THE U.S. SUPERCOMPUTER INDUSTRY : A STRATEGY FOR THE FUTURE

by

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ABSTRACT

This thesis examines strategic planning in the U.S. supercomputer field within the government and corporate sectors. Various firm strategies, U.S. government supercomputer policy, and Japan's National Super-Speed Computer (NSCP) project are examined, analyzed, and contrasted.

A supercomputer industry analysis is performed using data obtained by literature research, foreign trip reports, and personal interviews with top executives within the U.S. government and industry. External and internal factors are analized. Firms examined in this study include Control Data Corporation, ETA Systems, Cray Research, Denelcor, Hitichi, Fijutsu, and NEC as well as the recently established multi-corporation sponsored Microelectronic and Computer Technology Corporation (MCC). Current and future industry positions are projected for each firm.

A historical perspective of the U.S. supercomputer industry is developed to provide insight into the appropriate government-industry relationship. In addition, historical US and Japanese industrial policies in related fields are examined.

US government/corporate strategy alternatives are contrasted with the Japanese government/industry efforts in this same field. Cooperative U.S. government and corporate sector strategy alternatives are offered which involve an appropriate mixture of government and private sector R&D to fulfill the strategic objectives of both these sectors. Strategic policy recommendations focus on R&D investment.

A set of substantiated government/corporate supercomputer strategy recommendations are provided. The broad implications of the U.S./Japanese supercomputer battle are explored. Finally, the implications of the U.S. supercomputer industrial policy recommendations on U.S. high-technology industrial policy are discussed.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Since World War II, the economic growth of Japan has consistently outpaced that of the United States. This economic growth was initially confined to non-R&D intensive industries such as automobiles, consumer electronics and steel. However, during the past five years, Japan has been successful in penetrating a number of R&D-intensive industries, including semiconductors, robotics, and flexible manufacturing equipment. Recently, Japan has begun to focus on supercomputers.

"Supercomputers" are defined as the fastest, largest computers available at any point in time.[1] The United States has dominated the supercomputer industry since its inception. Japan's focus on supercomputers is a challenge to U.S. domination in this industry. In fact, Japanese firms have developed supercomputers of comparable performance to U.S. supercomputers in only three years. This remarkable success is pitting the U.S. and Japan in a "battle" for supercomputer supremacy. It is also forcing the American government to re-examine its supercomputer policy and American firms to re-examine their strategies.

[1]This thesis focuses on supercomputers and does not address fifth-generation computers. The distinction between supercomputers and fifth-generation computers is clarified in Chapter 2.

This thesis will examine the reasons for Japan's recent ascendancy in the supercomputer market and compare and contrast the Japanese and U.S. strategies for developing supercomputers; the relationships between government, industry, and universities; differences in technological innovation; and cultural and structural differences in these two countries.

The U.S.-Japanese supercomputer "battle" is of substantative interest to motivate this study. However, the broader implications of this subject also support doing this analysis. First, supercomputers provide an important base of technology for smaller, lower speed mainframe, minicomputer and personal computer segments. Large computer firms such as International Business Machine (IBM) and Control Data Corporation (CDC) believe that leading-edge supercomputer technology has flowed down to their lower-speed computer products. Second, both Hitachi and Fujitsu are introducing supercomputers with IBM compatible software. These products are clear threats to IBM accounts which involve high-speed computational applications. Since IBM does not currently provide supercomputers, prestige and potential loss of its world dominance in the computer market may force IBM to respond with a supercomputer offering. Third, supercomputers are becoming essential engineering tools, providing competitive advantages for a growing number of industries. For example, enlightened automotive and aerospace firms believe that supercomputers can reduce the

time and cost required to design sophisticated new products by as much as 30 to 40%. In addition, nearly all major petroleum firms have invested in supercomputers to reduce the risk and therefore the cost of petroleum exploration. Japanese development of supercomputers appears to be aimed at providing supercomputer capability to domestic Japanese industry. This action will have a profound impact on the future economic competitiveness of overall Japanese industry. Fourth, computers play a key role in performing national security tasks associated with secure communications and foreign intelligence. National security experts believe a loss of leadership in supercomputers could severely impact the health of the U.S. computer industry. National interest requires that the U.S. maintain a healthy supercomputer industry not only for the supercomputer segment but for the potential impact this segment has on the health of the overall computer industry. Any analysis of the supercomputer industry must include the views of this important community and their strong influence on government policy.

The development of supercomputer policy is complicated by the natural conflicts that arise between key stakeholders interested in this industry. For example, those stakeholders with a view toward economic competition would favor reduced barriers to foreign export of supercomputers, while those stakeholders with a view toward national security would favor barriers to supercomputer export due to potential military use

by hostile foreign governments. This thesis will attempt to offer a balanced set of recommendations form the viewpoint of all key stakeholders.

Finally, the House Democratic caucus has called for some form of industrial policy. The Reagan Administration is emphasizing free enterprise to maintain "healthy" U.S. industry, and, as a result has avoided efforts to set industrial policy. The supercomputer industry differs from most U.S. industry in that the U.S. government, through agencies such as the Department of Energy (DOE), the Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA), is the largest single user of supercomputers. Additionally, supercomputer capability is closely coupled to national security. For these reasons, the Administration, through the White House Office of Science and Technology Policy (OSTP), is offering a policy statement to ensure the health of the supercomputer industry. This supercomputer policy statement is unique in that it serves an important pathfinder role for future industrial policy involving other high-technology industries.

1.2 Goals

There are four major objectives of this thesis. First, this thesis will provide an historical perspective on the supercomputer industry and document the importance of product and executive champions in the development of successful

supercomputers. The changing role of the U.S. government in the supercomputer industry is described. A key portion of this section analysis the U.S. government involvement in supercomputer development to extract the most useful lessons learned for the most effective government-industry-university relationships.

Second this thesis will analyze the supercomputer industry. This analysis 1) includes all U.S. and Japanese supercomputer firms and projects the competitive position of the strongest industry participants over the next four to five years and 2) identifies and quantifies the primary factors which affect the industry and the key strengths and weaknesses of major competing firms. Individual firm strategies are also contrasted and critiqued.

Third this thesis addresses the complex issues of public and private sector policy in the supercomputer industry. Historical perspectives on government-industry-university relationships, modes of technological innovation, structural strengths of the U.S., stakeholder positions, and strengths and weaknesses of U.S. supercompute. firms are combined to develop a strategy to maintain U.S. preeminence in supercomputers.

Finally, the study provides strategic implications on the broader issues of economic competitiveness, national security,

threats to IBM, and high-technology industrial policy.

1.3 Methodology

A successful industry analysis requires a clear identification of the strategic business unit (SBU). The supercomputer industry can be considered a clearly defined segment of the computer industry. The supercomputer industry has its own standard industry code (SIC) and clearly defined set of competitors. Price changes by one supercomputer competitor affect the prices of all supercomputers. While the separation between the large mainframe market and the supercomputer market is somewhat blurred, the applications of most supercomputer users require performance in excess of that offered by large mainframes. Thus, no other segments of the computer industry can for supercomputers.

The methodology used in the industry analysis portion of this thesis is based on the frameworks developed by the Boston Consulting Group (BCG), General Electric (GE), Arthur D. Little Inc. (ADL), Hax, and Porter.(1)(2)(3)(4)(5) A modified version of the GE format is used as an assessment of industry attractiveness. The analysis of current competitors includes a description of the visions of all firms, their strategic postures, the missions of their supercomputer business units, an identification of their major strengths and weaknesses, and an examination of their strategic actions.

This thesis uses Horwitch's terminology to describe technological innovation.(6) There are at least three ideal or pure "modes" of technological innovation:

- o Mode I - technological innovation in the small high technology firm.
- o Mode II - technological innovation in the large, multi-product, multi-market, and multi-division corporation
- o Mode III - technological innovation in huge, multi-organization enterprises involving public and private institutions that are working together on a mission-oriented large-scale program.

Each mode has strengths and weaknesses, and does not always exist independently. The three U.S. supercomputer firms, Cray Research, Inc., ETA Systems, and Denelcor, utilize Type I technology innovation. The three Japanese supercomputer firms, Fujitsu, Hitachi and NEC, utilize Type II and Type III technology innovation.

Data and perspectives required for this effort were developed based on literature research, foreign trip reports, Congressional testimony, and personal interviews with top executives within the U.S. government and industry.

CHAPTER 2

SUPERCOMPUTER DEFINITION AND PLACE IN COMPUTER MARKET

This chapter defines the supercomputer and provides a description of the primary technical characteristics of a supercomputer. In addition, the supercomputer market is described and related to the overall computer market.

2.1 Supercomputer Definition

The computer industry can be roughly divided into five segments, primarily based on computational speed in millions of instructions per second (MIPS):

Personal computers	Less than 0.2 MIPS
Minicomputers	0.5 - 1.5 MIPS
Superminicomputers	1 - 5 MIPS
Mainframe computers	8 - 20 MIPS
Supercomputers	Greater than 40 MIPS

Supercomputers are large-scale, high-speed computer systems used to solve complex problems in a wide variety of industries. The primary attribute of supercomputers is high computational speed. Supercomputers exploit hardware advances to achieve increased speed. Fifth-generation computers are distinguished from supercomputers in that they are focused on advances in software and, in particular, by extensive use of artificial intelligence. The Press has tended to confuse

these two types of computers and call them both supercomputers. This thesis only deals with supercomputers and will not examine fifth-generation computer efforts.

Although high computational speed is the primary characteristic of supercomputers, other supercomputer characteristics include large, fast main and secondary memory, and vector or parallel processing capability.

High computational speeds are important to large-scale computer users, particularly the scientific community. This quantitative aspect of supercomputers has changed with improved technology. For example, supercomputers developed in the 1950's operated at computational speeds of 0.2 to 0.4 million instructions per second. The first commercially successful supercomputer, the Control Data Corporation 6600 (delivered in 1964), had a computational speed of 3 million instructions per second. By the early 1970's, supercomputer speed had reached 20 million instructions per second.

Today, supercomputer speed is measured in MFLOPS, or one million floating-point operations per second. "Floating-point" refers to binary representation of numbers expressed in scientific notation (mantissa and exponent). A single floating-point operation is the addition, subtraction, multiplication or division of two floating-point operands to get a floating-point result. To qualify as a supercomputer

today, a computer should sustain average rates of 20 million floating-point operations per second for a wide range of problems.(7) A comparison of supercomputers in terms of speed and memory is given in Figure 1.

The computational speed of supercomputers will continue to increase and this aspect of the definition of supercomputers will change accordingly. The Denelcor HEP in the four-processor-system configuration represents the lower limit of the supercomputer industry segment today. By 1986, the lower limit of the supercomputer industry segment should have a performance slightly in excess of the Cray 1/S with a computational speed of 100 MFLOPS.

Large, fast main memory is essential for problems which have a substantial data base. Today, supercomputers must provide at least one million or more words of main memory, usually 64-bits each.

Secondary memory is important for applications when the required data will not fit into main memory. Optimizing transfer of data between main and secondary memory involves considerable programming effort to maintain high computational speeds.

Manufacture	Model	First Installed	Number Installed	Speed (MFLOPS)	Memory (Million Words)
CDC	6600	1964	59	1.5	0.1
CDC	7600	1969	27	7	0.5
Burroughs	ILLIAC-IV	1970	1	25	16
Cray Research	Cray 1	1976	17	80	1
CDC	Cyber 203	1980	3	80	2
Cray Research	Cray 1/S	1980	33	100	4
CDC	Cyber 205	1981	22	400	8
Denelcor	HEP I	1982	3	3-48*	2
Cray Research	Cray X/MP	1983	7	420	4

Figure 1. Comparison of supercomputer performance and market success.

*Maximum size sold is 4 processor system capable to about 12 MFLOPS.

Source: Supercomputer Market: 1981 Report, and Processor Data Book, (Framingham, MA: International Data Corporation; October 1981; 1982; 1983).

Vector processing refers to the ability for the computer to handle computations involving an ordered list of data items - a vector. The number of elements in the list is the vector length. Vector computers allow a single vector instruction to execute pairwise operations on the entire vector. Ordinary operations applied to single numbers are referred to as scalar operations. Problems which can be "vectorized" execute at much higher speeds than scalar operations.

Parallelism is another method of increasing computational speed. Parallel computers execute operations concurrently on individual processors or functional units. The Cray-1, for example, utilizes seven functional units to implement specific instructions concurrently. The ILLIAC IV was an early experiment with a highly parallel architecture. It used 64 identical processors that operated in lockstep under a single instruction processor. The major vector supercomputers developed to date are single instruction multiple data (SIMD) computers. Machines that can handle multiple instructions as well a multiple data - MIMD machines - are in the research stage. The Denelcor HEP represents the first commercial MIMD supercomputer offering. As the cycle time of individual processors reaches a limit, supercomputer designs will turn to MIMD architecture to achieve continued gains in speed.

The computational speed of a supercomputer is a function of processor speed, memory size and access time, overall computer

architecture, and the specific problem to be solved. Computational speeds given in Figure 1 are for typical problems. For problems dominated by scalar and short-vector operations, the Cray X/MP is the fastest due to its very short cycle time. For problems programmed to include long vectors, the Cyber 205 is the fastest.

2.2 Place of the Supercomputer in the Computer Industry

The market for computers in 1983 is approximately $40 billion worldwide.(8) The mainframe portion currently represents the largest share of the market with about 60% of the total market. The supercomputer market has historically been a small portion of the whole computer market (less than 1%) as demonstrated by the numbers of installed computers listed in Figure 1. The average supercomputer sells for about $10 million. In the last 15 years, the two major vendors have been Control Data Corporation and Cray Research, Inc. Annual supercomputer revenues are estimated at $259 million in 1983.

Recently, CDC has formed ETA Systems to handle its supercomputer business, with the exception of the Cyber 205, which CDC will continue to enhance and market. CDC has given ETA Systems the technology, capital, equipment and key technical and management personnel to develop a new line of supercomputers considerably more powerful than the Cyber 205. In this thesis, these two firms will be treated together, even though they have separate corporate and market objectives.

