institute for Advanced Study of Social Information Science and Software Laboratory of Fujitsu Laboratories, Ltd.

Toshiba has a System and Software Engineering Division and a Technical Planning Coordination Division. The former is engaged in software engineering research and development. According to the information which was given by Dr. Hon’iden of Toshiba at a seminar in Tokyo in April, 1987, Toshiba had reorganized its software development technology-related functions and had started System Software Technology Laboratory.
Mitsubishi Electric has software research personnel in its Central Laboratory and in its Information Electronics Laboratory.

The Central Research Institute of Electric Power Industry's Information System Department has a small software engineering group who has been developing a requirement specification for a compiler called "SPACE". It is one of the few non-manufacturing companies who have software technology research personnel.

A leading software house, Software Research Associates, Inc. has developed and is marketing a software development environment consisting of a number of tools on UNIX.

In addition, the Information Technology Promotion Agency (IPA), which is supported by the government, set up the Software Technology Center (STC) in Oct. 1981. A number of experts have been invited as researchers from both JCM’s and software houses. As discussed in the previous chapter, in October 1985, IPA established the SIGMA Project Headquarters organization.

Various advanced technology projects have been undertaken by these organizations and universities. They have produced a large number of papers which have been presented at
technical conferences in Japan and overseas.

**Structured Design Diagrams**

The most significant achievement among the Japanese software development technologies is the use of graphic notation for control figures and diagrams which fit a common software engineering design methodology and help enforce the design disciplines (see figure 5.1).

In 1974, NEC developed Structured Programming Diagram (SPD). Two of Hitachi's researchers worked from 1976 through 1979 designing and improving a set of graphic design notations called PAD (Problem Analysis Diagram). They won an outstanding contribution award for this work from the Information Processing Society of Japan. PAD, SPD, and NTT's HCP (Hierarchical and Compact description chart) were submitted to ISO (International Organization for Standardization) as candidates for standard graphic design notations a few years ago. They are currently included as examples in the appendix of an ISO draft standards document.
A. FLOWCHART \rightarrow B. NEW FLOWCHART (ISO)

C. TREE STRUCTURED
D. SPD (NEC), '74
E. YAC (FUJITSU)
F. CP CHART (NTT)
G. HCP (NTT), '79
H. HCP FOR ADA (NTT)
I. TREE FLOWCHART (NTT)
J. PAD (HITACHI), '79
K. TFP/TFD (TOSHIBA), '85
L. UNI-SHEET (UNIVAC), '86
M. GREENPRINT (IBM), '80
N. FESDD (FUJITSU), '82
O. SDD (FUJITSU), '78
P. SEDL/1.1 GRAPH (IBM), '86

CP : Compact chart
HCP : Hierarchical and Compact description chart
PAD : Problem Analysis Diagram
TFP/TFD: (Technical description for Procedure/Data design)
SPD : Structural Programming Diagram
YAC : Yet Another control Chart

Fig. 5.1 - Flowchart to Tree-Structure Diagrams

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Prior to 1980, there were many efforts to build software development support systems, which consisted of various subsystems and tools. Currently, all JCM’s and NTT have developed systems programming development environments, some of which are said to be used in production. The following are examples of early development support systems which were reportedly built for internal use:

- **Hitachi**: CASD - Computer Aided Software Development System
- **NEC**: SDMS - S/W Development and Maintenance System
- **Toshiba**: SWB - S/W Engineering WorkBench System
- **Fujitsu**: SDSS - Software Development Support System
- **Mitsubishi**: PWS - Programming Work Station System
- **NTT**: WAVE - Widely AVailable Environment for software development

In addition, all JCM’s, several software houses, and a number of DP customers have adopted TQC (Total Quality Control) which has been extremely successful in production industries. Toshiba started 'zero defect' activities in software development more than 10 years ago. NEC started a pilot study in 1978 and launched a company-wide Software Quality Control (SWQC) program in 1981. Other computer manufacturers, including Nippon Univac and IBM Japan, followed suit.
Japan has been making steady progress in adapting and utilizing software engineering methodologies and quality control (QC) techniques and tools. This is due, in part, to their keen awareness of the state-of-the-art computing methodologies in USA and Europe.

Hitachi’s progress in software development up to 1983 is summarized below:

Software Plants established in 1969

Phase I (1969 – 1973) -- Management Technologies
- Definition of development phases (processes)
- Standards in each phase
- Control methodologies (cost, process, quality)
- Independent Assurance groups

Phase II (1974 – 1978 ) -- Development Technologies
- Structured design technology
- System description language
- Virtual machine
- Interactive system
- Centralized library management
- Separate CPUs for Product Assurance

Phase III (1979 – 1983) -- Automation Technologies
- CASD (Computer Aided Software Development System)
- CASP (Computer Aided Production Control System for Software)
According to "Software Development for Computers and
Communications at NEC," which was printed in IEEE Computer,
November 1984, the NEC’s approach to software productivity
and quality is as follows:

- Improvement in development by CAD/CAM and
  standardization
- Reuse of existing S/W by part reuse technology
  and circularization
- Waste prevention by cross-product plan
- Eliminating excess functions by methodology and
  tools for requirement definition
- Product quality improvement by S/W quality metrics
  and tools for quality assurance
- Personal quality improvement by education programs
  for new/old professionals/managers

The software development process which Fujitsu has been
using since 1977 is called "SDEM (Software Development
Engineering Methodology)". The development of SDEM began in
1976. According to Fujitsu literature, the methodology is
supported by the following techniques and tools:

- EPG (End User-Oriented Planning Guidelines)
- C-NAP (Customer-Needs Analysis Procedures)
- ISDOS (Information System Development and Optimizing
  System)
- PSL (Problem Statement Language)/PSA (Problem Statement
  Analyzer)
- SDP (System Design Procedures)
- MDL (Module Description Language)/MDA (Module
  Description Analyzer)
- PARADIGM, ADAMS (Application Development And
Management System), ADAMS/E (Application Development and Management System/Extended), Hyper COBOL, SIMPLE (SIMPLE Application Development and Maintenance System)

ACS (Application Control Support System)

SIMPLE/ACS APG (Application Generator)

DOCK/FORTRAN 77, FORTUNE (FORTRAN TUNEr)

CMDS (Command Scheduler), ATOS (Advanced Test Oriented System), VOP (Virtual Operator)

GEM (Generalized program Editing and Management facilities)

PAGE (Program specifications Automatic GEnerator)

More than a half of these tools are primarily for application program development. Furthermore, MDL/MDA, CMDS, ATOS, VOP, etc. are most likely intended for internal use only. SIMPLE is said to be a set of tools for test data generation and data base creation and/or verification.

The following are the systems programming phases at Fujitsu:

Planning (by Planning Department located at Nakahara, Kawasaki City)

- Survey and Planning
- Project Planning
  -- Basic Project Planning
  -- Detailed Project Planning

Design

- System Design
  -- Initial Design
  -- Logical Design
  -- Functional Design
- Program Design
  -- Structure Design
  -- Module Design

Programming
- Coding and Compilation (Make I)
- Unit Test (Make II)
- Integration Test (Make III)

Testing
- Component Test
- System Test

Packaging
- Release Tape Creation
- Regression Test

Product Test (by Product Test Department)

Operational Test (by Systems Engineering Department)

System Evaluation (by Development and Product Test Departments)

Maintenance (by Development Department)

As of 1985 the following tools were used to support their development process:

Design Phase: YAC II (30 to 40 % of projects)

Programming Phase: GEM, PRISM-X, PFD

Test Phase: ATOS, test commands, PRISM-X, etc.

All phases: Project Control System
Current Focus of Development Process Technology

The preceding sections touched on how JCMs have achieved significant progress. The following sections look at some of the more recent areas where JCMs are currently making efforts and achievements.

Statistical Techniques and Quality Control

JCMs, especially NEC, are using statistical techniques not only for simple analysis, but for estimation/prediction and evaluation of software development cost, workload, and quality, however, quantitative methods to measure software quality are still controversial. The following companies have done work in this area:

- **Fujitsu**: defect data, productivity, tailored COCOMO models
- **Hitachi**: cost and quality modeling system
  SQE (Software Quality Estimation System)
- **NEC**: cost, test (test item extraction, bug detection, workload)
- **Toshiba**: reliability evaluation tool, cost life-cycle model
- **NTT**: cost, quality (an error estimation method)
  TQCS (Total Quality Control Support) implemented on a PC

NEC was the first to expand the definition of 'quality of software' as a company standard. In 1984 they began measuring software quality from the user's point of view by applying SQMAT (S/W Quality Measurement and Assurance)
Technology) which was developed in NEC.

At the 8th ICSE which was held August 1985, NEC reported on SQMAT based on SQM (Software Quality Metrics) which was developed by G. Murine (METRIQS Inc.). In March 1986, Hitachi presented two papers on the quantitative measurement methods of software quality. The May 1986 issue of Hitachi Hyoron (research and development journal) carries a paper entitled "Software Quality Evaluation System (SQE)". Fujitsu and NTT have also been trying similar concepts to evaluate various aspects of software quality. Some papers on the use of quantitative definitions of software quality have been presented.

In September 1986, a Fujitsu's large system software product test department reported in detail on the quality evaluation of large-scale software by taking into consideration the degree of the inconvenience to the user caused by troubles (defects) in the software.

The quantitative evaluation of publications has also been tried. In the fall of 1984, a Hitachi QC circle reported a success story on the evaluation of manuals. In September 1985, Fujitsu presented "Quantitative Evaluation of 'Ease of Use' of Manuals". In September 1986, Hitachi presented an excellent report on "Development of Task-Oriented Manual of
Toshiba has been using ESQUT (Evaluation of Software Quality from User's viewpoint). The two papers presented in September 1985 discussed "Analysis of Measurements" and "Readability Evaluation" both using the ESQUT methodology.