Supercomputers represent an important segment of the computer industry. Marketing the "world's fastest" computer has become a symbol of prestige. For example, both Hitachi and Fujitsu began their 1983 annual reports with photographs and discussion of their supercomputer efforts. Some of the brightest computer scientists have been attracted to the supercomputer field. The next chapter will examine key individuals who have contributed to the vitality of the supercomputer business.

CHAPTER 3

HISTORICAL PERSPECTIVE ON THE SUPERCOMPUTER INDUSTRY

This chapter provides a historical look at the supercomputer industry and examines the role of champions in the development of successful supercomputers.

Donald Schon has addressed the importance of product champions in development of new products.(9) He states, "The new idea either finds a champion or dies... No ordinary involvement with a new idea provides the energy required to cope with the indifference and resistance that major technological change provokes....Champions of new inventions play persistence and courage of heroic quality". More recently others (Roberts , Peters and Waterman) have suggested a more complex scheme including a product champion plus some form of protector.(10)(11) Peters and Waterman identify two types of protectors - executive champion and godfather. The executive champion many times is a former product champion. He shields the product champion from the organization's tendency to kill new projects. A godfather is described as an aging leader who serves as a role model for championing.

Control Data Corporation (CDC) emerged as the dominant supercomputer firm in the early 1960's. The reasons for this early success are largely due to the championing of CDC's William C. Norris, founder and chairman, and Seymour Cray,

chief supercomputer architect.

3.1 Early Beginnings

William Norris gained an understanding of government needs for computational capability during World War II, when he served in a highly classified communications section involved in cryptography - Communications Supplementary Activities, Washington (CSAW). After the war, the Defense Department continued its interest in computer development. By promising defense contracts, the government encouraged Norris and other members of CSAW to seek outside financing to start a computer company.(12) They formed Engineering Research Associates (ERA) in 1945, and were awarded Navy contracts. The ERA group developed the magnetic memory drum and several first generation computers.(13)(14) In spite of these technological successes, ERA's earnings began to decline. By 1951, ERA needed additional capital to expand into the commercial market. Remington Rand, who previously acquired the Eckert-Mauchly group, acquired ERA in December 1952. This acquisition lead to the merger of the Eckert-Mauchly and ERA groups to form Univac computer division. Norris became general manager of Univac operations in 1955. However, internal rivalry and frustrations with senior Rand management, led to an outright rebellion of the former ERA engineers. Frustrations over top management at Remington Rand led Norris to later say "To run a computer company, it's necessary to have top executives who understand computers".(15) Norris and

other ERA engineers (including Seymour Cray) left Univac to form a new company - Control Data Corporation (CDC) in 1957.

3.2 First Days at Control Data

Bill Norris served as president of CDC. He focused CDC's initial business on military research and development and did not intend to compete head-on with the computer industry leader - International Business Machine (IBM). Seymour Cray convinced Norris that a powerful, solid-state (second generation) computer would be highly profitable. Development of a solid-state computer was a significant technical and financial undertaking for the small engineering firm, but Norris took the gamble. CDC cut salaries and used the cheapest electronic parts obtainable. CDC began development of a solid-state computer in 1958 and in 1960 delivered the 1604 to the Navy post-graduate school. The rapid development of the 1604 was due to previous design efforts on a military transistorized computer and the strong technical competence of Cray.(16)(17)

3.3 IBM's Stretch

IBM's first supercomputer was Stretch, a development effort begun under contract to Los Alamos in 1955 and delivered in 1961. The machine met only 70 percent of its promised specifications. Tom Watson, the president of IBM, reduced the price of Stretch to match the value of its performance. This lower price provided no profit margin for IBM, and Stretch was

withdrawn from the market. Only seven of the Stretch computers were completed and installed. Watson later remarked, "Our greatest mistake in Stretch, is that we walked up to the plate and pointed at the left-field stands. When we swung, it was not a homer but a hard line drive to the outfield. We're going to be a good deal more careful about what we promise in the future."(18) While STRETCH had strong technical champions within IBM, Watson was clearly not supportive of the effort in the early 1960's.

3.4 Seymour Cray and the CDC 6600

Shortly after the formation of CDC, Cray examined the possibility of developing a supercomputer and is credited for convincing CDC "that it was feasible for a little company to build a big computer".(19) Norris saw an opportunity to avoid a head-on confrontation with IBM, a strategy of flanking IBM in the supercomputer market aimed at government research laboratories, university centers, and certain large scientifically oriented corporations. Thus, Cray saw the opportunity to build a supercomputer, and Norris saw the opportunity to build a computer company. After their success with the 1604, Control Data's strategy focused on producing the biggest, most powerful, most sophisticated computer in existence. The company's prospects were viewed in relation to this one great supercomputer - designated the 6600.

The 6600 was publicly announced in August, 1963. Although

Cray's role in the development of the 6600 was in question from the start, it proved to be a significant technical achievement for him. Cray operated in the individual inventor style, the complete opposite of other large computer research and development organizations.(20) When development of the 6600 began, Cray, had become uneasy with "large corporate structure problems" and wanted to move to Wisconsin to start his own company. Norris was able to convince Cray to stay with the company, by agreeing to move the 6600 development program to Chippewa Falls, Wisconsin.(21)

The Big Box, as the 6600 was nicknamed, was over six feet high, fourteen feet long and weighed 7.5 tons. As the Big Box neared completion, its performance capabilities were far above the capabilities of the most powerful computers installed in the field. The 6600 could operate at speeds of three million instructions per second, more than three times faster than the IBM Stretch. The Atomic Energy Commission's Livermore Laboratories was interested in the 6600 and CDC focused on completing development and delivery to Livermore in early 1964.

<u>3.5 IBM Strikes Back with System 360-90</u>

The announcement of the 6600 in August 1963, set IBM in motion. Technical managers involved in the Stretch program began to urge senior IBM management to re-enter the supercomputer field as a competition-stopper. These events

led to a memorandum from Tom Watson making clear his sentiments:

"Last week, Control Data had a press conference during which they officially announced their 6600 system. I understand that in the laboratory developing this system there are only 34 people, including the janitor...I fail to understand why we have lost our industry leadership position by letting someone else offer the world's most powerful computer."(22)

IBM was engaged in the development of the 360. In an effort to compete head-on with the 6600, Watson set up a task force to build a computer to "blot out the 6600".(23) The ultra-high performance system was called the 360 Model 90. System specifications, price and performance were basically unknown in early 1964.

Unfortunately for CDC, debugging the 6600 took longer than originally expected, delaying delivery to Livermore until August of 1964. This delay came at a critical time, since on April 7,1964, IBM announced its new System 360 computer series.(24) This series was intended to make all other existing computers - including those being offered by IBM - obsolete. The 360 series also offered a wide range of computers with software compatibility. The 360 architecture relied on integrated circuits, which made it the first of the third-generation computers. During the early summer IBM announced its plans to introduce the System 360-90 "which

achieves new levels of performance and is capable of operating efficiently on programs written for other models of System/360". (25)

During 1964, internal documents from the IBM anti-trust hearings indicate confusion about the specifications and price of the System 360-90. (26) In a memorandum, IBM's chief legal officer argued that the System 360-90 development effort was needed to push speculative technologies, and that this justified working jointly with sophisticated users and delivery commitments prior to fully pricing the system. During this period IBM management was most concerned about legal issues and the System 360-90 (later assigned names Model 91 and 95) ran into technical difficulties. A technical champion for the System 360-90 never emerged and this more than any other factor led to its commercial failure. IBM withdrew the System 360-90 series in 1967.

During the late 1960's and 1970's, IBM supercomputer projects died. There were squabbles between divisions over technical scope and project funding. IBM cancelled its Josephson Junction program in 1983, ending their major supercomputer device research program. (27) In the early 1980's IBM formed a scientific computing division, but has not yet re-entered the supercomputer market.

3.6 CDC's Financial Crunch

In August 1964, CDC delivered the first 6600, and received orders for three additional machines. Each machine required a considerable "shakedown" period after initial installation. CDC engineers went to each installation to keep the machines working. These initial installation problems were expected for a machine like the 6600, but they led to concerns from future customers. In 1965, Norris focused on a sale of 6600's to the largest supercomputer user - the Atomic Energy Commission (AEC). CDC feared tough competition from IBM with its yet-to-be-developed System 360-90. After several weeks of negotiating CDC landed the contracts, with a stiff penalty payment if the machines were not delivered by October, 1965. Norris accepted the terms and took the gamble. Unfortunately, installation was delayed six months at a cost of $90,000 per month.(28)

At the same time, RCA reduced its computer prices. Norris felt obliged to cut prices on the 6600. Penalty payments and lower revenues in the second quarter of 1965 led to a sizable drop in earnings. Fearing financial losses, Continental Illinois Bank, which had extended considerable credit to CDC, recommended outside board members to temper Norris' management actions.(29) Norris gambled on the success of the 6600, and indeed orders began coming in steadily. IBM experienced difficulty with development of the 360-90, announcing it as a "limited project" and accepted no more new orders.

By the late 1960's, CDC dominated the supercomputer market. To ensure this lead, Cray began developing an even faster computer- the 7600. Introduced in 1969, the 7600 had a processing speed of 20 million instructions per second. This computer ensured CDC's lead in the supercomputer market in the early 1970's. Cray began the development of CDC's next supercomputer, the 8000 in the early 1970's.

3.7 Cray Research is Formed

In 1972, Cray founded Cray Research, Inc (CRI). Cray left Control Data because they began to de-emphasize construction and delivery of supercomputers. "It was a real opportunity for me to go off and do my own thing," Cray later said. "I'd certainly been doing it anyway".(30) Cray objected to borrowing, so he raised capital by floating stock. He hired 32 researchers from the CDC Chippewa Falls laboratory to began development of the Cray 1. Introduced in 1976, the Cray 1 was the world's fastest computer with a speed in excess of 20 MFLOPS. In 1975 John Rollwagen joined CRI, and today Rollwagen is president and chief executive officer. Cray relinquished his chairman post in 1981 to devote full time to the development of the Cray 2.(31) The initial delivery of a Cray 2 is expected in 1984.

3.8 CDC after Cray

With Cray's departure to form CRI, the development of the 8000, a follow-on to the 7600, was slowly phased out at the

CDC Chippewa Falls Laboratory. Additionally, the development of the Star 100 supercomputer at CDC's Arden Hills plant ran into delays from "heaping on" technical requirements for numerous parties. Delivery of the first Star computer to the AEC was delayed and penalty payments began to mount. Additionally, CDC received no follow-on orders for the Star computer. By the end of 1974, CDC terminated the STAR program, and took a massive write-off (estimated in excess of $30 million). This termination removed CDC from seriously competing in the commercial supercomputer business.

Neil Lincoln assumed technical leadership of the STAR-100 program just prior to the shipment of the first machine. After project termination, Lincoln reviewed the architecture of CDC's supercomputers to derive an architectural design for future generations of supercomputers. In 1975, Lincoln drew the essence of what has become the architectural design for the Cyber 200 series supercomputers. The following year, Lincoln and Lloyd Thorndyke (senior vice president for technology development) began development the Cyber 203 computer, with a funding cap of $10 million.(32) They successfully developed and sold the first Cyber 203's and 205's.

Cray was clearly CDC's supercomputer product champion, and in retrospect his departure in 1972 left a huge void at CDC. Norris believes in champions located down in the organization.

Without product champions he does not support large development efforts. His process of finding a champion has been described as putting N tom cats in a gunny sack, the one that walks out is the champion.(33) While Lincoln and Thorndyke emerged as supercomputer champions for the Cyber 200 series, they were never given full corporate funding support. Norris has not been fully committed to supercomputer efforts at CDC since the traumatic termination of the STAR 100, due in large part to the lack of a strong supercomputer champion.

3.9 Formation of ETA Systems

Lincoln and Thorndyke sensed a continued lack of corporate commitment to supercomputers at CDC and faced increasing difficulty in obtaining sufficient R&D funds to develop the next generation supercomputers. They approached Norris with the concept of spinning-off CDC's supercomputer business. In August 1983, Norris announced the formation of ETA Systems to continue the development of CDC's next generation supercomputer.(34) While retaining 40% ownership in ETA Systems, CDC provided the company with technologies, equipment, personnel, and invested capital. Norris stated, "There is a need to sponsor small, entrepreneurial companies engaged in the development of supercomputers. The supercomputer market requires a tightly focused organization with the flexibility to adapt rapidly to changes in technology, architecture, and design." Lloyd Thorndyke became the president and chief executive officer of ETA Systems, and

Neil Lincoln became vice president and chief architect. ETA's initial plans are to develop and deliver the GF 10, a supercomputer capable of 10 billion floating-point operations per second by the end of 1986.

3.10 Summary

The successful CDC 6600, 7600 and Cray 1 supercomputer developments were all conducted by small entrepreneurial teams. In the case of the CDC 6600 and 7600, Seymour Cray's development group never exceeded thirty people. In all three cases technological innovation was entrepreneurial (Type I). The success of CDC and CRI is due primarily to the championing of Norris and Cray.

Norris began managing CDC in the style of an executive champion. He protected the supercomputer efforts in times of high technical risk, and financial crisis. More recently, he has evolved into a "godfather" role. Recognizing the need to keep the entrepreneurial spirit within CDC, Norris has directed the start-up of numerous new ventures. Reflecting on the situation he faced at Remington Rand in the mid-1950's, Norris became increasingly concerned about the health of the CDC supercomputer business segment. As a result, he directed the start-up ETA Systems. The decision to build this new venture around a core of CDC supercomputer technical people must have been painful for Norris. His vision serves to motivate ETA to excel in the development of the GF 10.

Cray has quite simply been a product champion for the last 30 years. To this day, he is still in the laboratory developing the next generation of supercomputer.

While a fundamental reason for IBM's lack of success in the supercomputer industry has been the small size of the market, the failure of IBM to successfully enter the supercomputer market is in large part due to the lack of a product champion and the necessary executive champion support. Watson was not supportive of Stretch even though technical champions did arise in IBM. While Watson became supportive of the System 360-90, product champions for the System 360-90 never surfaced. I believe the major reason IBM is not in the supercomputer industry segment today is the absense of supercomputer champions within IBM.

CHAPTER 4

ROLE OF U.S. GOVERNMENT IN SUPERCOMPUTER : RESEARCH, TECHNOLOGY, DEVELOPMENT AND USE

This chapter examines the historical role of the U.S. government in the supercomputer industry. The first section addresses the government role in supercomputer research and techrology. Section two describes the government as a user of supercomputers. The third section examines the role of the U.S. government in the development of commercial supercomputers and analyzes the most successful government-industry relationships. The fourth section examines the government's role in supporting university supercomputer research and computer science education. The final section summarizes the U.S. supercomputer policy recommendations of the White House Office of Science and Technology Policy (OSTP).

4.1 Support of Research and Technology

The government has played a major role in the development of the computer industry, particularly in its infancy. This role will be examined through the four-generations of computers and will emphasize the government's efforts which impacted supercomputer evolution.

During the first generation, 1947-1959, many companies entered the business. At this time, vacuum tubes were used as the

active component in the implementation of computer logic. Second generation computers were characterized by transistorized. These computers began to appear in 1960. Most of today's supercomputers have their origins in second generation technology. Third-generation computers appeared from 1965 to the early 1970's and featured processors constructed with integrated circuit technology. The fourth generation of computers began in the late-1970's and currently represents the state-of-the-art. Large scale integrated circuits, solid state memory, and advanced architectures for parallel computation typify this fourth generation. The fifth generation is expected to emerge in the late 1980's. Fifth generation machines will match computer architecture to applications such as data base management and artificial intelligence.(35)

4.1.1 First Generation Technology

The Ballistic Research Laboratories of the Army Ordnance Corps. supported the development of the first electronic computer - ENIAC.(36) A second first-generation computer, the UNIVAC, was acquired by the National Bureau of the Census for the 1950 census. Numerous other first-generation industry/university computer projects were supported by government funding. These projects included EDVAC, IAS, RAYDAC, SEAC, SWAC, and WHIRLWIND.(37) The Navy's Communications Supplementary Activities, Washington (CSAW) and the Army Security Agency (ASA) issued numerous classified

contracts in the late 1940's and early 1950's for computers named DEMON, ATLAS I and ATLAS II.(38) These efforts provided a strong technical base for commercial computers developed at ERA, UNIVAC, and CDC.

4.1.2 Second Generation Technology

By the late-1950's, transistors could be used in large numbers to produce computers whose performance would outrun the largest first-generation computers. The government provided the venture capital to develop these second-generation transistorized computers. The National Security Agency (NSA) initiated contracts for computers named BOGART and SOLO in 1954 and 1955 respectively.(39) Delivered in 1958, SOLO was the first completely transistorized computer. These efforts influenced the design of the CDC 1604, and the CDC 6600. The Atomic Energy Commission's (AEC) Livermore and Los Alamos research laboratories initiated two separate contracts for the first supercomputers. Los Alamos contracted with IBM for the Stretch computer and Livermore contracted with Univac for the Livermore Atomic Research Computer (LARC). Both computers were developed by the early 1960's. An additional contract, initiated in 1958, resulted in a modified version of Stretch (HARVEST) for use by the NSA. While neither the Stretch or LARC became a commercial success, each provided significant technical benefits to the industry. The Stretch architecture included a "look ahead" feature which allowed the fetching of instructions while the central processor was working on the

current instruction. This feature is central to the pipeline architectures used in current vector computers.

4.1.3 Third and Fourth Generation Technology

The government played a lesser role in the development of third and fourth generation computers. The major supercomputer technology contributions of the government are in parallel architecture research. The Advanced Research Projects Agency (ARPA) supported numerous computer architecture research programs in the 1960's and 1970's. During the 1960's, ARPA funded Dr. Dan Slotnick's work to develop a highly parallel computer named ILLIAC IV.(40)(41) In the late 1970's, the National Aeronautics and Space Administration (NASA) contracted with Goodyear Aerospace to develop the Massively Parallel Processor (MPP) aimed at supercomputer capability for image processing applications.(42) The MPP employes 16,000 parallel processors and is an extreme extension of the ILLIAC IV parallel processing architecture. The MPP was delivered in 1983 and is currently undergoing initial tests. The Army Ballistic Research Laboratory (BRL) began the development of the Denelcor Hetrogeneous Element Processor (HEP) in 1976. The Denelcor HEP is the first multiple instruction, multiple data (MIMD) architecture supercomputer. The Denelcor effort led to the successful development and delivery of a HEP system to BRL in 1982.

In response to the challenge of the Japanese fifth generation program, the Defense Advanced Research Projects Agency (DARPA) began a new $50 million research program in 1983 to pursue fifth generation technology for military applications.(43) Smaller programs are underway at the National Science Foundation (NSF) and NASA. These programs focus on academic, government and industrial research in computer science and technology.

During the 1970's, industry pioneered advances in supercomputer technology. For example, the Cray 1/S and X/MP computers pioneered the use of Freon coolant, and high density packaging.(44) Due to these and other design features, clock period has been reduced to 20 nanoseconds (ns) for the Cyber 205 and 9.5 nanoseconds (ns) for the Cray X/MP. Both the Cray and Cyber computers embody very efficient vector processing architectures.

4.1.4 Electronic Device Technology

The government also played a central role in the development of the semiconductor industry. The Department of Defense (DOD), beginning in the 1950's, and NASA, beginning in the 1960's, provided the capital to develop new semiconductor devices. The majority of this research was for electronics used in "embedded" military and space systems such as the Apollo Guidance Computer and the Minuteman guidance system.(45) These embedded computers were generally much

slower than general purpose computers because of the constraints on size, environment, and power.(46) In addition the government became the major user of semiconductors in the 1950's and early 1960's, providing market stimulus to this emerging business. A significant computer device technology program was initiated by the NSA in 1957 - Project LIGHTNING. This program included research at Sperry Rand, RCA, IBM, Philco and GE to develop "thousand megacycle" electronics.(47) This $25 million program included development of magnetic film devices, tunnel diodes, and the forerunner of the Josephson junction.

Electronic device research is supported today by DOD and NASA for application to their unique missions. During the 1970's, government support of semiconductor research and development dropped to less than 10% of the 1950's-1960's levels.(48) As shown in Figure 2, the government portion of the electronic device market in the early 1980's has dropped to about 7%. In 1980 the DOD initiated the Very High Speed Integrated Circuit Program (VHSIC), to assure a technological lead in electronics for military systems. The primary focus of this program is, again, on special purpose integrated circuits for embedded processors. In 1983, twelve firms established the Microelectronics and Computer Technology Corporation (MCC) in 1983. The consortium allows these twelve computer firms to share in the development of microelectronic technology and provides some degree of protection for proprietary technology.

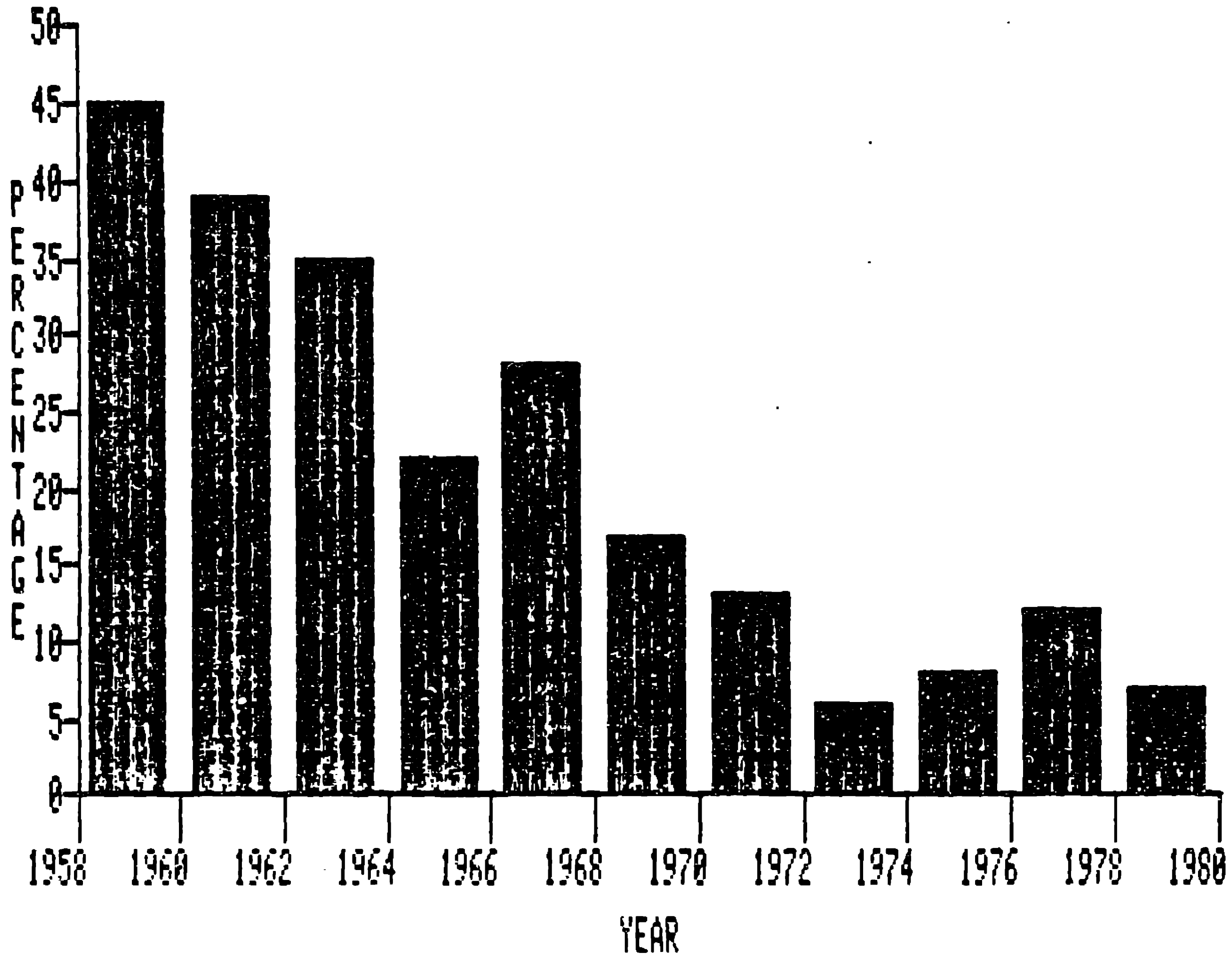


Figure 2. Federal semiconductor purchases as a percent of total sales.

Source: Magaziner, I. and Reich, R. Minding America's Business, (New York, N.Y.: Law & Burns, Inc. 1982); and "VHSIC Program Plan", (Washington, DC: DOD, OSDRE, 1980).

4.1.5 Summary of Government Role in Supercomputer Technology

Figure 3 summarizes the government role in the evolution of the computer industry. The government was responsible for creating the technology base for first and second generation computer tachnology, and early government support of the semiconductor industry provided the key components for third and fourth generation computers. In addition, government support of advanced computer architectures continues today as a precursor to future computer generations.

4.2 Government Use of Supercomputers

The government has been the first user of every U.S. supercomputer and has remained the primary user of supercomputers. The government acquired 29 machines by 1976, or about 40% of the total number built. By the end of 1983, 27 current generation supercomputers (79 produced) have been installed in government laboratories. The Department of Energy has fourteen, NSA has four, NASA has three, and NSF, National Oceanographic and Atmospheric Administration (NOAA), and DOD each have two. The government is the dominant user of current generation supercomputers with over 35% of the installed base.

TIME	DRIVING NEED	SPONSOR	COMPUTER	TECHNOLOGY	COMMERCIAL FOLLOW-ONS
MID 1940S	BALLISTIC TABLE CALCULATIONS	BRL	ENIAC	VACUUM TUBE	IBM 701 UNIVAC 1
LATE 1940S	CRYPTOLOGIC	CSAW	DEMON	MAGNETIC DRUM STORAGE	ERA 1101
MID 1950S	CRYPTOLOGIC	NSA	BOGART SOLO	TRANSISTOR	CDC 1401 S-1000
MID 1950S	DESIGN CAPABILITY FOR NUCLEAR DEV.	AEC	STRETCH LARC	TRANSISTOR	360-91 CDC 6600
LATE 1960S	ANTI-ICBM SYSTEM ANALYSIS	DARPA	ILLIAC	SEMI. MEMORY PARALLEL PROCESSING	STAR 100 CRAY-1
LATE 1970S	BALLISTIC RES.	BRL	HEP-I	PARALLEL PROCESSING	
EARLY 1980S	IMAGE PROCESSING	NASA	MPP	PARALLEL PROCESSING	

Figure 3. Historical role of the government in advancing computer technology.

Source: Snyder,S. "Influence of U.S. Cryptologic Organizations on the Digital Computer Industry", The Journal of Systems and Software 1, 1979, p. 87-1-2. and Credeur, K. "Comparisons of Some Large Scientific Computers 1964-1986", <u>NASA Technical Memorandum 81928</u>, (Hampton, VA: Langley Research Center, April 1981).

Estimates of current and future government use of supercomputers is given in Figure 4.(49) These estimates are from an Office of Science and Technology Working Group study, which included members from DOE, NASA, DOC, and DCI. The curve includes projections of expected use of "Class VI", the current generation, and "Class VII", the next generation. Class VII is typified by the Cray 2 and the GF 10. The first Class VII supercomputer should become available in 1984.

The government has developed systems and applications software to enhance the use of supercomputers. The DOE has developed very efficient operating systems (e.g. CTSS, LTSS) that are now available for other commercial users. A variety of applications software has been developed by government laboratories for reactor research, atmospheric science, weapons research, aerodynamics, oceanography and geophysics.(50)

4.3 Support of Supercomputer Development

This section examines 1) the relationship between the government and industry during development of the major supercomputers, and 2) the lessons learned from these relationships to establish the most effective government-industry relationship.