Although most people in the USA are skeptical regarding the effectiveness of quality control (QC) circles in software development, the number of QC circles have increased at Japanese software development sites. For example, the number of quality circles (called 'SWQC (Software Quality Control) groups') in NEC grew from 930 in 1983 to 1,500 in 1984 and to 2,000 in 1986. A large number of success stories are being reported. In NEC, 900 papers on SWQC group activities were submitted in 1986.

Another example is an extensive QC activity education and promotion campaign which has been conducted in Fujitsu's Telecommunication Division and five related companies involving 2,000 software developers since June 1984.
Test Techniques and Tools

Although greater emphasis has been placed on better design work and design review, improvements in testing techniques and tools has continued. Particularly interesting are Hitachi and Fujitsu’s methods to generate test cases (which reduce workload, but increase coverage), and the test coverage measurement tools used by many of the JCM software organizations. These tools measure what percentage of instructions and/or branches were actually executed in test. Several papers have reported that these tools help significantly to improve the quality of software products.

The following are test methodologies and tools which are frequently used:

Test Case Generation Tools -

Hitachi: AGENT (Automated GENeration system of Test cases)

Fujitsu: Design of Experiments - Advanced Statistical method for determination of test items using orthogonal matrix

Test Coverage Measurement Tools

Fujitsu: TCC (Test Coverage Checker) for M-series; also included in ADAMS

Hitachi: TESCO (TEST COverage manager) in CASD (Computer Aided S/E Development System; test facility in EAGLE

: TCA (Test Coverage Assist) in OSTD (OS Test Driver)

NEC : TACT (Test Animating Coverage Tool); test coverage for C

Toshiba: ASSISTQ (Advanced Support System for Interactive Symbolic Testing Quality) and
XMAS/QA (Cross Manufacturing and Analysis System/Quality Assurance) for path and model coverage
Toshiba: Test coverage measurement system for COBOL programs
M'bishi: CI coverage analyzer for MELCOM-COSMOS 900 II
NTT: PAVES for SYSL, COBOL and Ada; ATEST (Ada Test Evaluation Support Tool)

The effectiveness of test coverage tools may be seen in the following information which was reported by a QC circle in Hitachi concerning the testing of newly developed compilers:

- Test items were added to increase coverage to more than 95%
- 71% of errors detected using existing PCL (Program Check List)
- 20% of errors detected using additional items
- 40% of errors detected by Test Coverage (9% of total)
- 09% of errors detected by Test Group
- Product test time reduced

Automatic Test Operation Tools
Fujitsu: ATOS (Advanced Test Oriented System)
Hitachi: OSTD (OS Test Driver)
Toshiba: CONTEST (COmprehensive Test environment)
: Automated testing tool on DP9080

Dynamic Source Level Debugging on Display Screen Tools
Fujitsu: DOCK/FORTRAN 77
: Stepper in Dr. YAMPS
Toshiba: Advanced Support System for Interactive Symbolic Testing (ASSIST) and Cross Manufacturing and Analysis Sys (XMAS)
M'bishi: Symbolic source level debugger for MELCOM-COSMOS 900 II
M'bishi: PEC with Debugger used for C
NTT: VIPS (Virtual Interactive Programming System)
J Univac: UNI-SWEET debugging FORTRAN
Application Development Support Systems

Since the middle of the 1970’s, a number of application development support systems for the development and maintenance of application programs based on the software engineering methodologies have been developed and provided to customers. Most of them generate COBOL source code for commercial applications and a few support PL/1 also.

The list below shows most of them, but is not exhaustive and includes a few generator-type products which run under support systems. The most advanced ones seem to be Hitachi’s EAGLE and NEC’s SEA/1. Fujitsu is currently developing a new development environment based on the intelligent workstation. The SIGMA Project is developing a common application development environments to be shared primarily by software houses.

**Fujitsu** : ADAMS (Application Development And Management System) (4/83)  
: ADAMS/E (Application Development and Management System/Extended) (10/84)  
: Hyper COBOL (1980)  
: EASY-1 (1981)  
: INTERACT II (1981, 19820)  
: SIMPLE (SIMPLE Application Development and Maintenance System)  
: ACS (Application Control Support System)  
: SIMPLE/ACS APG (Application Generator) (1985)  
: Software CAD (a tentative name) (on IWS under development since 1985)

**Hitachi** : CORAL (Customer Oriented Application Development System) (1980)
NEC : SEA/1 (Software Engineering Architecture/1) (3/83)
: MYSTAR (1984)
: SPCLAN (Software Production and CirculaLation Network support system)
M’bishi : PRODUCE

The general characteristics of these tools are as follows:

Entire software life-cycle covered
New, changed, and mixed developments supported
Most of them generate COBOL source code
- Unavailable functions can be easily added
Reuse of code emphasized
- Vendor-supplied parts and skeletons
- User-coded parts and skeletons
Data dictionary for resource management
Documentation produced semi-automatically
Design diagrams for visualization
- e.g. PAD and DFD by EAGLE
Test case and test data generation
- e.g. EAGLE

Emphasis now being shifted to use of IWS
It is expected that CAD/CAM techniques will be used more and that AI techniques will be included in the future.

Software Requirement and Design Languages

The requirement specification languages and design languages (including graphic notations) which have been developed and/or used by JCMs and NTT are summarized below:

Fujitsu

- MDL (Module Description Language)/MDA (Module Description Analyzer)
- PDAS (Programming and Design Assist System)
- PDAS (Programming and Design Assist System)/SV (Switching software Version)
- YAC (Yet Another control Chart)
- YAC II (Yet Another control Chart II)
- FESDD (Fujitsu Essential S/W Diagram Description) similar to PAD
- SDD (S/W Diagram Description) Support System

Hitachi

- FRAME (Formalized Requirement Analysis Method)
- RDL/RDA (Requirement Definition Language)/(Requirement Definition Analyzer)
- SDF (Structured Data Flow diagram)
- MDL/MDA (Module Design Language)/(Module Design Analyzer)
- DBDS (Data Base Design System)
- PAD (Problem Analysis Diagram)
- SDL (Software Design Language)
NEC

SDL (System Design Language)
SPD (Structured Programming Diagram)
PCL (Pattern Customizing Language)
PDL (Parts Description Language)

Toshiba

FCL (Functional Component Connection Language)
FCD (Functional Component Diagram)
MCL (Module Connection Language)
FSD/Osd (Functional & Operational Sequence Diagrams)
TFF (Technical description Formula for Fifty SM design)
TFP/TFD (Technical description Formula for Procedure/Data design)

Mitsubishi:

Dela (DEsign LAnguage) based on Ada
Dela/A, an analysis tool
Graphical representation of Dela
  - Ada data type constructs
  - Data flow
  - Module organization
  - Module structure (using HCP)

NTT

HCP (Hierarchical and Compact Description Chart)
Ada (for design/implementation language)
HCP expanded to cover all Ada constructs
Graphic Tools in Software Development

Various tools to support data entry using graphic notation and design diagrams have been developed including a system that generates diagram drawing tools for different types of diagrams. Software development support systems utilizing graphic capability have been built as well.

SDL/PAD (Software Design Language/Problem Analysis Diagram) included in Hitachi’s ICAS (Integrated Computer-Aided Software engineering system) generates source code from a low-level design diagram and also does reverse conversion. Another example is a tool called PEC (Program chart Editor Compiler) which uses HCP (Hierarchical and ComPact description chart) as a design diagram and was developed by Mitsubishi in 1984.

The following are integrated software development support systems which include tools supporting and/or utilizing graphics:

- **Hitachi** — ICAS (Integrated Computer-Aided Software engineering system)
- **Fujitsu** — SDL (Functional Specification and Description Language) Support System for communication software development
- **Fujitsu** — Dr. YAMPS (Document recognizable Yet Another Manufacturing of Programming System)
- **NEC** — SDMS (Software Development and Maintenance System)
- **Toshiba** — IMAP (Integrated Software Management and Production Support System)
Mitsubishi ----- MELSEWS (MELcom Software Engineering Workstation System)
NTT ---------- HD (HCP chart Designer)

**Design Diagram Drawing**

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fujitsu</td>
<td>SDD (Software Diagram Description) Support System for low-level design, code generation, and debugging</td>
</tr>
<tr>
<td>Fujitsu</td>
<td>Editor in Dr. YAMPS, YAC II Editor on PC</td>
</tr>
<tr>
<td>Fujitsu</td>
<td>DFD (Data Flow Diagram) editor in Software CAD</td>
</tr>
<tr>
<td>Hitachi</td>
<td>SDL/PAD (Software Design Language/Problem Analysis Diagram)</td>
</tr>
<tr>
<td>Hitachi</td>
<td>SDF (Structured Data Flow diagram) on EAGLE</td>
</tr>
<tr>
<td>NEC</td>
<td>GDS (Graphic Drawing System) CCITT/SDL Drawing Tool generated by GDS SPD (Str Prog Diag) Drawing Tool generated by GDS</td>
</tr>
<tr>
<td>NEC</td>
<td>SPDE (SPD Editor) included in SPDTOOLS</td>
</tr>
<tr>
<td>NEC</td>
<td>Graphic Schema System</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>DIG/M (HCP, PAD, N-S Chart, flow chart)</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>Graphic I/O for design language called Dela (being developed)</td>
</tr>
<tr>
<td>Toshiba</td>
<td>FSD/OSD (Functional &amp; Operational Sequence Diagram graphic editor)</td>
</tr>
<tr>
<td>Toshiba</td>
<td>TFF (Technical description Formula for Fifty SM design) editor, code generation (under development) in IMAP</td>
</tr>
<tr>
<td>Oki</td>
<td>HCP Chart Processor</td>
</tr>
<tr>
<td>Toyo Info Sys</td>
<td>CADAP (PAD, SPFLOW, flow chart), generation of source code</td>
</tr>
<tr>
<td>J Univac I. S. -</td>
<td>UNI-SWEET, FORTRAN only, generation of source code</td>
</tr>
</tbody>
</table>