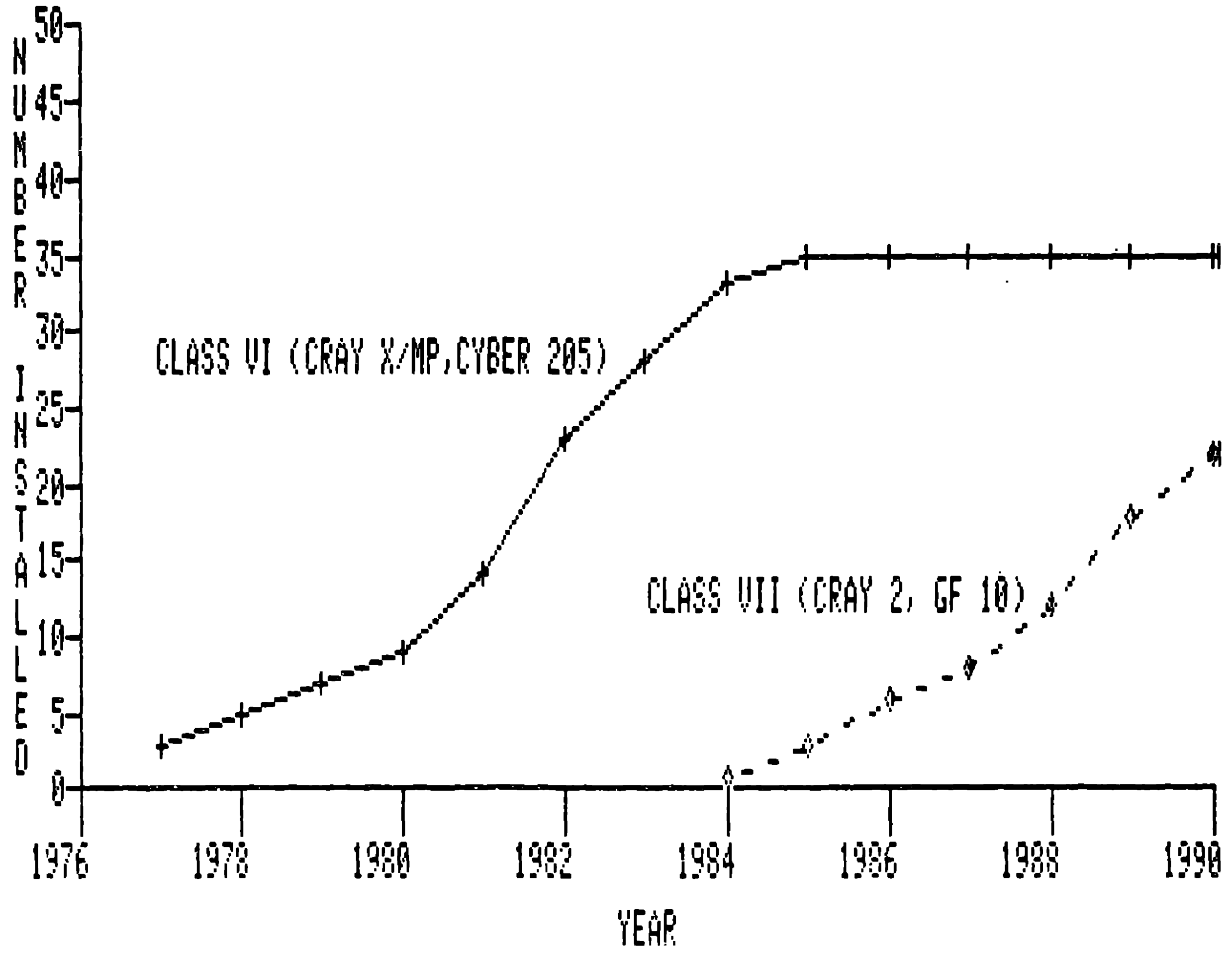


Figure 4. Government installed supercomputers.

Source: "Report to the Federal Coordinating Council on Sciene, Engineering, and Technology Supercomputer Fannel on Recommended Government Actions to Retain U.S. Leadership in Supercomputers, Draft, 1983.

This thesis discusses two important types of government-industry relationships : (1) friendly buyer, and (2) fly off. In the friendly buyer relationship, the government agrees to purchase supercomputers from industry prior to their development. In such a relationship, the government sets very loose "requirements" and provides considerable software development support after delivery. By contrast, in the fly off relationship, the government contracts to purchase supercomputers only after they pass detailed system specifications. Most fly off acquisitions involve two or more contractors in the early phase of development. A competition is held and the government selects one firm for further development phases, all other firms are eliminated from that round of development and acquisition.

4.3.1 Stretch and LARC

In the 1950's, the AEC funded the development of the Univac LARC, and the IBM Stretch - the first supercomputers. The huge size of the two machines hinted of their future commercial failure. Research and development costs on Stretch are estimated at $50 million; program losses are estimated at $20 million. These losses forced IBM to withdraw Stretch from the market.(51) Watson's analysis of the Stretch program isolated the major problem: setting unobtainable performance requirements. This problem has plagued government-funded supercomputer development programs. Additionally, when the government sets performance requirements or dictates technical

approach, development costs escalate. These performance requirements are often specific to the type of problems faced by the funding agency, this specificity results in computer architectures that are inefficient for general-purpose supercomputer users.(52)

These huge programs drained in-house technical talent at IBM and Univac for five years. This traumatic experience contributed to the fact neither IBM or Univac were successful in entering the supercomputer industry.

4.3.2 CDC 6600

Development of the CDC 6600 was radically different from development of Stretch and LARC. The CDC 6600 was developed with company funding for the general purpose user. The government had specified no performance requirements. Instead, the government was the first user and became a friendly buyer. CDC believed in the "utility" concept. This concept implies that supercomputers could be used as a central utility to meet a firm's general purpose computing needs. By contrast to the LARC and STRETCH, the 6600 was developed by a small staff in the remote Control Data Chippewa Falls facility.(53) In 1965, to ensure early commercial success, Norris encouraged the AEC to use the CDC 6600. Although the AEC involvement resulted in penalty payments for late delivery, it provided for the development of software and ensured user acceptance. Penalty payments had a significant

financial impact on CDC, but the 6600 became the first commercial supercomputer success with 59 computers delivered.

4.3.3 ILLIAC IV

In 1966, DARPA contracted with Burroughs to design and construct the ILLIAC IV. NASA joined in the funding of ILLIAC IV in 1970, and ultimately became the user of the system. Technical features of this supercomputer included: parallel architecture (64 elements), array memory, and very high transfer rates between memory and computational units. Initially planned for an array four times its final size and computational speeds up to 1/2 billion operations per second, cost escalations and schedule delays resulted in a smaller version. The cost-plus-fixed-fee contract estimate was raised from $8 million to $40 million.(54) Maintenance and operations costs for the computer were estimated at $2 million per year from the date of initial operations, 1972, to its termination in 1981. The ILLIAC IV demonstrated parallel processing capability and helped develop computational fluid dynamics and computational chemistry. Only one ILLIAC IV was produced. The computer was a commercial failure because of its high cost, and lack of applications software.

4.3.4 STAR 100

The AEC's Livermore Laboratory contracted with CDC for the development and delivery of the STAR 100 in the late 1960's. The AEC considered the ILLIAC IV and the Texas Instruments

Advanced Scientific Computer (ASC) as contenders with the STAR 100. The AEC was prepared to cancel the STAR contract and acquire ILLIAC IV or ASC computers if they came closer to the AEC's performance requirements. The government-industry relationship represented by the STAR contract can be described as a flyoff. The STAR 100 introduced vector processing capability which eliminated discontinuities due to varying length vectors. Although, the ILLIAC IV was designed for vector calculations, however, it exhibited sharp discontinuities in computation speeds for operations on vectors of varying lengths. Additionally, the STAR 100's unique architecture to solved coupled partial differential equations. These features, which were strongly dictated by the AEC, contributed to escalated development costs. Developmental problems led to late delivery and penalty payments. The STAR 100 computer was developed under a fixed-price contract from Livermore for $24 million, but CDC adsorbed several million in completing the STAR 100 program. The fixed price contract with penalty payments for late delivery applied significant pressure to CDC at a time when they had lost key technical talent and during a period of economic downturn in the computer industry.(55) Only four STAR computers were developed. A key reason for the STAR's commercial failure was, again, the development of a unique-architecture machine which did not support a wider community of users. CDC learned from the Star program, and later spent several years developing a more general purpose architecture

for its next series of supercomputers (Cyber 200 series).

4.3.5 Cray 1 and Cyber 203/205

Like the CDC 6600, the Cray 1 computer was developed using only company funds. This development effort, from 1972 to 1976, cost less than $5 million. The Cray 1 was designed as a general purpose supercomputer and became a commercial success. By 1980, 17 computers were delivered. Over 49 of its derivative models were delivered by the end of 1983. CDC's successful Cyber 203/205 supercomputer series were also developed with only corporate funding. The government was a significant user, and a friendly buyer, providing substantial software development support, for both the Cray 1 and the Cyber 205.

4.3.6 NASA Numerical Aerodynamic Simulation Program

In 1975, NASA began studying the feasibility of developing a supercomputer to use in numerical aerodynamic simulation. Initial designs for the Numerical Aerodynamic Simulation (NAS) capability were completed in 1981 and included capabilities for a one billion floatinq point operations per second with 200 million words of memory were completed in 1981. These designs were developed under competitive phase B contracts which, again, represented a fly off relationship with contractors.

In mid-1982, NASA significantly changed its development

approach for NAS and terminated the phase B efforts. Under the new NAS approach, NASA will acquire a prototype supercomputer in 1984. This computer is expected to provide a peak speed of 2000 megaflops, with 64 megaword of main memory. A second supercomputer, procured in 1987, would be capable of a peak speed of 10000 megaflop, with 256 megaword of memory.(56) Delivery dates for computers will be paced by the internal schedules for commercial supercomputer development, without penalty payments for late delivery. The NAS will evolve to a multi-vendor facility so that parallel commercial efforts can proceed.

The policy adopted by NASA for the acquisition of NAS capability is based on the historical lessons. The policy returns to the friendly buyer relationship of the 1960's and away from the flyoff relationship of the 1970's.

4.3.7 Lessons Learned

Supercomputers developed with government support usually pushed well beyond the state-of-the-art, and exhibited unique architecture features. The government generally established system requirements, and while the final performance capabilities were short of initial requirements, the efforts resulted in advances in supercomputer architecture and technology. These major supercomputer development efforts were usually flyoff competitions between two vendors. Contractual agreements included hard delivery dates with late

penalty payments. These payments created significant financial hardships for manufacturers. Development generally required four to five years with costs of$25 to $50 million. STRETCH, LARC, and STAR were government supported supercomputer developments which utilized Type II and Type III technology innovation. The magnitude of these efforts, coupled with poor market success, soured senior management at IBM, UNIVAC, and CDC on supercomputer development programs. The British government had a similar experience in the development of the ATLAS supercomputer in the early 1960's. This large Type III technology program also resulted in a commercial failure.(57)

Most commercially successful supercomputers were developed by industry without direct government support for hardware or system development. Designs supported a wider range of supercomputer users. The government was usually an early user, and a friendly buyer. The government also participated in the development of systems and applications software. Development usually required three to five years and costs were moderate (less than $15 million). Although current estimates of industry supercomputer development costs are increasing to above $30 million. The CDC 6600, CDC7600, Cray 1, Cray X/MP, and Cyber 205 supercomputers are all in this class.

4.4 Support of American Universities

This section analyzes the historical relationship among American universities, the government and the supercomputer industry. The role of American universities includes supercomputer research and use and computer science education.

4.4.1 Supercomputer Research

In the 1940's and early 1950's, universities played a key role in the development of first-generation computers. EDVAC, IAS, and WHIRLWIND were developed with industry - university - government support.(58) However, the role of universities in supercomputer development diminished in the late 1950's.

During the 1960's the only university supercomputer effort was that of the University of Illinois.(59) The university worked with DARPA, NASA, and Burroughs to develop the ILLIAC IV. During the late 1960's, DARPA initiated computer science research programs involving several American universities which led to the formation of ARPANET. DARPA has supported university research in computer science has continued since that time. The University of Illinois and Purdue University developed software in the late 1970's for NASA's MPP.(60)

In the early 1980's, the government began to rekindle the government - industry - university relationship. The focus of this renewed relationship is DARPA's new strategic computing program.(61) The program is directed toward the symbolic, or

logical, processing technologies of fifth generation computers and is intended to strengthen the ties between U.S. universities and computer companies. NASA and NSF have initiated smaller computer science programs also aimed at strengthening ties with American universities.

4.4.2 Use of Supercomputers and Computer Science Education

In the 1960's, American universities became involved in the use of supercomputers for science and engineering research. However, costs of owning and operating supercomputers, and the lack of government funding to support supercomputer centers has led to "the supercomputer famine in American universities".(62) Only three of the 79 supercomputers now installed are in American universities. To compensate for the lack of supercomputers, university researchers are devising methods to gain access to remote supercomputer sites. A 1982 report on the use of supercomputers in science and engineering, recommended ways to overcome these problems: 1) increase access for the scientific and engineering research community through high bandwidth networks, 2) increase research in computational mathematics, software, and algorithms and 3) increase training of personnel in scientific and engineering use of supercomputers.(63)

Although the per capita level of scientists and engineers in the U.S. is currently second to only the U.S.S.R., this level has been decreasing since the mid-1960's, with a slight upturn

occuring in the late 1970's. More alarming is the number of computer science graduates in Japan compared to the number in the U.S. Computer science is the most popular college field in Japan, while the U.S. graduated only 225 Ph. Ds in computer science and computer engineering in 1982.

4.5 Government/OSTP Supercomputer Policy Statements

In January 1983, a Federal Coordinating Committee on Science, Engineering, and Technology (FCCSET) Panel on Supercomputers was formed within the White House Office of Science and Technology Policy. Composed of members from DOE, DCI, NASA, NSF, DOD and DOC, the FCCSET panel was charged with dealing with the following issues:

1. What should the Government do to ensure that the U.S. retain its lead in supercomputers?

2. What should the Government do to make supercomputers available to more researchers, particularly in universities?

A preliminary set of recommendations, which I will assess in Chapter 9, include(70)(71):

1. The government should set as a goal the development of supercomputers with at least 200 times the capability of Class VI machines (Cray 1, Cyber 205) in this decade. The

government should provide an incentive by guaranteeing to buy at least three of each supercomputer system that meets the goal.

2. The government should accelerate its purchases of supercomputers in order to ensure the health of the industry. Profits from sales of new supercomputers will contribute to the development of the next class. The Government should continue to be a friendly user, particularly for prototype machines that represent important steps toward achieving the 200x goal.

3. It currently appears that the only feasible technical approach to meeting the 200x goal in the near future is to utilize parallel processors. Government laboratories, and universities should purchase "experimental" machines with parallel architectures for experimentation. These "experimental" machines should be put on a network to promote development of new languages, algorithms, software tools, and applications systems.

4. Government support of long range research and development for scientific supercomputing should be increased. This research is required to develop the new approaches necessary for the substantial increases in computing power required in the next decade. Since most of this research would be supported in universities, an important product

of this research will be the training of supercomputer architects and developers of the future.

5. The development of high performance components and peripherals required for future generations of supercomputers is a well recognized problem. The group recommends some form of government help in advancing components and peripherals, however, the exact mechanism was not determined.

6. The Government should take action to greatly increase access to supercomputers at sites such as the Magnetic Fusion Network, the National Center for Atmospheric Research, and NASA's Ames Research Center. A longer term goal is the development of a coordinated national supercomputer network. Improved access will not only bring this modern scientific tool to universities and improve their competitive position in research, but it will also help train new scientists and engineers in the use of supercomputers.

7. Research and development tax incentives for the industry should be explored.

8. U.S. export control of supercomputers has a significant effect on U.S. supercomputer vendors since Western Europe represents 40% of the market. Acceleration of the export

licensing process should be explored so that U.S. vendors were not unduly penalized in competing for foreign customers.

9. A permanent interagency group should be established to coordinate individual agency supercomputer activities as necessary to implement the above recommendations. This group should function at both the policy and technical level.

CHAPTER 5

SUPERCOMPUTER INDUSTRY ANALYSIS : OVERVIEW

This chapter provides an overview of the supercomputer industry. The primary focus of this chapter is factors outside the direct control of competing firms. These factors determine the attractiveness of the industry for individual competitors. Industry attractiveness is presented for firms presently in this industry segment, for new entrants, and for Japanese firms. The key factors which determine the attractiveness of the supercomputer industry are market size and growth rate, technology and government support. Competition and financial factors are also important, but they currently impact industry attractiveness to a lesser degree.

5.1 Market Factors

Market size and growth rate are of primary interest to supercomputer competitors. In addition, technical and geographic market segmentation are discussed. Finally, an analysis of trends in supercomputer use is provided to validate supercomputer market growth projections

5.1.1 Size/Growth

As indicated in Figure 1, the supercomputer market is small in comparison to other segments of the overall computer market. Cost and availability of applications software has limited supercomputer use to large research laboratories and

government agencies. Two companies dominate the supercomputer market: 1) Control Data and 2) Cray Research, Inc.(CRI). Hitachi and Fujitsu have both entered the supercomputer market with delivery of a Hitachi S810-20 supercomputer to the University of Tokyo in November, 1983, and with delivery of a Fujitsu VP-100 supercomputer to Nagoya University's Plasma Research Institute in December, 1983.(66) Limited benchmark performance data is now becoming available. Denelcor, Inc., a small company based in Denver, has been marketing a supercomputer called the Heterogeneous Element Processor (HEP). The HEP is based on parallel processing architecture and has not yet obtained substantial market support. Low market penetration is due to limited software and lower general-purpose performance.

The size and growth rate of the supercomputer market is best illustrated by examining total revenues over the past four years. Figure 5 provides estimated supercomputer sales/leases data for 1980 through 1984. Installed supercomputer value must be adjusted for percentage of rentals, reinstallments, and service to arrive at annual revenues. Estimated supercomputer revenue by year is given in Figure 6 for Cray Research, Control Data and Denelcor. These data indicate a 1983 market of $259 million and a compounded four year growth rate of 28%. I project this growth rate to continue for the next five years.

Type	Year	Ave. Cost	First Date	Number	Sales/Lease	Value
Cray 1	1980	8,500	4/76	4	3/1	34,000
	1981	8,500	4/76	2	2/0	17,000
	1982	8,500	4/76	1	1/0	8,500
Cray 1/S	1980	8,600	11/80	3	3/0	25,800
	1981	8,600	11/80	13	6/7	111,800
	1982	8,600	11/80	16	10/6	137,600
	1983	8,000	11/80	6	4/2	48,000
Cray 1/M	1983	5,500	10/83	3	2/1	16,500
	1984	5,500	10/83	10E		
Cray X/MP	1983	12,000	10/83	7	4/3	84,000
	1984	12,000	10/83	12E		
Cyber 203	1980	9,500	11/80	3	3/0	28,500
Cyber 205	1981	10,500	01/81	2	1/1	21,000
	1982	10,500	01/81	9	4/5	94,500
	1983	8,700	01/81	10	5/5	87,000
	1984	8,700	01/81	8E		
Denelcor	1982	5,500	12/82	1	1/0	5,500
HEP-I	1983	2,500	12/82	2	1/1	5,000
	1984	2,500	12/82	4E		

Figure 5. Estimated supercomputer sales/rentals 1980-1983 excluding reinstallments.

Source: Pocessor Data Book, (Framingham, MA: International Data Corporation, 1980,1981,1982,1983)

Company	1980	1981	1982	1983
Control Data	31 (33%)	35 (26%)	70 (33%)	80 (30%)
Cray Research	61 (67%)	102 (74%)	141 (67%)	175 (68%)
Denelcor	-	-	1	4 (2%)
Total	92	137	212	259

Figure 6. Estimated total supercomputer market and market share (%) 1980-1983.

Source: "Annual Report", (Minneapolis, MN: Cray Research, Inc.,1980,1981,1982,1983); "Annual Report", (Minneapolis, MN: Control Data Corporation, 1980,1981, 1982, 1983); and "Annual Report", (Aurora, CO: Denelcor, Inc.,1981,1982,1983).

The supercomputer market can be segmented based on two important variables - computational power and IBM software compatibility.(67) In September 1982, CRI introduced the Cray 1/M a low-price supercomputer ($4 million) in addition to the high-performance Cray X/MP.(68) In January 1983, CDC dropped prices on the Cyber 205.(69) These actions divided the supercomputer market into high end users, looking maximum computational performance (e.g. Cray X/MP and Cyber 205), and low end users, looking for supercomputer power at the lowest possible price (e.g. Cray 1/M). Cray Research believes that this strategy will increase the size of the supercomputer market, and that once a firm becomes a low end user, they become candidates for future high end sales.(70) Fujitsu and Hitachi supercomputers are IBM software compatible and are

attractive to current IBM mainframe computer accounts. These introductions created an IBM compatible software supercomputer market which will be differentiated from the current CDC and Cray supercomputer market segments.

The supercomputer industry has become a global industry. Figure 7 presents a global distribution of supercomputer installations. Cray Research and CDC have established wholly-owned foreign subsidiaries. Similarly, Fujitsu and Hitachi have started marketing their supercomputers through joint ventures.(71) Foreign installations currently account for 30% to 40% of the total supercomputer market and will account for about 50% of the total supercomputer market by 1986, divided roughly into 25% Japan, 20% Europe and 5% Asia.(72) The rapid growth of the domestic Japanese supercomputer market is closely tied to the decisions of Fujitsu, Hitachi, and NEC to enter the supercomputer industry. The expansion of foreign use of supercomputers is of growing concern for US industry who as a result face stiffer future economic competition.

5.1.2 Trends in Supercomputer Use

About 50% of the current supercomputer users plan for future additions or upgrades in computational capability.(73) Most users intend to maintain hardware and software from the same vendor, due to the switching costs. Similarly, those users with IBM compatible software should develop strong ties with IBM compatible software supercomputer vendors.

Type	Total Number Installed	US Installation	Foreign Installations
CDC 6600	54	40	14 (26%)
CDC 7600	28	22	6 (21%)
Cray 1,1/S,1/M	59	35	15 (41%)
Cray X/MP	7	3	2 (40%)
Cyber 205	21	13	8 (38%)
Denelcor HEP-I	3	2	1 (33%)

Figure 7 Ratio of US to foreign installations for several generations of supercomputers.

Source: Processor Data Book, (Framingham, MA: International Data Corporation, 1980, 1981, 1982, 1983).

While supercomputers can stand alone, most supercomputers are installed with front-end large-scale processors. The front-end processors include IBM (4342,3033), CDC (Cyber 76,7600, 730), Amdahl (V6,V7B) and other vendors equipment. The front-end processor is used to efficiently feed jobs to the supercomputer, control batch jobs, read/write operations, and support unit record equipment. In addition, many supercomputer installations include high speed network hardware (eg. hyperchanel, or loosely coupled network). While the cost of a supercomputer is significant, the related cost of front-end processors, network hardware, and memory systems can often dominate the overall system cost. A major strategy of CDC after the spin-off of ETA Systems is to focus on the

sales of total supercomputer systems, while purchasing the supercomputer processor from ETA Systems.(74)

In recent surveys, users were asked what new applications they envisioned for supercomputers.(75)(76) Responses varied widely, between scientific, commercial service bureau or university users. Scientific users see substantial increase in simulation applications particularly plasma physics, structural design, physics, astronomy, chemistry, computer science, atmospheric modeling, and numerous other engineering disciplines. Exxon, Atlantic Richfield Company (ARCO), Texaco, and SOHIO are using supercomputers for petroleum research. With increasing supercomputer capability other commercial applications will emerge. As shown in Figure 8, NASA's Numerical Aerodynamic Simulation (NAS) program is built around the need for increased supercomputer power to solve aeronautical design problems of increasing complexity, culminating in the ability to perform Navier-Stokes modeling of a complete aircraft.(77) The impact of numerical aerodynamic simulation capability on the airplane industry will be significant in the late 1980's as the necessary supercomputer power becomes available. The NAS program strengthens the argument that as supercomputer power increases, the market will also increase with the addition of new applications. These trends in supercomputer use support the projected supercomputer industry growth rate of 28% per year.

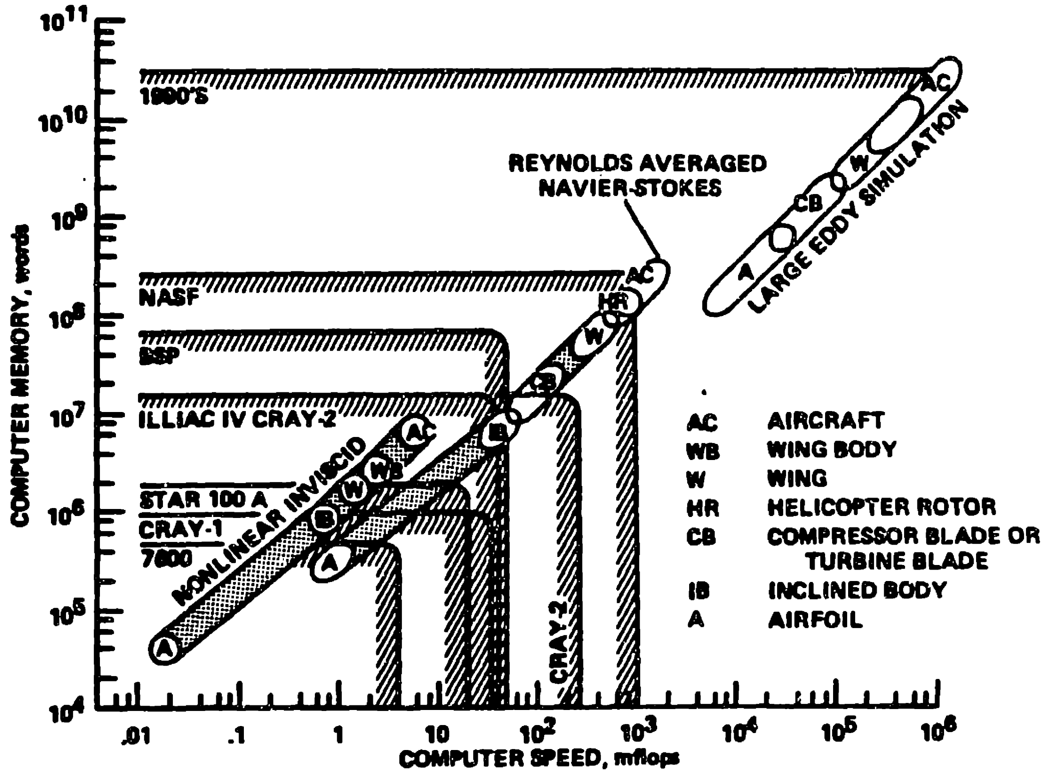


Figure 8. Computer memory/speed requirements for computational aerodynamics.

Source: Chapman, D. "Computational Aerodynamics Development and Outlook", AIAA Paper 79-129, (New York, N.Y.:American Institute of Aeronautics and Astronautics, January 1979).

5.2 Technology Factors

5.2.1 Supercomputer Research and Development

Supercomputer R&D is the single most important factor in the success or failure of supercomputer competitors. Figure 9 depicts the level of research and development (R&D) in the computer industry. From this figure, it can be noted that the level of R&D at CRI and within the supercomputer segment of CDC, greatly exceeds the computer industry mean. In fact CRI is within the top ten U.S. firms in R&D as a percent of revenues. The high cost of R&D detracts from the attractiveness of the supercomputer industry.

Technology strategies of firms can be grouped into six classes - offensive, defensive, imitative, dependent, traditional, and opportunistic.(78) Offensive and defensive technology strategies are the most relevant for the supercomputer industry. Offensive strategy is based on substantial investment in R&D to develop new products and to be the first to market these products. Defensive strategy is based on R&D investment to be able to respond rapidly to new products developed by competitors and is generally associated with being second into a new market.

The technical challenge of developing faster supercomputers drives research teams to push the state-of-the-art. When this technical development effort is coupled with key customers with an insatiable appetite for faster machines, the magnitude

of supercomputer research and development is intensified. Today it is common for supercomputer firms to be developing the next generation supercomputer before marketing the latest generation computer. This offensive technology strategy leads to thr introduction of major new products every three or four years. New supercomputers must offer a significant advance in performance (factor of 5 or 10) to be successfully marketed. Hitting a market window one year after your competitor can be disastrous to sales. A defensive technology strategy is less effective in this industry due to the long development period and continued introduction of rapidly advancing products.