**Source Code Generation and Reverse Conversion**

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi</td>
<td>SDL/PAD</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>PEC (Program chart Editor Compiler)</td>
</tr>
<tr>
<td>NEC</td>
<td>Forward Translator (SPD to source code)</td>
</tr>
<tr>
<td></td>
<td>SPD Documenter (source code to SPD)</td>
</tr>
<tr>
<td>Toshiba</td>
<td>TCGEN (Tff to Code GENerator)</td>
</tr>
</tbody>
</table>

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Design Diagram Drawing on PC/IWS

Hitachi -------- SDL/PAD on T560-20, 2050 with UNIX
Fujitsu -------- YAC II on Word and DP Station, and
               YAC II Editor on PC
NEC --------- DS (Diagram design Support)
NEC ---------- SPDTOOLS (SPDE, PGEN, and DGEN)
Toshiba ------ TFF editor on UNIX
NTT ---------- HCP Chart drawing (and source code
               generation with a host)
Keio Univ ---- PAD Editor (diagram drawing)
Keio Univ ---- PAD diagram and FORTRAN/BASIC
               generation
Hitachi Eng ---- PAD diagram and FORTRAN generation
Toyo Info Sys -- CADAP on PC-9800

Review/Inspection and Debugging

NEC ---------- TACT (Test Animating Coverage Tool)
             displayed with unexecuted portions
             and frequently executed statements
             identified; not graphic yet
NTT --------- VIPS (Visual Interactive Program Sys)
             multi-windowing, display of data in
             graphic and source code with high-
             lighting a statement under execution
             (PL/I based system programming
             language only)
Fujitsu ------ Design review and debugging using Dr.
             YAMPS
Toshiba ------ Review and inspection using IMAP
M'bishi ------ Review and inspection using MELSEWS
             (by 3/87)
J Univac I. S. - Debugging using UN-SWEET

Use of Workstations for Software Development Environments

With the increasing power of and the decreasing cost of
intelligent workstations (PCs connected to host systems or
other PCs via LAN), a new trend of building total software
life cycle support environments using intelligent terminals
is gaining momentum in Japan. They provide tools to support
the software development life cycle (SDLC).
The latest status of the development in this area was reported by an article which appeared in March 17, 1986 issue of the Nikkei Computer. It was entitled "Distributed Software Development Systems Using Workstations Are Nearing Practical Use."

The following is a list of those systems being built on intelligent workstations:

- **Hitachi** -------- ICAS (Integrated Computer-Aided Software engineering system) on T560-20; 2050 with UNIX
- **Fujitsu** -------- Dr. YAMPS (Document recognizable Yet Another Manufacturing of Programming System) on AWS with UNIX Software CAD on SUN 2 with UNIX
- **NEC** ---------- SPDTOOLS (SPDE, PGEN, and DGEN) on NS200 and PC-9800 EWS4800 with UNIX System V
- **Toshiba** ------ IMAP (Integrated Software Management and Production Support System) on SUN series with UNIX
- **Toshiba** ------ PLANET on TOSBAC UX-300
- **Toshiba** ------ MYSTAR (software on IWS under development)
- **Mitsubishi** ----- MELSEWS (MELcom Software Engineering Workstation System) on PSW AND EWS both with UNIX
- **NTT** ---------- HD (HCP chart Designer) on PC-9800 with MS-DOS or CP/M-86 SCAD (Software CAD) on SUN workstation with UNIX
- **J Univac I. S.** -- UNI-SWEET on SS series with UNIX
- **M’shi Res Ins.** -- FASE (for FORTRAN 77) on SUN series with UNIX
- **Nomura Comp S.** - G System (for COBOL) on CEC 8000 with UNIX
- **Toyo Info Sys** -- CADAP on PC-9800 with MS-DOS
- **SIGMA Project** -- on three prototype workstations with UNIX from 9/86

Papers evaluating the functions and user interfaces of these workstations for software development use have begun to appear as shown below. The first two were presented in March 86.
1986 and the last four were presented in October '86.

"Utilization of Commands on Workstations (UNIX)" by NTT

"Improvement of Software Development Environment Using PC-UX and LAN" by NEC

"Humanized and Simple Man-Machine Interface for Software Development Environment" by NTT

"How to Input Commands Efficiently in UNIX" by Mitsubishi

"A User Interface Design Tool for Windows" by Mitsubishi

"The First Step toward the UIMS to Meet the End User’s Requirements" by Mitsubishi

Reuse and Reusability

The 'reuse of software' has been greatly emphasized in Japan for the past few years. All the recent application development support systems developed by JCMs include the facilities for reuse mostly based on the so-called 'parts concepts'. A number of different techniques for creating, registering, storing, retrieving, and modifying reusable software have also been explored and implemented.

It is generally recognized in the academia that there are four approaches to reusability as follows:

1. Building libraries of routines (procedures, functions, subroutines, subprograms, etc.), which seems to work well in areas where a (possibly large) set of individual problems may be identified, subject to a few limitations
(a small set of parameters, clear distinction of individual problems, and no complex data structures)

2. Use of modular languages such as Module-2, CLU, and Ada, which have a notion of module (variously called module, cluster, package) providing a higher-level program structuring facility than the routine)

3. Overloading (provided in Algol 68 or Ada) which allows the use of the same name regardless of the implementation, and generality (provided in Ada or CLU) which allows a module defined with "generic parameters" representing types

4. Object-oriented design, which bases the modular decomposition of a software system on the classes of objects manipulated by the system rather than on the functions the system performs

For commercial applications the first approach is supplemented by adding facilities to help make changes easily. Without using modular languages, similar effects as achieved by the second approach have been realized in at least one case. NTT has also developed a number of standard parts using Ada. Thus it can be said that in Japan so far the first three approaches (excluding 'overloading') have been used in different ways, sometimes in mixed ways.

The study of the object-oriented programming has been under way by university people (especially by Prof. A. Yonezawa of TIT) since late 1970's. The only development activity for object-oriented design tools is an object-oriented version of Hitachi's EAGLE, which was presented as being under consideration in October 1986.

Most of the reusable software pieces used by JCMs are
classified into the following two types:

- **Black box** — internal structure and (detailed) processing logic are unknown to the user
- **White box** — contents can be modified by the user

Reuse capability based on the 'software parts' concept is built into the following application development support systems:

- **Fujitsu**: ADAMS (83), ADAMSE (84) -- PARADIGM (81)
  - (a set of standard skeletons)
  - Software CAD (prototype, 86) -- frame templates
- **Hitachi**: CANDO (81), EAGLE (84), EAGLE2 (85)
  - EAGLE/SAT (86) -- patterns and parts
- **NEC**: SEA/1 (83) -- patterns and parts
- **Toshiba**: MYSTAR (84) -- skeleton at 4 levels
  - IMAP (TCGEN-II) (86) -- parts (black boxes)
  - PWB/SP (based on software parts)
- **IPA**: SIGMA Project (90)

At Toshiba Fuchu Works where customized software is developed (for each different process control system to be delivered), the reuse of software appears to have been achieved to a great extent with well established coordination and management as well as supporting software tools. The utilization of existing parts is enforced by means of design reviews with special emphasis on reuse. As of the middle of 1984, 30 new parts for reuse were said to be added.

It appears that communication software modules can be rather easily made reusable. Fujitsu, Hitachi, and NEC have reported considerable success in the reuse of code in
communications software development. According to a paper which was presented by Fujitsu in March 1983, 10 paradigms were used in 80% of the code of 100 service modules. A paper on communication library management, which was presented by Hitachi at a JUSE seminar in 9/84, stated that 95% of each system used common modules and that each module was shared by an average of 5 systems. An NEC paper on standard parts for electronic switching software, which was presented in 3/84, said that 100 modules had been registered and that an average of 30% of a program consisted of parts.

In the area of systems programming for large systems, a Fujitsu paper reported the use of software parts to some extent in utility programs and SCP service aids. 30% of 11 SCP utility programs produced from parts and parts reuse reduced new coding for SCP service aids by 43%.

Hitachi people have presented reports on 'Auto-DS', which is a tool to generate detailed design diagrams (PAD charts) from Assembler language source code, which they expect to help in the reuse of old code.

The facilities for reuse of software in system programming are included at least in Fujitsu’s PDAS, PDAS/SV, and Software CAD, Hitachi’s ICAS, and Toshiba’s IMAP.
The various technologies for reusability that have been reported are as follows:

**Fujitsu**: MASCOT (Methodology & Assembly System with Software Component Technology)  
- YAC II Editor (registration and retrieval of memos and parts)

**Hitachi**: Retrieval of parts using AI technique

**NEC**: Pattern customizer, pattern customization control language (PCL), parts description language (PDL)

**Toshiba**: PARTNER (PARTs designNER)  
- SPISE-II (S/W Production by Interactive Synthesis Engineering V2)  
- 50SM --- parts-oriented design/implementation technology  
- SPRINT (Software Parts Reuse INteligenT system)

**M'bishi**: Parts management tool using Prolog  
- MELCOM Parts Retrieval System

**NTT**: Ada tools (registration, retrieval, modification)  
- Parts reuse using Ada-based design language in stepwise refinement

In addition to the reuse of code, the reuse of design specifications is growing in importance and has been incorporated into the following tools:

**Hitachi**: Reuse of specifications by storing in a model database

**Toshiba**: 4-level abstract schemes for reusable Software, Ada-based language

**NTT**: Reuse of specifications for communication control programs

NEC has developed a tool (SYSDES in SEA/1) to generate system design information from source code, JCL, and menus. This was presented in October 1986 and Toshiba’s Dr. Y. Matsumoto has published a paper on four software development levels, each of which permits the reuse of parts at the same level using an Ada-like language (IEEE Trans of S.E., Vol. SE-10, No. 5, 9/84).
Artificial Intelligence for Software Development and Maintenance

Recently, JCM's have been increasing research and development efforts on the use of knowledge base (expert) systems for software development, e.g. for reuse of software, program generation, debugging, etc. For example, NTT had reported improving programming productivity and maintainability by using knowledge base technology as early as October, 1983 (IBMc, 1988).