The race to develop the next generation supercomputer is currently on. To a large extent this R&D push is due to the efforts of Japanese companies to enter this market. Figure 10, presents a comparison of published supercomputer performance data for today's two fastest supercomputers and five new supercomputer introductions planned in the next four years. Limited performance data on the Fujitsu VP 100 and Hitachi S-810/20 are now available. Preliminary benchmark test data for 14 Livermore kernals is given in Figure 11. These kernals do not reflect a realistic mixture of vector/scalar instructions, however, based on these test data it is estimated that the Fujitsu VP 200 and Hitachi S-810/20 are credible supercomputers with performance in the range of the Cray X/MP and Cyber 205. In addition, it is estimated that the Fujitsu VP 200 is faster than the Hitachi S-810/20.

Company	R&D Expenses 1981 % of sales	1981 $ million	1982 % of sales
Amdahl	17.0	75	
Burroughs	5.3	177	6.3
Control Data	6.5	294	6.7
(Supercomputer Segment)	13.0 est.		14.0 est.
Cray Research	16.0	16	20.0
Data General	10.1	74	
Digital Equipment	7.9	251	9.5
Fujitsu	8.5	234	8.9
Honeywell	6.9	369	8.6
IBM	5.5	2451	8.0
Group Mean	9.3		9.7

Figure 9. R&D investment by computer industry firms.

Source: "Office Equipment Systems and Services", <u>Industry Surveys</u>, (New York, NY: Standard and Poor's, October 21, 1982); "Annual Report", (Tokyo, Japan: Fujitsu, 1981,1982).

Computer	Ship Date	Clock Speed (NS)	Vector Rate (MFLOPS)	Main Memory Size (MW)
Cyber 205	02/80	20	400	8
Cray X/MP	10/83	9.5	420	4
Fujitsu VP 200	4Q/83	15	500	32
Hitachi S-810/20	4Q/83	15	630	32
Cray 2	4Q/84	4	2000	64
NEC SX-2	1Q/85	6	1300	32
ETA GF 10	4Q/86	5	10000	--

Figure 10. Projected performance of the next generation of supercomputers.

Source: Bailey, R. (Moeffet Field, CA: NASA Ames Research Center, September 1983).

Kernel	Computational Speed (MFLOPS) Cray-1 CVIVIC-83	Cray X/MP CFT-82	Cyber 205	Fujitsu VP 100	Hitachi S-810/20
1	76.9	150.7	79.1	187.0	228.0
2	57.1	75.4	88.0	91.0	239.4
3	58.8	94.4	88.0	168.0	211.9
4	37.8	4.3	12.2	59.0	59.2
5	7.8	8.7	5.6	8.0	5.4
6	7.6	8.0	6.5	8.0	4.6
7	83.5	149.3	51.0	190.0	232.7
8	51.4	21.0	15.7	88.0	48.8
9	89.5	89.5	47.3	131.0	207.6
10	30.0	58.9	23.5	28.0	49.0
11	2.9	3.1	7.6	4.0	9.8
12	23.3	67.7	86.2	70.0	93.0
13	3.5	4.8	2.0	6.0	4.2
14	5.0	6.9	4.3	7.0	8.5
Average	38.2	53.0	36.9	74.6*	100.0

Figure 11. Comparison of Japanese supercomputer performance on Livermore kernels.

* Estimated performance of Fujitsu VP 200 is 132 MFLOPS.

Source: Fuss, D. and Leighton, J. "Foreign Trip Report", (Livermore, CA: Lawrence Livermore National Laboratory, November 14-22, 1983) and Tsuchimoto, Takamitsu (Tokyo, Japan: Fujitsu Ltd., January 26,1984).

5.2.2 Technology Maturity/Volatility

Supercomputer design requires advances in architecture, software and electronic components, as well as power supply and thermal control technology. The technology base and breadth of design capability at CRI and CDC/ETA Systems provide these firms with distinct advantages over new entrants to the supercomputer industry. These strengths are balanced by the threat of new technologies, which provide opportunities for new competitors. The Japanese supercomputer technology

program sponsored by the Ministry of International Trade and Industry (MITI) has focused on the development of electronic components including Josephson junction devices, and gallium arsenide devices.(79)

A primary feature of the Cray and ETA Systems designs is the use of pipeline architecture (the ETA GF 10 will have 8 parallel processors). New highly parallel architecture designs being studied in Japan under the MITI supercomputer project and at Denelcor and Goodyear Aerospace offer the potential for substantial advances in computational speed. Highly parallel architectures present a risk to Cray Research and ETA Systems.

5.2.3 Differentiation

Cray supercomputers are differentiated from CDC supercomputers in two ways - architecture and software. While both manufacturers have attempted to build general purpose computers, each is better suited for specific classes of computational problems. The Cray computer has the highest performance for scalar computations and problems involving small vectors, while the CDC architecture is well suited for problems involving long vectors.(80) The operating software for each machine is unique. In addition the key applications programs for supercomputers are written in FORTRAN with special attention to vectorizing of code. Applications programs written for Cray machines require substantial rework

to operate efficiently on CDC machines and vice versa. Differentiation of Cray and CDC supercomputers is high, due in large part to the high cost of switching software.

NASA is developing a dual vendor supercomputer capability under its Numerical Aerodynamic Simulator (NAS) program. When implemented in 1985, the NAS capability will allow a researcher to use the latest supercomputers with a common software interface. At the same time CDC, Cray, and Denelcor are developing UNIX-based operating systems for their next generation supercomputers. This should reduce software switching costs and differentiation. The Japanese supercomputer development efforts at Hitachi and Fujitsu are focused on the development of user-friendly compilers and IBM compatiblity.(81) These strategic moves should also reduce the differentiation of supercomputers in the future.

5.3 Government/Social-Political Factors

5.3.1 Government Support

As explained in detail in previous sections, the U.S. government has historically supported the development of supercomputers and is the largest single user. In the past ten years the level of government support to develop supercomputers has decreased. However, government use of supercomputers has increased. The most recent U.S. government policies support supercomputer development through guarantees to buy a specific number (e.g. three) of successfully

developed machines.(82) Increased government support of supercomputer architecture research, and support of component development is projected over the next three to four years. This should aid U.S. firms.

At the same time MITI initiated the National Superspeed Computer Project, in January 1982. This project is aimed at developing a 10 billion floating-point operations per second (BFLOPS) computer by 1989.(83) This project has clearly helped the development of Hitachi's S-810/20 and Fujitsu's VP 200 supercomputers.

Since the U.S. government represents over 35% of the supercomputer market, they exert significant pressure on the suppliers of supercomputers. The DOD has a strong "buy American" policy. Other civilian government agencies have more discretion over foreign purchases. However, it is unlikely that they will purchase foreign supercomputers.(84) This will clearly strengthen the attractiveness of the industry for U.S. firms and reduce the attractiveness for foreign firms.

<u>5.3.2 National Security</u>

Because of the highly classified nature of the National Security Agency (NSA), it is impossible to be very specific about their requirements and involvement in the supercomputer industry. They have historically played a key role in the advancement of supercomputer technology and their

effectiveness depends of supercomputers to perform sophisticated tasks associated with communications security and foreign intelligence.(85) The overall performance of NSA will clearly increase as the state-of-the-art in computing technology increases. The agency is currently working with private industry to enhance supercomputer performance.(86) Our national interest require that we maintain a dependable domestic supercomputer capability. The presidents chief science advisor stated " We can't permit foreign manufactures, whose development cost may be heavily subsidized by their governments, to jeopardize that capability".(87) This overriding concern will ensure an implicit government policy to maintain the health of the U.S. Supercomputer industry. This policy will clearly enhance the attractiveness of the industry for American firms.

5.4 Competitive Factors

5.4.1 Type of Competitors/Intensity/Diversity

The industry has been dominated for the past twenty years by Cray Research, Inc. and Control Data Corporation, as shown in Figure 1. Recent entrants to the supercomputer market include Denelcor, Inc., Fujitsu, and Hitachi. In addition, Nippon Electric Company (NEC) announced plans to enter the market in 1985.

The intensity of competition between CDC and Cray has been rather high over the past few years. In one article, their

feuding was compared to the Hatfields and the McCoys.(88) In general the rivalry has been healthy, since many of the Cray employees once worked for Control Data. The timing of announcements of new computers and price cuts have been the primary signs of a tough competition. Sales executives from both companies talk up the performance of their computers and talked down the performance of their competitors. Most supercomputer users have a detailed knowledge of system performance, often with bench mark performance data on both machines. These users are not likely to buy a $10 million computer based on sales hype.

Control Data and Cray Research are diverse companies. Cray competes in only the supercomputer business. CDC competes in several business segments including financial and computer services, computer systems, and peripheral products. The spin off of CDC's supercomputer business to form ETA Systems has removed much of the diversity between Cray Research and CDC/ETA Systems.

Hitachi and Fujitsu are very large firms with efforts in consumer electronics, computer systems, power systems, communications, and industrial machinery. Both firms are in the mainframe computer market. The entrance of these Japanese firms represents a significant change in the industry structure. This high level of diversity between U.S. firms and Japanese firms is likely to lead to differing strategies.

5.4.2 Degree of Integration

Cray Research, CDC/ETA Systems and Denelcor purchase the majority of their components. Fujitsu and Hitachi supply CRI and CDC/ETA Systems with semiconductor memory technology. It is believed that Fujitsu and Hitachi are holding back one generation of technology for sale to the U.S. and using current generation memory technology for their own supercomputers.(89) The dependence on outside suppliers for key electronic components is being overcome to some degree through construction of a semiconductor manufacturing facility at Cray Research. Cray Research has been investing in subsidiary facilities for the manufacture of gallium arsenide components. The cost of maintaining a complete capability to manufacture electronic components is expensive for a small company. It is projected that Denelcor and ETA Systems will not attempt vertical integration. At the same time, Hitachi, Fujitsu and NEC have semiconductor businesses. Their MITI sponsored research programs are providing these firms with inhouse availability of key supercomputer components. The importance of vertical integration is reduced somewhat by the rather low volume of the supercomputer market at some 20 to 25 computers per year.

5.4.3 Barriers to Entry/Exit

Both CRI and CDC's new venture ETA Systems have the broad technical experience, equipment, and personnel to develop the next generation of supercomputers. The existing customer base

is loyal, in large part due to the high cost of switching. This broad technical knowhow and strong customer loyalty provides a formidable barrier for new entrants to the supercomputer industry. Furthermore, the cost of new supercomputer development is high ($10 million to $40 million). The MITI supercomputer program is clearly aimed at minimizing this barrier for Japanese firms.

Considerable exit barriers exist in the supercomputer industry. For example, it is difficult to exit from the supercomputer business, because of the importance of supercomputers to national security. In addition this business is one of high emotional barriers to exit due to the pride of U.S. researchers in maintaining a lead over the Japanese in this high-technology business. According to Porter, an industry with high entry and exit barriers is likely to exhibit high, risky profits.(90)

5.5 Financial Factors

The attractiveness of an industry is always a function of the potential profitability. Figure 12, presents a comparison of the profitability of the leading computer firms. Cray Research is the industry leader in profitability as measured in terms of return on assets, return on equity and sales margin. This high profitability indicates the attractiveness of the supercomputer industry.

Firm	Year	Return on Total Assets (%)	Return on Shareholders' Equity (%)	Sales Margin (%)
Amdahl	1980	4	6	14
	1981	6	11	17
Burroughs	1980	2	4	15
	1981	4	6	19
Control Data	1980	6	11	15
	1981	6	11	15
Cray Research	1980	14	20	45
	1981	15	21	45
Data General	1980	10	19	20
	1981	6	12	15
Digital Equipment	1980	11	17	19
	1981	10	15	20
Fujitsu	1980	-	-	17
	1981	4	11	18
Hitachi	1980	12	13	12
	1981	11	13	13
Honeywell	1980	8	16	14
	1981	6	13	13
IBM	1980	14	23	31
	1981	12	19	31
Mean	1980	8.1	14.3	22.4
	1981	7.2	13.3	20.6

Figure 12 Profitability measures of computer industry firms.

Source: "Office Equipment Systems and Services", Industry Surveys, (New York, NY: Standard and Poor's, October 21, 1982); "Annual Report", (Tokyo, Japan: Hitachi, 1980,1981); and "Annual Report", (Tokyo, Japan: Fujitsu, 1981,1982).

Cray has remained profitable, despite the relatively low number of annual sales (15 to 20). The manufacture of supercomputers does not lend itself to economies of scale. IBM has been quite successful in the computer business by exploiting economies of scale. The size of this market, and it's lack of economies of scale has been a major factor in the failure of IBM to successfully enter the supercomputer market.

5.6 Industrial Attractiveness Summary

Figures 13 to 15, present a summary of the key factors in determining the attractiveness of the supercomputer industry discussed in the preceding sections. The three figures represent the attractiveness of the industry to the current participants (e.g. Cray Research, and ETA Systems), to new domestic entrants (e.g. Denelcor) and to new Japanese entrants (e.g. Hitachi and Fujitsu) for 1983 and 1987. The value (--) represents a highly unattractive factor while the value (++) represents a highly attractive factor.

Based on these figures the overall assessment of industry attractiveness is as follows:

	1983	1987
Current industry participants	High	High
New domestic entrants	Medium	Medium
New Japanese entrants	Low	Medium

The major forces which contribute to the industry attractiveness (opportunities) for the current industry participants are:

1. Market size/growth rate

2. Government support/national security

3. High barriers to entry due to technical knowhow

4. High profitability

The major forces which detract from the industry attractiveness (threats) for the current industry participants are:

1. Technology breakthrough

2. Degree of integration

3. Diversity of competitors

4. Potential government acts to slow export

These forces shape the individual company strategies as discussed in the following sections.

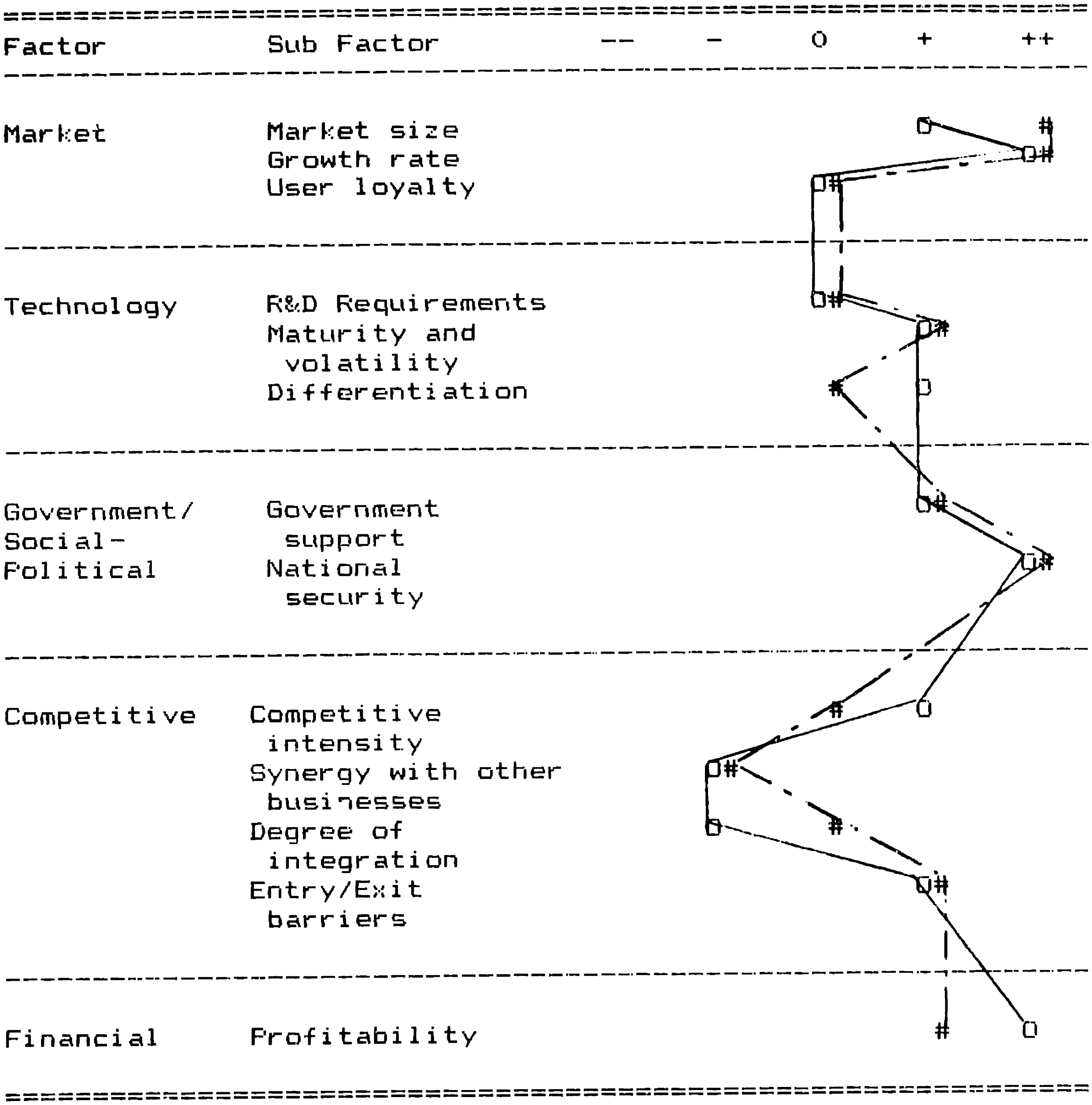


Figure 13. Summary of supercomputer industry attractiveness for current participants.

Legend:

——— 0 represents 1983

—— - — # represents 1987

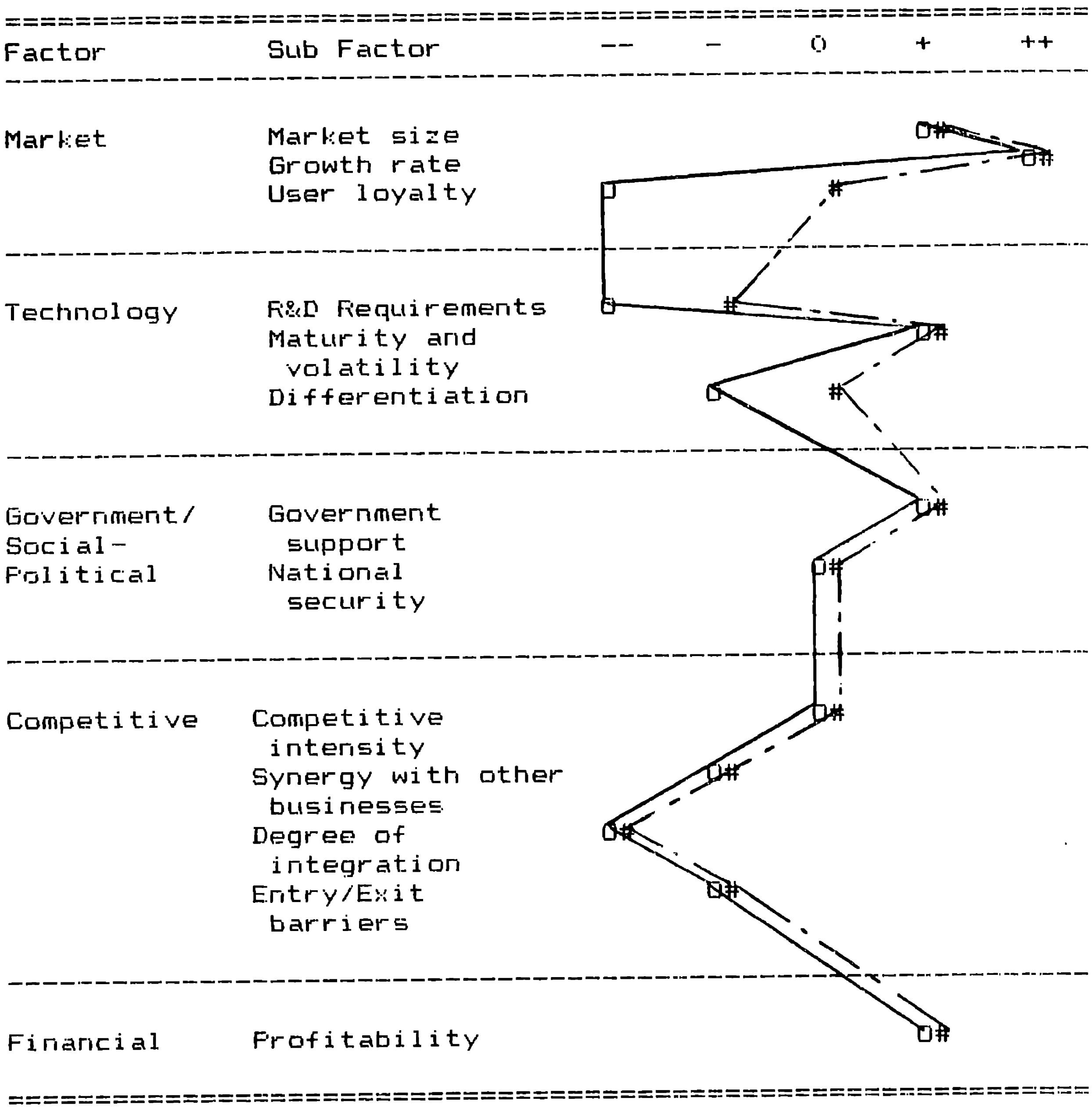


Figure 14. Summary of supercomputer industry attractiveness for domestic entrants.

Legend:

——— 0 represents 1983

— · — # represents 1987

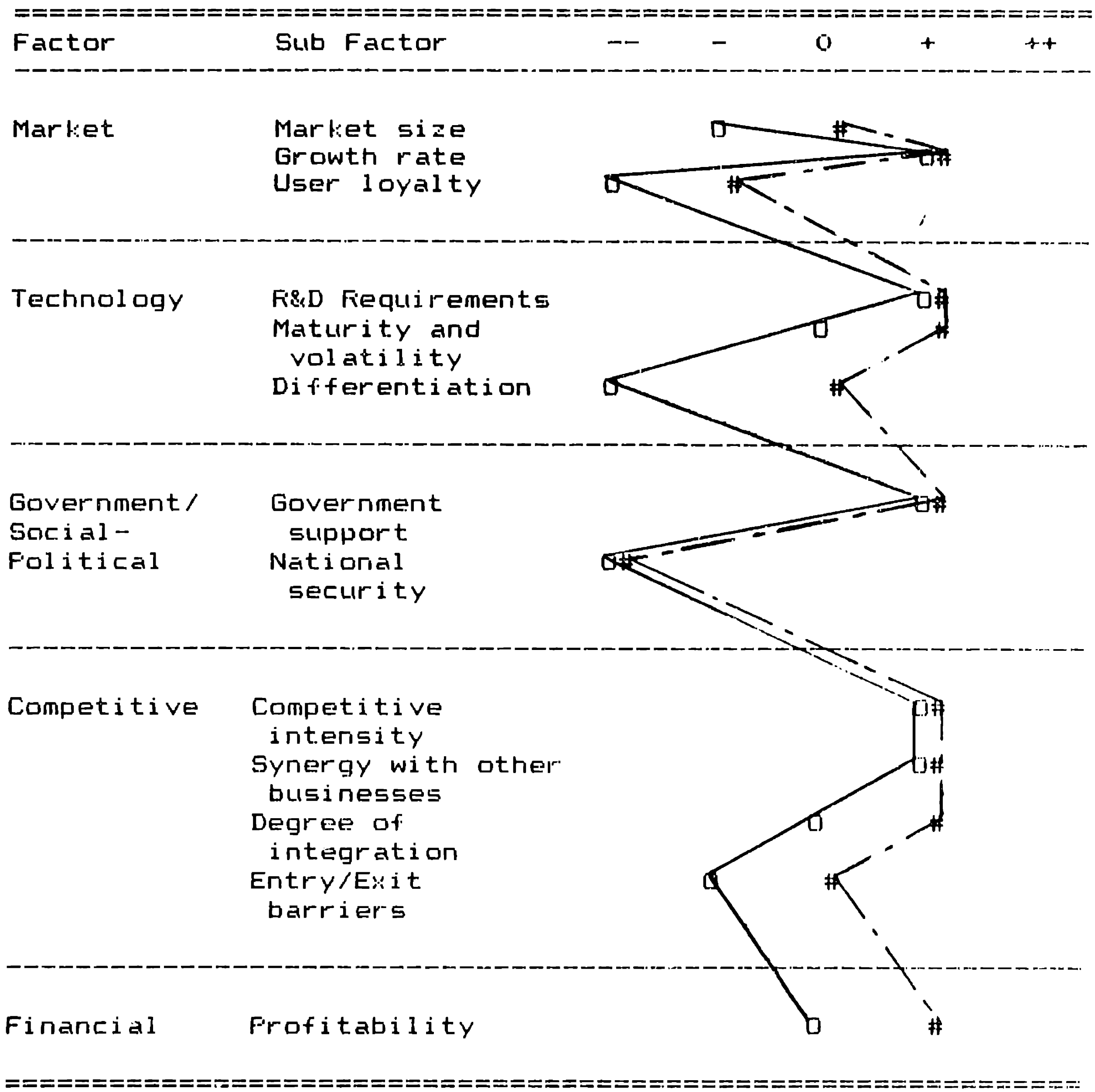


Figure 15. Summary of supercomputer industry attractiveness for Japanese entrants.

Legend:

——— O represents 1983
—·— # represents 1987

CHAPTER 6

U.S. SUPERCOMPUTER FIRMS

This chapter examines U.S. firms competing in the supercomputer industry. Corporate vision, key strengths and weaknesses and supercomputer business strategies are examined to develop a projection of each firm's market position in the supercomputer industry in 1987. These projections are combined with industry attractiveness estimates developed in Chapter 5 to form a traditional industry matrix.

6.1 Control Data Corporation

6.1.1 Corporate Vision: Mission, and Philosophy

Control Data Corporation (CDC) is a world-wide computer and financial services business, committed to a strategy of addressing society's major unmet needs as profitable, business opportunities.(91) Since the early 1960's CDC has been dedicated to earning a fair profit through a unique approach to improving productivity and the quality of life. The strategy is built applying computer technology and know-how, and financial and human resources to markets that have evolved from society's major unmet needs. Such needs include:

o Increased productivity.

o A healthier small enterprise sector.

- Better healthcare at lower cost.

- Higher quality, lower cost, more accessible education.

- Alternative energy sources and energy conservation.

- Urban revitalization.

- Rural development.

When addressing such societal needs, Control Data frequently seeks to establish cooperative ventures. Combining their resources with those of other corporations, non-profit organizations, and governments. Their strategy calls for a balance between investments for the future and steadily increasing earnings. This implies investing in the development of new products and markets that offer attractive future returns, but require several years before the reach maturity.

Central to this strategy is the design and development of a broad array of products and services based on or related to computer technology. Technology innovation, therefore, becomes the driving force to build stable, enduring and profitable businesses. There are risks involved, as projects often take years to produce returns and profits (e.g. PLATO).

CDC is comprised of two major business segments: Information Services and Products and Financial Services. The Information Services and Products business is made up of three components: Computer Services, Computer Systems and Peripheral Products.

The Computer Systems component of the business provides medium- to large-scale computers (Cyber 170 family), supercomputers and specialized systems. CDC offers a wide variety of computer services including: scientific and engineering, business, specialized (e.g. Ticketron, Cybersearch), computer-based education, and professional. Periperal products provides, through several joint ventures, a wide variety of peripheral products (rotating memories, mass storage systems, printers, computer memories, and terminals) and supplies (disk packs and cartridges, magnetic tape, flexible disks, and disk management software).

Underlying CDC's strategy is the belief in the primacy of the individual. They have sought to create a culture where people are encouraged to develop their specific strengths and interests. They believe it is important to recognize and nurture individual differences in order to better the individual and strengthen the company.(92)

CDC strongly believes in cooperation by all sectors of our society in order to most efficiently utilize resources in producing products and services. In 1982, CDC took a lead in

the formation of the Microelectronics and Computer Technology Corporation (MCC). This organization is focused on support of cooperative research and development in four areas:

- o Advanced computer architectures.

- o Software productivity tools.

- o Integrated computer-aided design and manufacturing tools.