According to a newspaper report of February 7, 1986, Hitachi was establishing an "Artificial Intelligence" related software development department (300 to 400 programmers in 3 or 4 years) in its Totsuka Software Factory. Some of this new group are most likely involved in using AI techniques in software development.

A May, 1986 Hitachi brochure said that ICAS-REUSE structures parts hierarchically according to rules based on an artificial intelligence technology and on April 18, 1986, the Japanese press reported that Hitachi had developed a prototype of a software design expert system, "MDL/MDA" with a knowledge data base that was created from the know-how of experienced software engineers. The system provides an easy-to-use, menu-driven interface, allowing the software
designer to produce accurate design documents in shorter times and to reuse existing pieces of software.

The Fifth Generation Computer Project now under way in Japan may also contribute to the advancement of artificial intelligence use in software engineering. One such indication is an experimental AI-based COBOL application generator which has been developed by NEC with funding from the Institute for the New Generation Computer Technology (ICOT). Commercialization is expected by 1990.

Toshiba has developed a tool to evaluate maintainability of software by combining a software evaluation system with an expert system and Oki Electric has been developing a Project Diagnosis Expert System on an engineering workstation.
Has There Been Quality and Productivity Improvement?

Very few firms have disclosed to the public the quality of their products and productivity of their developers in product programming areas. On the other hand, some information has been provided by the manufacturers on the improvement of quality and productivity by using application generators and application support systems.

In any case it is very difficult to make any direct comparisons between manufacturers. There are significant differences inherent in the types of products they produce, the development processes they use, the way defects are recorded, etc. Given these differences, it is perhaps more useful to look at relative improvement realized through the use of application support tools and systems.

The following is un-systematic collection of information on quality and productivity improvement by JCMs (IBMc, 1988).

**Fujitsu**

According to a paper which was presented at the 4th QCSP Symposium, JUSE, 1984, a communication software development
project achieved 2.4 KLOC/person month productivity by using the Total Project Management System/JEF.

According to a paper which was presented at the 5th QCSP Symposium, JUSE, in a two-year effort, productivity of 500 KLOC in 1000 person months was achieved in COBOL compiler development. A high-level system description language was used. Project control was performed taking quality into consideration.

In September, 1986, Mr. Mitsugi, Fujitsu’s Managing Director, stated that SIMPLE/ACS APG can improve productivity in the detailed design and programming phases by a factor of 1.5 to 2.5 and quality by 40% as compared to the native ACS.

In a project using YAC II, quality and productivity were said to improve by 34% and 28% respectively, from module design through programming.

In a project using Dr. YAMPS, productivity, from detailed designing through debugging, was doubled and maintenance was cut to one fifth.

According to "An Overview of SDAS", which was published by Fujitsu in 5/87, the productivity improvement using the SDAS
high-productivity tools is as follows:

**CASET**

- Statements reduced to $\frac{1}{2} - \frac{1}{5}$ of COBOL
- Productivity 1.5 times greater in design, implementation, and test

**BAGLES II**

- 40% less errors in design and implementation
- Statements reduced to $\frac{1}{2} - \frac{1}{3}$ of COBOL
- Productivity 1.8 times greater in design, implementation, and test

**YPS**

- Productivity 1.3 times greater over life cycle

Overall productivity improvement 2 times greater

- 40% of applications covered by packages (2 to 5 times)
- 60% of applications covered by high productivity tools (1.5 times)

**Hitachi**

It was reported at the 7th ICSE that by using SDL/PAD, the following productivity improvement was achieved:

- Efficiency of program design and error correction improved by 20%
- Design error detection time reduced by 65%
- The number of days necessary for coding reduced
- 40% reduction in manpower from program design to debugging
- 40% reduction in the total of days necessary for development
According to the results of a survey of more than two years use of EAGLE by Hitachi customers, the average productivity was improved by factor of 2 and the number of errors was reduced to one third.

A report printed in the May, 1986 issue of Hitachi Hyoron includes an example of EAGLE2’s achieving productivity improvement of a factor of 2.2 over the "conventional" development method.

In a study involving software engineers with three or four years of experience, the use of MDL/MDA with a knowledge data base achieved the following improvements:

- Software design time : reduced to 1/5
- Errors in design phase: reduced to 60%
- Productivity : up 2 times

NEC

The usage and effectiveness of NEC’s STEPS was reported in the June 1984 issue of the IEEE Computer as follows:

1. Used by more than 1,200 development groups
2. 20 to 50 percent cost reduction in analysis and design phases
3. 50 to 80 percent cost reduction in program manufacturing phases

The initial objective of SWQC at NEC was to improve programmers’ productivity by a factor of 2 to 3 in 3 or 4
years. Although five years have passed since the SWQC was started company-wide, it is unknown whether the objective has been achieved or not.

The 9/30/86 issue of Nihon Keizai Shimbun reported that SPDTOOLS increases productivity in programming for minicomputers and workstations by 30% to 40%.

According to a paper presented in March 1985, the quality of software in developing an office information system using SEA/1 improved by a factor of 2.8 by synthesizing parts into the bodies of the programs.

Six months later, NEC presented productivity and quality improvement based on empirical data as follows:

<table>
<thead>
<tr>
<th></th>
<th>Productivity</th>
<th>Quality (no. of bugs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SEA/1 w/o emp inf</td>
<td>1.6</td>
<td>1/2.8</td>
</tr>
<tr>
<td>SEA/1 w emp inf</td>
<td>2.4</td>
<td>1/5 to 1/10</td>
</tr>
</tbody>
</table>

NEC’s quality targets for system software development were as follows as presented at the JUSE seminars:

<table>
<thead>
<tr>
<th></th>
<th>1979</th>
<th>1982</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defects/KLOC in the 6 months after FCS</td>
<td>less than .3</td>
<td>less than .2</td>
</tr>
<tr>
<td>Defects/KLOC beyond 6 months</td>
<td>less than .1</td>
<td>less than .07</td>
</tr>
</tbody>
</table>
At the 4th Symposium on QCSP, JUSE, it was reported that, in a project which developed 700 KLOC software including high-precision control functions and support tools, 1,100 person months were spent from requirement definition thru final installation tune-up. This productivity is equivalent to 8 KLOC/person year.

Regarding the effectiveness of the SWB system, an article entitled "Tools for Compatibility" which was printed in the August 1986 issue of "High Technology" reported the following:

- An average of about 65% of the code comes from previous programs
- Some 2000 lines of code per person month
- About 0.3 bugs per 1,000 lines of code (so good that the company offers a 10-year warranty)

At NCC’86, Dr. Matsumoto stated that their software factory (approx. 2,200 programmers at one location) manufactures 4.5M assembly-equivalent lines of code per month, and the ratio of the newly developed over re-used code is between 55% and 60%. The productivity CAGR is between 8 to 10%. The quality in 1980 and 1985 was 5 defects/KLOC and 1.5 respectively.
Use of Tools in DP Customers’ Programming Organizations

The January 6, 1986 issue of Nikkei Computer, a journal published by Nihon Keizai Shimbun (Japan Economics Newspapers) published the results of a survey on "The Use of Software Production Technologies (by customers) and its Future Perspective", summarizing the responses which were received from 415 companies in October, 1985 (IBMc, 1988). According to this, the breakdown of the users of the application development technologies is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Integr System</th>
<th>Paper-less</th>
<th>Design Diagram</th>
<th>Proto-typing or</th>
<th>General Others</th>
<th>No of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fujitsu</td>
<td>11.5%</td>
<td>7.7%</td>
<td>23.1%</td>
<td>15.4%</td>
<td>46.2%</td>
<td>26</td>
</tr>
<tr>
<td>Hitachi</td>
<td>34.6</td>
<td>11.5%</td>
<td>19.2%</td>
<td>19.2%</td>
<td>26.9%</td>
<td>26</td>
</tr>
<tr>
<td>NEC</td>
<td>25.0</td>
<td>16.7%</td>
<td>37.5%</td>
<td>33.3%</td>
<td>37.5%</td>
<td>24</td>
</tr>
<tr>
<td>M‘bishi</td>
<td>66.7%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33.3%</td>
<td>3</td>
</tr>
</tbody>
</table>

According to this report, 39.1% of the 115 companies which provided answers are presently using high-performance program generators; and 63.2% of the 277 companies responding predict the use of automated software development support systems in three years.

Hitachi is the highest in the ranking of their customers’ use of automated software development support systems (34.6% of the 26 accounts who responded to the particular item) and NEC is top of the list in their customers’ use of structured
design diagram tools.

The use of graphic tools in software development seems to be still low as indicated by the average percentage and the total count (18.3% and 21 customers out of the 115), but 96 accounts (34.7%) out of 277 say that they will be using graphic tools (structured design diagrams) in three years.

The results of the Second Survey on the Usage of Software Packages for general-purpose computers were printed in Nikkei Computer, 10/26/87. They included the following information regarding the use of software development tools. 932 companies (25.4%) responded out of 3,671 companies to which the questionnaire was sent.

<table>
<thead>
<tr>
<th>Name</th>
<th>(Supplier)</th>
<th>No. of Licenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM</td>
<td>(Fujitsu)</td>
<td>151</td>
</tr>
<tr>
<td>ADJUST</td>
<td>(Fujitsu)</td>
<td>138</td>
</tr>
<tr>
<td>AIDS/X</td>
<td>(Fujitsu)</td>
<td>119</td>
</tr>
<tr>
<td>LIME</td>
<td>(Hitachi)</td>
<td>78</td>
</tr>
<tr>
<td>NHHELP</td>
<td>(Hitachi)</td>
<td>63</td>
</tr>
<tr>
<td>Hyper COBOL</td>
<td>(Hitachi)</td>
<td>51</td>
</tr>
<tr>
<td>SEA/1</td>
<td>(NEC)</td>
<td>41</td>
</tr>
<tr>
<td>EAGLE2</td>
<td>(Hitachi)</td>
<td>38</td>
</tr>
<tr>
<td>CSP</td>
<td>(IBM)</td>
<td>22</td>
</tr>
<tr>
<td>The LIBRALIAN</td>
<td>(Protec)</td>
<td>21</td>
</tr>
<tr>
<td>CORAL</td>
<td>(Hitachi)</td>
<td>21</td>
</tr>
<tr>
<td>SIMPLE</td>
<td>(Fujitsu)</td>
<td>21</td>
</tr>
<tr>
<td>PANVALET</td>
<td>(Assist)</td>
<td>20</td>
</tr>
<tr>
<td>IDL</td>
<td>(NEC)</td>
<td>19</td>
</tr>
<tr>
<td>ADAMS</td>
<td>(Fujitsu)</td>
<td>18</td>
</tr>
</tbody>
</table>

Note: GEM and LIME are program library support products.
Conclusions

An overview of Japanese research and development in software engineering from 1982 to 1983 written by Professor Y. Ohno of Kyoto University summarized the situation as follows:

A trend toward developing Japanese styles of methods, tools, and programming environments

Highly motivated research studies aimed at constructing an automated production line of software

Areas of specific concerns: requirement specifications, program design and specifications, design methodologies and specifications for parallel/concurrent processing, programming tools and environments, testing and evaluation, and software management

In the concluding remarks, Professor Ohno says, "the next stage of the software research in Japan will be to establish the CAD of software which may rest on the knowledge base and automated generation of software from its specifications."

Japan has been making steady progress in adapting and utilizing software engineering methodologies and quality control (QC) techniques and tools. This is due, in part, to their keen awareness of the state-of-the-art computing methodologies in USA and Europe. Japanese software development professionals have been eager to learn the latest software engineering technologies and are continually exploring published technical papers and sending experts to technical conferences abroad. They not only absorb new ideas, but modify and enhance them as well. In the case of
software development process technologies, they have put these ideas into highly practical use. Their efforts don't appear to have created significantly innovative concepts and products, but they have done many good product engineering jobs. Their efforts to improve productivity and quality have yielded not dramatic, but tangible, world respectable results.

A US government report recently said "The Japanese are apparently ahead of US firms in making improvements to existing technologies from the US and Europe, and in incorporating these advances into highly marketable products. The Japanese have also made impressive gains in the development of software tools and have encouraged their widespread use to boost productivity. Both the Japanese government and the leading computer manufacturers began investing in the automation of the software development process nearly seven years ago" (IBMc, 1988).

Also, D. Brandin, former head of ACM and chairperson of the Computer Science group of the Department of Commerce's Japanese Technology Evaluation Program (JTECH) stated in a recent talk on an assessment of US vs Japan software engineering: "Although Japan is far behind in basic research, she is far ahead in product engineering and rapidly widening the gap with the US in this area."
Competitive Environment and Firms' Strategies

Foreign Competition

Unlike the automobile, machine tool, and consumer electronics industries, the computer and software industries in Japan have had to deal with intense local competition from foreign firms, primarily IBM and more recently DEC, during their development. Despite government efforts to obtain technology and control foreign competition, several U.S. firms have successfully taken on the Japanese industry in its own market and have continued to adapt to the increased technological capabilities of Japanese firms. IBM is the most striking example of this. Its influence has been so significant that a discussion of IBM's entry, development and adaptation to increasing competitive pressures is a key ingredient to a discussion of the Japanese software firms' strategies. DEC has also become a significant player not only achieving increasing success in the Japanese market, but also demonstrating to Japanese firms that alternatives to an IBM compatible strategy can be viable.

Other US firms such as Univac, Burroughs, NCR, HP, Xerox, Data General, and Tandem all maintain a presence in Japan,
but are not especially significant players. The recent explosion of the PC market has enabled firms such as Microsoft, Lotus Development Corp. and Ashton-Tate to establish marketing subsidiaries in Japan and to successfully export PC software packages to Japan.

IBM Japan

IBM Japan, Ltd. was formed as a wholly owned subsidiary in 1937 to sell IBM products into the Japanese market. It’s assets were confiscated during the war, but were returned when the company was re-established in 1949. At that time IBM Japan’s activities were limited to sales and service, with products being imported from the parent company often under the tight control of Japanese government policy. In 1960 IBM was successful in gaining government approval to manufacture in Japan in exchange for technology licensing agreements. This was a hard fought agreement with IBM finally winning out due to its significant comparative advantage in technology, a commodity desperately sought by the Japanese computer industry. MITI still retained considerable control over IBM Japan, through capital investment regulations and production limitations, but adopted the strategy that the best way to compete with IBM was to follow it, while protecting the domestic industry to
avoid domination (Management Today, Oct., 1986). This essentially led to the growth of powerful Japanese computer firms following a predominantly IBM compatible product strategy.


Troubled by it’s loss of market share leadership in Japan and seeking to capitalize on the significant growth potential in the Asian market, IBM began instituting major changes in its policies, organization and strategy in IBM Japan and the Far East. In 1984 IBM reorganized its Americas/Far East world trade subsidiary forming Asia/Pacific Group (A/PG) and moving its headquarters and 200 people to Tokyo. The objective of this restructuring was to move the corporate decision-making closer to the action, the Asia-Pacific crescent, an area experiencing the highest economic growth rate in the world (Think (1), 1985).

IBM Japan, accounting for 2/3’s of A/PG’s revenues, began to take on an increasingly central role in IBM’s Asian
operations and began implementing policy changes referred to as the "Japanization" of IBM Japan. These changes included building an in-house semiconductor plant to improve vertical integration, hiring former bureaucrats to strengthen ties with the Japanese government, doubling the software engineering staff to concentrate on products tailored for the Japanese market, and altering IBM's direct sales approach by using a major trading firm as exclusive marketer for certain products sold in Japan (International Management, May, 1985). Also, IBM Japan has bought into Japan Business Computer Co., is contracting some manufacturing to Japanese suppliers, is signing up lots of companies as sales agents and software developers, is purchasing more components locally, and is forming joint ventures and alliances such as the one with Mitsubishi Trading Co. and Cosmo 80 in an effort to expand further into telecommunications and improve relations with MITI and NTT (Electronic Business, Dec., 1983).

Joint Ventures are expected to complement IBM business in terms of assisting IBM growth and this alliance strategy has been developed to be part of and consistent with the overall country strategy (IBM, 1988). The following is a list of recent IBM Japan joint ventures:
Advanced Systems Technology, Inc. (AST) AST provides systems integration, office automation, networking services and operates education centers for information processing. AST also develops applications software for the distribution industry. Ownership: IBM Japan, Ltd. (39%), Mitsubishi Corporation (39%), Cosmo 80 Ltd. (20%), The Mitsubishi Trust and Banking Corp., The Mitsubishi Bank, Ltd. and The Fuji Bank, Ltd. (2%). Consolidated: July 1987, Capital: 2B Yen

Diamond Business Engineering Corp. (DBE) DBE will support the sale and installation of software packages for Mitsubishi Bank’s third generation on-line banking system. Ownership: IBM Japan, Ltd. (35%); Mitsubishi Bank and affiliated companies (55%); others (10%). Established: November 1987, Capital: 200M Yen

Japan Information Engineering Co. (JIEC) JIEC develops and markets advanced systems engineering services and software packages. Ownership: IBM Japan, Ltd. (35%), Computer Service K.K. (65%). Established: September 1985, Capital: 300M Yen

Japan Business Computer Co., Ltd. (JBCC) JBCC develops and manufactures equipment for IBM computers and is an IBM dealer. Ownership: IBM Japan, Ltd. (35%), others (65%). Equity Participated: August 1983, Capital: 1.6B Yen

Nippon Information and Communications, Ltd. (NI+C) NI+C offers enhanced telecommunications services, products, and integrated systems including network services throughout Japan. NI+C also offers software development services, applications systems and is an IBM dealer. Ownership: IBM Japan, Ltd. (50%), Nippon Telegraph & Telephone (50%) Established: December 1985, Capital: 6B Yen

Shikoku Systems Development Corp. (SSDC) SSDC offers software development support and contracting services primarily in the Shikoku region. Ownership: IBM Japan, Ltd. (35%), Tokushima Press (32%), others (33%). Established: October 1986, Capital: 80M Yen

Nissan Systems Development Corp. (NISD) NISD develops application software and offers systems engineering services relating to the automotive industry. Ownership: IBM Japan, Ltd. (35%), Nissan Motor Corp. (65%). Established: March 1987, Capital: 150M Yen

System Frontier Corporation (SFK) SFK offers software support and services for the banking industry. Ownership: IBM Japan, Ltd. (35%), Takugin Group (50%), others (15%). Equity Participated: June 1987, Capital: 200M Yen
Advanced Application Corporation (AAC) AAC offers software support and services for the finance industry. Ownership: IBM Japan, Ltd. (35%), Nippon Software Co., Ltd. (65%). Established: June 1987, Capital: 150M Yen

A & I Systems, Co., Ltd. (A&I) A&I offers software support and services for the banking industry. Ownership: IBM Japan, Ltd. (35%), ABC Corporation (65%). Established: May 1987, Capital: 150M Yen

Central Information System Co., Ltd. (CIS) CIS offers software development support and contracting services primarily in the Tokai region and is an IBM dealer. Ownership: IBM Japan, Ltd. (19%), Tokai Bank Group (77%), others (4%). Equity Participated: July 1987, Capital: 29.4M Yen

ITEP Co., Ltd. (ITEP) ITEP offers software development support and contracting services primarily in the Kyushu region and is an IBM dealer. Ownership: IBM Japan, Ltd. (15%), Honbou Group (55%), others (30%). Equity Participated: August 1987, Capital: 100M Yen

Through these ventures, IBM Japan is increasing its capabilities to compete in the continued large market of customized application software and industry specific systems solutions. IBM Japan is also improving its competitiveness by transforming its product line from a globally standardized set of offerings, into products which are tailored through software technology to the specific needs of the Japanese market. This is demonstrated by the strong success of the 5550 computer which operates in the Japanese kanji character set, in IBM Japan’s emerging leadership in research and development for world market products and in its ability to change the way it does business in its local market. Its success at "Japanization" is supported by the fact that Tokyo University graduates had more computer science and engineering majors join IBM Japan
in 1985 than joined any competitor (Think (2), 1985).

IBM is also beginning to address the need for consistent application enabling interfaces across operating environments and the need for tools to support the development of applications on top of these interfaces. On March 17, 1987 IBM made the following announcement: "Today, IBM announces IBM Systems Application Architecture (SAA), a collection of selected software interfaces, conventions and protocols that will be published in 1987. IBM Systems Application Architecture will be the framework for development of consistent applications across the future offerings of the major IBM computing environments -- System/370, System 3X and Personal Computer" (IBMd, 1987).

In April, 1988 IBM announced the formation of a new software business area responsible for SAA implementation. This division, headed by Earl Wheeler, will produce products that provide consistent application enabling interfaces across operating environments and development support tools to assist programmers in creating applications to run in these environments. IBM Japan's role in this has yet to be clarified, but it is likely that they will be involved in the graphic user interface tools that are planned and the enabling of these tools to support Kanji.
DEC

DEC, with its VAX product line and non-IBM compatible but highly consistent software, is taking on IBM and Japanese competition throughout the Asian market. Nihon Digital Equipment Corporation was formed in 1968 and has been playing an increasing role in the Japanese market ever since. The wholly owned subsidiary has yet to establish manufacturing in Japan, but has been active in R&D and software product development tailored to unique Japanese needs. DEC’s success has demonstrated that there are technologies that can compete effectively against IBM and has suggested to Japanese computer executives that unique technologies of their own may be far more important in the future than their historical approach of following IBM (Japan Economic Journal, 04/25/87). DEC along with Data General, AT&T, Hewlett Packard, Zerox and Oliveti, is also participating in the Sigma Project which is UNIX based and viewed as a potential long term alternative to IBM compatibility (Japan Economic Journal, 05/02/87).

DEC has also stepped up its activities in artificial intelligence by entering into a contract with Nippon Telegraph and Telephone Co. to combine VAX hardware with Japanese language versions of NTT AI software for sale throughout Asia (Japan Economic Journal, 05/02/87).
Japanese Computer Manufacturers' and Government Strategies

During the early days of the Japanese computer and software industries, the major JCM's were dependent on technology tie-ups with US firms and licensing agreements with IBM for most of their technology. When firms like RCA and GE exited the computer business, most JCM's were forced to become more self-sufficient as their primary sources of technology evaporated. Fujitsu was the one exception to this in that it had not entered into any direct technology tie-ups, choosing instead to rely on indirect product technology transfer from the US and its own R&D efforts. In software this meant that most firms followed an IBM compatible strategy in order to leverage the already existing large base of software written for IBM operating environments. This continued until only recently when Hitachi and Fujitsu were caught stealing IBM trade secrets by an FBI sting operation and forced to begin diverging their strategies away from IBM compatibility and developing more of their own unique technology. However, the major JCM's have invested heavily in software development process technology, using widely available software engineering knowledge to develop many computer aided software engineering (CASE) tools and instituting a factory concept to software development. They have surpassed western technology in their implementation of these techniques and continue to devote significant efforts to further
improvements.

The government has played a key role in supporting CASE technology by shifting its strategy heavily in favor of software development process technology with a comprehensive plan to standardize and improve the software development environment and an education plan to increase the quality and number of skilled software development professionals. MITI has chosen UNIX as the preferred development environment and the JCM’s are now including UNIX as a major component in their strategies.

In order to cope with deteriorating export earnings due to the sharp appreciation of the Yen and increasing pressure from foreign nations on trade imbalances, the JCM’s have stepped up their efforts to produce EDP products overseas and, in continuing efforts to improve their technology and capitalize on foreign market opportunities, many Japanese firms are also increasing the complexity and scope of their software activities.
Development Process Technology Strategy

Japanese computer manufacturers are streamlining their R&D and continuing to invest heavily for the future (IBMc, 1988). Toshiba views quality to be more important than quantity in the future and is putting emphasis on R&D rather than investment in facilities. Its capital R&D investment for the first half of fiscal year 1987 was 89,400 million yen or 6.9% of its total revenue and has budgeted 7.2% of sales for (187,000 million yen) for the full year. Hitachi spent 8.9% of its revenue or 128,394 million yen on research in the first half of fiscal 1987 and planned to invest another 133,152 million yen in the second half. Mitsubishi plans to reorganize its R&D division aiming to address selected target areas, including software development. In the communications/information processing field, makers are allowing approximately 5% of their revenue for R&D. Application technology is being given special attention. Fujitsu has a new building under construction on the site of its Kawasaki plant and NEC is reinforcing its Central Research Center. NTT is also looking at R&D with a focus on application technology.

At a JUSE seminar held in October, 1987, software executives from major JCM’s were asked about their thoughts on how to reduce the software development cycle. A summary of their
responses follows:

Mr. Kataoka of Hitachi:

Prototyping - to avoid "re-production" caused by misinterpretation of users' requirements.

Reuse of code

Break-up of specifications and staged development -- it is very hard to decide particularly on where to cut and what to defer. Not only a strong negotiation with marketing and users is needed, but also technical encapsulation needs to be considered.

Because of progress in design methods, he thinks it is much easier to implement the first two.

Mr. Ishii of Fujitsu:

Reuse. He thinks "object oriented design" is the key.

Dr. Hanata of NTT:

In his organization headed by him as laboratory director, a work flow for software development is constantly reviewed and revised. At each project completion, a project review is done to identify what needs to be revised. He thinks this has been effective.

Also he said that "postmortem" has been honestly and religiously done after the completion of a project so that similar errors can be avoided. This is one of the key concepts of TQC (company-wide quality control) -- "Learn from the past with data."

Mr. Kataoka insisted on shifting emphasis from code to design efforts and greater efforts to write correct specifications. He explained that with his more than 20 years of programming experience, he is still attending design review as "design" is the key to reduce "rework".

Overall NTT and the JCM's are working to reduce the software
development cycle by focusing on:

Constant review and update of the development process and activities at each stage

"Design reviews" as a major leverage point for software development productivity

Reuse with methodology, tools and organization integrated.

Reduction of the development cycle through participation of all the project members. This team or group concepts fits well in Japan.

Government Strategies for the Future

The 1970 law enacted by MITI to promote Information Technology, which formed the Information Technology Promotion Agency (IPA) to act as the central body to coordinate action plans and formulate strategies for software, has provided the basis for the government’s role in Japan’s software technology strategy. MITI, through the IPA, developed a staged plan (JISA, 1987):

Phase 1: 1971 - 1975
Phase 2: 1976 - 1980
Phase 3: 1981 - 1985
Phase 4: 1986 - 1990

The phase 4 plan was announced in March, 1986 in response to a proposal made by a committee chaired by Mr. S. Hanai, an executive at Toyota Motors. The plan includes the following software related items added to the previous plans:
1. Efficient software development
2. Systems for artificial intelligence
3. Systems for education support
4. Personal computers utilization

The objectives for the following categorized areas are addressed:

- Control programs
- Communication control programs
- Language processors
- System description languages (C and Ada)

Software development support facilities addressed in the SIGMA Project

- System development management
- System development assist
- Implementation assist
- System verification and evaluation assist
- Maintenance assist
- Operation assist
- Integrated system development assist for the entire life cycle
- Data Base Management System (DBMS)

Application programs:

-- Common programs such as user interface, pattern recognition, document processing, security protection, etc.

-- Educational and training programs such as CAI

-- Social and public purpose programs such as home care, security control, traffic control, etc.
Industry programs

Academic institution programs such as effective usage of super computers, etc.

MITI’s supports in the these areas are funded by both the government budgets and loans from Japan Development Bank. For the fiscal year 1986, assistance from both sources totaled $594 million.

According to Nihon Keizai Shimbun dated 9/15/87, MITI planned to introduce a quality measurement system for general-purpose software as a means to strengthen the software industry. An evaluation team consisting of representatives of software houses, computer manufacturers, and men of learning and experience is to be organized to evaluate and make public the following:

- Accuracy of software functions
- Useability
- Understandability of screen displays

This is intended to cope with the problems like the following:

The prices of PC and office computer programs are not based on the quality of the functions, but on their sizes (LOC).

Software products are not accepted as mortgages by financial institutions because their social evaluation is not determined and their asset values are vague.

The users do not have criteria to judge the quality of the software products and learn of their quality only after they have used them.
According to the 10/08/87 issue of Nihon Keizai Shimbun, MITI has drafted a bill aimed at decentralizing the software industry from the Tokyo region. The bill calls for the government to build basic facilities and provide tax and financial incentives in order to lure companies away. Software industrial centers would be constructed at some 20 locations across the country, particularly in northern Japan including Hokkaido.

Nihon Jyohou Sangyo Shimbun (Japan Information Industry Newspaper) dated 4/6/87, reported that MITI has developed the following plan to address the significant anticipated shortage of software engineers needed for the informationalized society of the 1990’s (IBMc, 1987):

1. Central university on information processing
   - Research and development on how to educate software technology
   - Train instructors to teach software technology at local universities

2. Local universities for information processing to meet local requirements

3. CAI systems for training DP specialists under development at one of MITI’s affiliated agencies, IPA.

To promote earlier acquaintance with computers, MITI had started the Computer Education Center (CEC) together with Ministry of Education last year. CEC has already been in full swing with various activities to promote CAI. A study group consisting of computer manufacturers, software houses and educational institutions has been finalizing specifications of a specialized personal computer for CAI.
An expected shortage of 970,000 software engineers in the year 2000 was reported in an article published in the 4/21/87 issue of Asahi Shimbun as a finding of a subcommittee of MITI’s Industry Structure Council. They project:

Current software industry occupies 1.05% (3,500,000,000,000 yen, $23 billion) of Japan’s GNP with 430,000 software engineers

In the year 2000, it is expected to occupy 3.97% (34,600,000,000,000 yen, $233 billion) of Japan’s GNP with 2,150,000 software engineers

At that time, 1,180,000 software engineers are projected to be available, resulting in a shortage of 970,000 persons. Even with a successful implementation of the SIGMA Project, 400,000 additional persons are still expected to be needed. The shortage of those who will be capable of doing problem analysis and program design is expected to be 310,000 persons.

Based on this analysis, the subcommittee recommended the following to MITI:

1. More personnel interactions among undergraduate, graduates and industry and an increase in capacity for those classes related to information processing
2. Development of a standard curriculum for vocational schools for information processing specialists
3. Development of educational software for elementary and junior high schools
4. Conversion from industry sub-segments with surplus population -- 330,000 people
In addition, according to the August 3, 1987 issue of the Daily Network News, IPA decided to start eight research and development and survey projects, three of which are related to software development technologies:

- "Intelligent Software Development Environment"
- "Programming Language based on New Paradigms"
- "Software Quality Functional Expansion and Sizing"

Much like the SIGMA Project they will be staffed with researchers from industry. They will last two or three years, prototypes will be built and their use in private companies will be monitored.

Movement Away From IBM Compatibility

Since the Japanese government allowed IBM to manufacture locally in exchange for technology licensing agreements back in the 1960’s, Japanese computer manufacturers, with the exception of NEC, have followed a predominantly IBM compatible strategy. Hitachi and Fujitsu have been the leading IBM compatible computer makers, but they are trying to expand their strategies by introducing new architectures (Nihon Keizai Shimbun, Jul. 21, 1987). JCM’s, even those who have followed a policy of offering non-IBM compatible machines, have looked to IBM for technological leadership in computer and software development, and have found it
necessary to introduce technologies similar to IBM's SAA (Japan Economic Journal, Dec. 19, 1987).

Fujitsu and Hitachi stress that they are following their own independent course, but there is little doubt that they are expending significant effort to catch up with IBM. Fujitsu President Takuma Yamamoto says "Our company will continue to uphold the line of IBM-compatible computers, but at the same time we will concentrate on developing new technologies that IBM does not have. It is increasingly clear that software holds a major key to determining the destinies of computer makers." In June, 1987, Fujitsu announced a Systems Integrated Architecture (SIA) technology that allows users to develop software independent of hardware or operating system differences (Nikkei High Tech Report, Jun. 22, 1987). SIA, which allows hardware systems based on different design philosophies to use the same software, is essentially the same as IBM's SAA that preceded Fujitsu in the market, but Fujitsu has added functions that allow users to automatically generate programs from specifications and to develop an overall framework as well as individual programs.

In June, 1987, Hitachi presented its Hitachi Application Architecture (HAA), which it claims will enable both IBM-compatible and UNIX-based computers to share, access and process the same data and information almost regardless of
differences in operating systems and processing capabilities. By March, 1988, the company will publish the detailed specifications of a variety of HAA interfaces for different operating systems (Nihon Keizai Shimbun, Jul. 21, 1987). Hitachi has also been making significant changes to its operating systems designs. The company’s new OS, VOS1/ES2, announced in September, 1987, has a large number of new functions not included in earlier IBM-compatible OS products and actually has a lower level of overall compatibility (Nikkei High Tech report, Nov. 9, 1987). NEC has also announced a new software architecture named DISA to enable its software packages to run on a variety of computers, including large and personal computers (Nihon Keizai Shimbun, Dec. 2, 1987).

**Movement Towards a UNIX Based Strategy**

The use of AT&T’s UNIX in software development has been spreading rapidly. International Data Corp. predicts that by 1991, UNIX will be the main operating system for a quarter of the worldwide computer market (see figure 6.1). Currently the major problem impeding the spread of UNIX is the multiplicity of versions, with at least a dozen major varieties in existence, all slightly different (Business Week, Mar. 14, 1988). Last year AT&T began efforts to create
Source: Business Week, Mar. 14, 1988

Figure 6.1

a single dominant version of UNIX and is working with Microsoft and Sun Microsystems to make such a version available later this year.

X/Open, a group of companies cooperating to set international standards for UNIX, was established last year by AT&T, Digital Equipment, Unisys, STC International Computers, N.V. Philips, Bull and Siemens AG. Japanese computer makers are expected to participate as well, which according to industry sources, will move the worldwide standardization of operating systems into a new phase (Japan Economic Journal, Nov. 28, 1987).

In Japan, the decision to use UNIX for the IPA's SIGMA
Project (in which AT&T is participating) has given significant stimulation to JCM's to use UNIX in software development, and many people now feel that UNIX is the base for software development environments using intelligent workstations (IBMc, 1988). The UNIX System V operating system used by SIGMA is viewed as a means for Japanese companies, especially Hitachi and Fujitsu, to escape from near total reliance on IBM-compatible software (Japan Economic Journal, May 2, 1987).

Fujitsu was the first company in Japan to put UNIX (UTS from Amdahl) on general purpose computers. This was followed by Hitachi whose decision was reported by a newspaper in December 1985. The Japanese language version of UNIX System V was announced by ATT on February 4, 1986 and the July 9, 1986 issue of Nihon Keizai reported that a UNIX Study Group had been organized to develop draft standards for UNIX on 32-bit PCs by the end of 1986. The group is supported in by 8 computer manufacturers. AT&T and MITI are observer members.

In addition to the use of UNIX for scientific and engineering application programming, its file capabilities are being expanded for commercial applications. As an example, Toshiba presented a paper on a UNIX file system for business use in October 1986.
Fujitsu started shipping UNIX UTS-S on its S-300 series in October 1985 and UNIX UTS-M for use on M series in January 1986. Nikkei Computer, 3/17/86, reported that Fujitsu was also going to open a UNIX Support Center around April 1986. The company has recently announced five new E-series supercomputers, each of which is equipped with Advanced Virtual Machine (AVM) which allows for simultaneous running of different operating systems such as Fujitsu’s own and UNIX (Japan Economic Journal, Sep. 5, 1987).

In March 1986, Hitachi announced Workstation 2050 which uses a multi-tasking OS called 'HI-UX', whose nucleus is UNIX. In December, 1987 the company announced its first super-minicomputer, the HITAC E7700, which uses the UNIX System V operating system (Japan Economic Journal, Dec. 12, 1987). Hitachi also plans to begin developing software applications in the US for its workstations that will be based on UNIX (Nikkei High Tech report, Nov. 9, 1987).

NEC began shipping A-UX (based on UNIX System V) on its intermediate and large systems in March, 1987 and its EWS4800 workstation for software development also has a UNIX operating system.
Alliances and Market Expansion by Japanese Firms

The leading JCM's are extremely active in the latest and most complex software technologies and are supplementing their own R&D efforts through technology alliances, joint ventures, software subsidiaries and sub-contractors, and in the process, are globalizing their software development activities. The following is a small sample of the numerous activities that have taken place.

Hitachi

Hitachi has a 92% equity share in Nippon Business Consultant Co., Ltd., one of Japan's largest independent software vendors, formed in 1969 and soon to be listed on the Tokyo Stock exchange (IBMa, 1987). Hitachi Software Engineering, est. 1970, is a wholly owned subsidiary devoted to a full range of software products. In 1981 Hitachi reached an agreement with Syncsort to market Hitachi software packages in the U.S. and they have also contracted with the Chinese government to jointly develop Chinese language based software for its personal computers (Japan Economic Journal, 05/07/85). Hitachi has also begun to develop integrated software at its Marketing Systems Division in California (Japan Economic Journal, 07/18/87).
**Fujitsu**

Fujitsu is using its Australian subsidiary to coordinate software imports from Australian software makers back to Japan (Japan Economic Journal, 02/14/87). Its Korean subsidiary has been working with the Korea Advanced Institute of Science and Technology to develop automated Japanese-Korean translation software (Japan Economic Journal, 10/31/87). In 1983 Fujitsu established a 50-50 joint venture with Matsushita Electric, MF Information Systems, Ltd. responsible for system design, software, development, hardware interfaces, etc. for all orders received by the Matsushita Group.

**NEC**

NEC Software, Ltd. was spun off in 1975 and by 1983 had formed three more software subsidiaries. Between 1983 and 1987 they established 11 additional software subsidiaries (IBMa, 1987). NEC has been widely publicizing its "Computers and Communications" strategy and has been successful working with many software vendors to develop products for its PC's (Japan Economic Journal, 05/07/85). In 1981 NEC and the Chinese Computer Engineering Service Corporation established the Japan-China Software Center to train Chinese software engineers and eventually supply NEC with software. 
applications.

Toshiba

In 1986 Toshiba made an agreement with Sun Microsystems for engineering workstations. (IBMa, 1987)

Mitsubishi

In 1986 Mitsubishi made an agreement similar to Toshiba’s for EWS with Appolo Systems. (IBMa, 1987)

Others

CSK Corp. has reached an agreement with IntelliCorp to market its new AI system in Japan which operates on general purpose computers and allows knowledge-based systems to be easily connected to existing data bases (Japan Economic Journal, 06/20/87).

Sumitomo Corp. has acquired exclusive Japanese marketing rights for videotex software developed by DISK International Ltd. and is developing Japanese language versions (Japan Economic Journal, 01/29/85).
Conclusions

Japanese computer manufacturers have developed complex and long term technology strategies to close the software technology gap with the western world and have adapted those strategies to effectively compete with foreign firms. They have focused their internal R&D efforts primarily on development process technology while following a predominately IBM compatible product technology strategy. They have used alliances, subsidiaries and sub-contract software houses to develop advanced product technologies and supplement development resources. Under strong leadership JCM's have adapted and incrementally advanced widely available software engineering methodologies.

MITI has played a vital role in directing the technology strategy of the JCM's through comprehensive cooperative R&D projects and promotion activities and has taken steps to improve the skill base of the available workforce. The SIGMA project and its follow-ons are leading the Japanese software industry into a promising but still unproven direction.

Recently, Japanese firms have been maintaining their IBM compatible product lines while advancing their own unique technologies and architectures and also taking bold steps in the UNIX direction. They are globalizing their development
efforts in order to counter the Japanese yen appreciation as well as gain access to leading edge technology.
Summary and Conclusions

The Japanese software industry has successfully transferred and incrementally built on readily available software and software engineering technology, succeeding in dramatically narrowing the technology gap which existed as recently as 5 years ago. It is flourishing in an environment of strong growth and intense competition. It developed in the shadow of the computer hardware industry under the strong and careful protection and promotion policies of MITI and has recently come into its own right as a major industry segment. It had taken a back seat to U.S. technology throughout its development history, but has effectively transferred key technologies in graphics, CAD/CAM, AI, language processing and translation and has extended them through internal R&D efforts.

The major Japanese computer manufacturers and several government projects have focused on improving the software development process and applying manufacturing methods and automation to software production with impressive productivity and quality results. Cooperative R&D among the major JCM’s and MITI along with stable long term government policies have enabled the JCM’s to advance the state-of-the-art in Computer Aided Software Engineering.
(CASE) with an efficiency of resource use seldom found in US industry.

MITI has set a clear and bold direction with the SIGMA project, attempting to achieve a new level of fully integrated CASE tools on a UNIX base and establish an industry wide common development environment. Critics point to the lack of significant innovation in the SIGMA effort and question the viability of UNIX, however, the productivity and quality gains possible through automation, reuse and environment consistency could be enormous. Combined with MITI's education programs and the rapidly rising popularity of UNIX as an alternative to proprietary operating systems, SIGMA may very well arrive at an extremely opportunistic time in the evolution of the worldwide software industry. The feasibility of SIGMA has already been demonstrated and the major JCM's have strongly supported its development. What remains as MITI's challenge is to gain widespread support for its use, especially among the independent software houses. Japan has historically excelled at smoothing disputes and building consensus and is therefore likely to succeed with SIGMA as well. As long as the current software development paradigm continues to evolve incrementally, the long term investment in software development process technology that Japan is making will give their industry a competitive advantage in producing the
vast amounts of software that will be required in the future.

MITI is also looking far beyond the SIGMA effort and has already launched several follow-on projects. "MITI Preparing Post SIGMA Project Toward Establishment of a Tool to Develop Next Generation Software", an article which appeared in 3/31/86 issue of Nikkei Computer, reported that MITI has started to develop the "Formal Approach to Software Environment Technology" (FASET), a next generation CASE tool which will enable automatic creation of a program based on a specification (formal specification) prepared in a special specification language. Projects are also underway to incorporate AI technology into development process automation.

The major JCM's are also strongly committed to CASE and are producing tools and complete life cycle environments both for internal use and commercialization. They are diversifying their strategies by maintaining their IBM compatible products lines, investing heavily in R&D to incrementally improve their product technologies and proprietary environments and also backing the SIGMA effort and moving rapidly toward UNIX as an alternative environment to the traditional IBM world. They are expanding their global reach and technology access through an increasing
number of international joint ventures, alliances and foreign subsidiary development sites. They have the financial strength to maintain these broad-based strategies and compete effectively, especially in the explosive Asian market.

What this means for US software producers is that they are likely to feel significantly increasing competitive pressure from Japan on a global basis. Software is rapidly becoming the critical factor in hardware purchasing decisions and the increasing gap between software demand and the worldwide industry’s capability to satisfy it may provide a sufficient window of opportunity for Japanese firms to significantly increase their market presence. US firms have been slow to adopt and develop CASE methodologies and tools, and although many individual tools exist, few are compatible or integrated (Business Week, May 9, 1988). Only recently has there been increased interest in CASE technologies and product development in the US. Unlike Japan, most of this has come from small start-ups attempting to exploit a rapid growth area. Major manufacturers have lagged behind in their support of CASE as a strategy and its incorporation into their development processes.

A paper entitled "Quality - Assurance Technology in Japan" by K. Kishida, et al., which was printed in the September,
1987 issue of IEEE's Software, says that a survey (conducted in 1986) of the state of SQA in Japan finds that the situation is much like, but slightly different, than in the US. This survey overstates the equivalence between the two industries in that it focused on small Japanese software houses, without recognizing that the technological leadership in Japan resides in the major computer manufacturers. It also does not reflect the progress in the development and use of software tools which has accelerated in recent years. Also, the integrated development environments which became available to customers in 1984 and the use intelligent workstations which began to emerge in 1987 are not mentioned in this report (IBMc, 1988).

A recent US government report says "The Japanese are apparently ahead of US firms in making improvements to existing technologies from the US and Europe, and in incorporating these advances into highly marketable products. The Japanese have also made impressive gains in the development of software tools and have encouraged their widespread use to boost productivity. Both the Japanese government and the leading computer manufacturers began investing in the automation of the software development process nearly seven years ago" (IBMc, 1988). Also, D. Brandin, former head of ACM and chairperson of the Computer Science group of the Department of Commerce's Japanese
Technology Evaluation Program (JTECH) recently gave an assessment of US vs Japan software engineering: "Although Japan is far behind in basic research, she is far ahead in product engineering and rapidly widening the gap with the US in this area."

Unless US firms begin to make concerted efforts to achieve the productivity and quality improvements that will be required to meet future demand for software, they will be vulnerable to Japanese competition and fighting to catch up in development process technology. Once again a leading US industry could be exposed to market share erosion from Japanese competitors backed by government policy and programs and with superior production technology, a long term perspective and an ability to cooperate for efficient technology development.
## APPENDIX A

### SIX MAJOR KEIRETSU GROUPS

<table>
<thead>
<tr>
<th>Main Bank</th>
<th>Mitsubishi Bank (28 companies)</th>
<th>Mitsui Bank (24)</th>
<th>Sumitomo Bank (21)</th>
<th>DKB Trust (47)</th>
<th>Fuyo Bank (29)</th>
<th>Sanwa Bank (44)</th>
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<td>NEC</td>
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<td>Sumitomo Real Estate</td>
<td>Seibu (Dept. Store)</td>
<td>Sapporo Breweries</td>
<td>Takashimaya (Dept. Store)</td>
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</table>

Note: Hitachi, Kobe Steel, Nissho-Iwai and Nippon Express belong to multiple groups.

Source: IBMa, 1987
APPENDIX B

Relationship Between The Major Japanese and Foreign Manufacturers

AT & T <---------------------- New Relationship (rumor)

Amdahl

CPU, DASD
MT, Display, Ptr

Memorex

DASD, FDD, Ptr
FDD

M A S

CPU, DASD
FDD, MT, Ptr

Hitachi

New Relationship

Hitachi CPU

Hitachi

NEC

ACOS 1000
ACOS 850

NEC Supercomputers

Honeywell

ACOS 1000
ACOS 750

Bull

LSI

ICL

Siemens

50% Equity

Compaq

50% Equity

Nixdorf

DASD

NCR

FDD, Ptr

HIS

ACOS 850

NEC Supercomputers

Honeywell

Bull

50%

15%

42.5%
Sun Microsystems

AT & T

Minicomp *

Olivetti Japan

Olivetti

80%

20%

OIC

EM

IBM

UNISYS

CPU, DC, DASD

Ptr, Display

Mitsubishi

Ampex

DASD, FDD

FAI

Siemens

EWS

FAI

OCR

IBM

Appolo

EWS

CR

OK I

Ptr

Ptr

Ptr, Term

Mixdorf

140

Notes: * AT&T's minicomputers are also marketed by Ricoh.
** IBM buys Kanji printers from Hitachi also.

Source: IBMa, 1987
MITI Supported Projects

Source: IBMc, 1988
APPENDIX D

Papers Presented at the 33rd National Conference (October, 1986) of the Information Processing Society of Japan (IPSJ)

### Languages & Software Engineering

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### Operating Systems

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