- o Systems and chip-level packaging technology

MCC is aimed at providing a higher return on invested resources through cooperation. It is an initial private sector attempt to counter the cooperative strategic targeting efforts of foreign countries (e.g. MITI).(93) I believe that MCC will provide significant benefits to the U.S. computer industry. However, for the reasons listed in Section 8.3, I believe MCC will be of less benefit to the supercomputer segment of the U.S. computer indusry.

6.1.2 Strategic Posture of CDC

The strategic thrusts of CDC are derived from broad environmental assumptions and the competencies and driving forces within the firm. The present competencies (strengths) of CDC are as follows (94):

o Worldwide reputation large-scale scientific computers.

o Market leader in peripheral products market.

o World leader in data services through Cybernet.

o Extensive computer networking experience (e.g. Ticketron and Cybersearch).

o Technology and courseware for computer-based education (Plato).

o Global financial service network of over 800 offices.

CDC has established a set of operating strategies to achieve the companies growth objectives. The following corporate strategies have guided CDC's business strategies for the past several years:

o An emphasis on computer-based information services.

o Building a presence in the education market.

o Combining and expanding financial and information service for the small business market.

o Continuing an industry leadership position in the

peripheral products market.

- o Concentration on large-scale scientific and engineering computers.

The last strategic objective is focused on continued CDC presence in the scientific and engineering computer market. With the formation of ETA Systems, the future thrust of this business segment will be split between CDC for continued development and marketing of Cyber 205 class supercomputers and ETA Systems for the development and marketing of the next generation supercomputers (GF 10).(95) For the present, CDC corporate vision and strategic posture guide the strategies of ETA Systems. However, with time this linkage will weaken.

A growing number of U.S. firms are experimenting with the strategy of new ventures to provide for corporate growth. Roberts has analyzed this trend and developed a spectrum of venture strategies from venture capital to internal ventures.(96) The ETA Systems venture falls in the middle of this spectrum. Roberts indicates that this strategy can be successful, but corporations must be willing to allow five to seven years for the new venture to become established.

6.1.3 CDC Supercomputer Business Level Assessment

This internal analysis of the strengths and weakness of CDC's supercomputer business should be coupled with the

supercomputer industry attractiveness assessment discussed in earlier sections. CDC currently markets the Cyber 205 supercomputer. The Cyber 205 is a high-powered vector and scalar processing system. CDC will continue to market this computer and to provide enhancements.(97) ETA Systems will focus on development and marketing of the GF 10 (10,000 MFLOPS). This assessment is based of the strengths and weaknesses of ETA Systems and the combined marketing capabilities of CDC and ETA Systems. The key factors for this analysis are market performance, marketing capabilities, technology capability, financial performance, and manufacturing/management capability.

6.1.3.1 Market

CDC has maintained about a 33% market share of the supercomputer market over the past four years (see Figure 6). This market is growing at a rate of about 28% per year. These factors make CDC/ETA Systems a strong number two in this rapidly growing market.

A key to CDC's success, has been customer loyalty. In part this is due to the continued use of CDC based software carried over from the CDC 7600, and Cyber 203's. A second major reason for selection of CDC supercomputers has been its performance for problems which can be solved using long vectors. Five Cyber 205's have been selected for numerous weather/environment modeling applications and two have been

selected for petroleum research. CDC has an extensive North American sales network. In addition, CDC is marketing the Cyber 205 through wholly-owned subsidiaries in Europe and in the Far East. Currently CDC has installed Cyber 205's in England, France, West Germany, Holland, and Australia.(98)

6.1.3.2 Technology

The technical know-how, equipment and designs from CDC's supercomputer business have been transferred to ETA Systems. Building on this base, ETA Systems is developing a new generation computer designated the GF 10. The performance of this computer is estimated in Figure 10. The GF 10 also builds on several new technologies. The first is the use of eight parallel processors to increase overall system speed using multi-processor operating system software.(99) The computational speed of each processor will be increased to three to five times that of the Cyber 205 using the following key technologies:

- o Very high-density complementary metallic oxide semiconductor (CMOS).
- o Liquid nitrogen cooling and new packaging.
- o Memory systems based on 256K integrated circuits.

The GF 10 will be available for installation about the same

time as the Cray 3. The GF 10 is based on the use of cooled CMOS component technology, while the Cray 3 is projected to be based on gallium arsenide technology. The current generation Japanese supercomputers are based on silicon ECL technology. However the next generation may be based on gallium arsenide technology. As a key member of MCC, CDC will benefit from the efforts of this cooperative venture. Specifically, efforts to develop improved packaging technology, advanced architectures, and computer assisted microelectronic circuit design will be available to CDC and subsequently to ETA Systems.(100)

A key reason for the formation of ETA Systems is to allow adequate funding for R&D. Within CDC, the supercomputer segment had to fight the CDC priorities for funding. With the start-up of ETA systems, CDC has agreed to provide approximately $40 million toward an expected investment of $100 million by the end of 1986. The federal government has indicated a willingness to purchase the first few GF 10 supercomputers.(101)

6.1.3.3 Financial

CDC profitability is 11% return on equity (see Figure 12). Since CDC does not provide financial data at the supercomputer business level, it is difficult to estimate the profitability of the supercomputer segment. As the market leader in this field, Cray Research's profitability of 20% return on equity provides an upper limit for CDC's supercomputer business

segment performance. CDC's profitability in the supercomputer business is estimated at 15% return on equity. Sales of supercomputers are usually coupled with sales of smaller CDC Cyber computers, network hardware, and peripheral products which add to the overall profits of CDC.

A major negative factor for ETA Systems is their ability to raise the necessary capital for development of the GF 10. This problem is exacerbated by the fact that ETA Systems does not have a revenue base to attract venture capital or promote sale of equity. Government support in the form of guaranteed purchases of the GF 10 should help ETA Systems significantly.

6.1.3.4 Manufacturing/Management

ETA Systems was formed with 127 top CDC scientists and engineers. Lloyd Thorndyke was selected to head the new group. He was senior vice president of technology development at CDC where he had responsibility for the development of the Cyber 203 and 205. Neil Lincoln also joined ETA Systems, as chief architect. He brings 25 years experience in computer design to the effort, the last ten of which were spent deeply envolved in the design of the STAR 100, Cyber 203, and 205. This management team provides ETA Systems with a very firm base for the development of the next generation supercomputer.(102)

6.1.3.5 CDC Supercomputer Business Level Summary

A summary of CDC's current market and financial strengths are given in Figures 6 and 12. The discussion in the proceeding sections can be summarized by the following comparison of the relative strength of CDC/ETA Systems to its major competitor (Cray Research):

Factor	1983	1987
Market performance	Medium	Medium-Low
Marketing capabilities	High	Medium-High
Manufacturing/Management	Medium	Medium
Technology	High	High
Financial	High	Medium
Overall Assessment	Medium-high	Medium

Based on this assessment it is projected that CDC/ETA Systems will maintain a second place to CRI over the next four years. It is projected that market share for CDC/ETA Systems will drop significantly over this period. Competition from other domestic and Japanese firms is expected to account for CDC/ETA System's loss of market share. Loss of market share is based on two factors. The first is a projected errosion of Cyber 205 base with the advent of introductions of the higher-speed systems including the Cray 2 and the Japanese supercomputers. The second reason for this loss of market share is the timing of the GF 10 introduction, which will not allow substantial growth of the ETA Systems market by 1987. CDC/ETA Systems

should regain market share in the late 1980's if the GF 10 meets its performance goals. Changes in business strategies over this period may change this assessment slightly.

6.2 Cray Research, Inc.

6.2.1 Corporate Vision: Mission, and Philosophy

Cray Research, Inc. (CRI) was founded in 1972 to design, develop, manufacture, and market large-scale, high-speed supercomputers. The company operates in only one industry segment (the supercomputer segment). This corporate focus has been a major strength of Cray Research.(103) The first product, the Cray-1 was shipped in 1976. Since that time, CRI has been the technological and market leader in the supercomputer market segment.

CRI has recently developed a statement of the "Cray style".(104) It provides the firm with a sense of a mission and a source of pride. The Cray style captures the values of the individuals which have been attracted to the firm. The key elements of this company culture are as follows:

- o Individuals take business seriously, not themselves.
- o A strong sense of quality in products, services, people, components, and work environment.
- o Verbal communication is encouraged, "call don't write"

o People are accessible at all levels.

o Confidence and pride born of early success; try it and fix it if it dosen't work.

Until the early 1980's, Cray Research was a one-product company. With the introduction of the Cray-1/M and the Cray X/MP in 1982, CRI has broadened the supercomputer market. This effort to develop a segmented supercomputer market has a profound internal impact. The development of the Cray X/MP under Steve Chen is an important achievement for CRI, for it proves that they can continue to produce the world's most powerful computers (i.e. that is they can do it again). At the same time, the Cray-2 development under Dr. Seymour Cray continues. CRI is proud of the fact that they can create an environment where new creative talent can emerge, and at the same time provide an environment where an exceptional individual like Seymour Cray can continue to be creative. This shift marks the beginning of a transition of CRI from a entreprenurial startup, to a professionally managed growth firm.(105)

Since CRI operates in only one business segment the strategic posture of the firm is really one-in-the-same with the business level strategy.

6.2.2 Cray Research Supercomputer Business Level Assessment

This internal analysis of the strengths and weakness of CRI's supercomputer business should be coupled with the supercomputer industry attractiveness assessment discussed in earlier sections. The key factors for this analysis are market position, technology capability, financial performance, and manufacturing/management capability.

6.2.2.1 Market

CRI has maintained about a 67% market share of the supercomputer market over the past four years (see Figure 6). This market is growing at a rate of about 28% per year. These factors make CRI the market leader in this rapidly growing market.

A key to CRI's success in supercomputers, has been its strong marketing team.(106) Strong customer loyalty is due in part to the continued use of Cray and government developed software for Cray computers (e.g. COS,CTSS,LTSS). A second major reason for selecting Cray computers has been its high speed for scalar problems, and problems which can be solved with the use of short vectors. Fourteen Cray computers have been acquired by the Department of Energy for weapons and fusion energy research. This is the single highest concentration of supercomputers in the world. Other government Agencies such NSA and NASA have more than one Cray computer. CRI actively markets its supercomputers through wholly-owned subsidiaries

in Europe and the Far East. Currently, CRI has delivered supercomputers to England, France, West Germany, Holland, Sweden and Japan.

6.2.2.2 Technology

CRI, and it's founder Seymour Cray, have been responsible for the introduction of much of the current state-of-the-art in supercomputer technology. CRI was the first to use liquid-Freon cooling and, they introduced high-density packaging and unique architectures. The Cray X/MP has a clock cycle time of 9.5 nanoseconds, by far the fastest scalar processor in the world. Current efforts at CRI are aimed at completing the development of the Cray-2 computer in 1984. Rated at a speed of roughly 2000 MFLOPS, the Cray-2 will retain a strong lead in supercomputer speed.(107) In addition, CRI is also developing the Cray-3, a gallium arsenide based supercomputer. The departure from silicon technology for the processor is a bold technical step. To support the expected needs for gallium arsenide electronics, CRI has invested in ventures to acquire a future source of components. Performance specifications, and initial delivery dates for the Cray-3 have not yet be announced. It is anticipated that the Cray-3 will be available before the next generation Japanese supercomputers.

In 1982, CRI invested nearly $30 million in R&D for development of the Cray X/MP and Cray 2. This level is likely

to be exceeded in 1983. During the past several years, CRI has been able to convince stockholders that 20% of revenues must be invested in R&D to maintain market leadership position. This offensive technology development strategy is considered by the firm as the key to their future.

6.2.2.3 Financial

The overall profitability of CRI is 20% return on equity, highest in the overall computer segment, (Figure 12). This high profitability has clearly attracted other competitors to the market. This high profitability is subject to substantial technology and competition risk.

6.2.2.4 Manufacturing/Management

John Rollwagen, the chief executive of CRI, has an engineering degree from MIT and an MBA from the Harvard Business School. His blend of administrative and technical talent has been important to the development of CRI. With Cray's return to the laboratory in 1981, Rollwagen has assumed the management leadership role at CRI. He has been instrumental in developing the open, creative environment to foster high risk technology development.

The financial and other resources available to CRI are significantly less than other major computer companies. Compared to its major competitor, CDC/ETA Systems, CRI has a larger supercomputer staff. Overall employment at CRI has

grown at an annual rate of 45% over the past five years to over 1300 employees. CRI currently has over 300,000 square feet of manufacturing and development facilities. In addition, they are involved in the development of a semiconductor fabrication facility to reduce their dependence on outside component suppliers.

If there is one negative aspect about Cray Research, it is their growth and the threat this growth has on the innovative spirit within the firm. John Rollwagen is working to create a management system which will not inhibit creativity.(108)

6.2.2.5 Cray Research Supercomputer Business Level Summary

A summary of CRI's current market and financial strengths are given in Figures 6 and 12. The discussion in the proceeding sections can be summarized by the following comparison of the relative strength of CRI to its major competitor (CDC/ETA Systems):

Factor	1983	1987
Market performance	High	High
Marketing capabilities	High	High
Manufacturing/Management	Medium	Medium
Technology	High	High
Financial	High	Medium-High
Overall assessment	High	Medium-High

Based on this assessment it is projected that CRI will maintain its position of market leader. CRI's market share will remain relatively constant over the next four years. The entry of Japanese manufactures is not anticipated to slightly reduce CRI's market share (maximum loss of market share 5 to 10%). Changes in business strategies over this period may change this assessment slightly.

6.3 Denelcor, Inc.

6.3.1 Corporate Vision: Mission and Philosophy

Denelcor was founded in 1968 to provide computational capability for the general scientific and simulation markets. The company initially produced analog computer products. In 1978 Denelcor became a public firm and began a strategic transition from analog computers to digital computers. Under the direction of Mr. James Hill who joined the firm as president in 1981, Denelcor has become focused on a single computer market segment - supercomputers.

The central product of the firm is the Hetrogenous Element Processor (HEP) a multiple instruction multiple data (MIMD) architecture supercomputer. The HEP was developed during the late 1970's through funding received from the Army Ballistic Research Laboratory (BRL) and represents the first commercially available general purpose MIMD architecture supercomputer. This system allows up to sixteen processor element modules (PEMs) to be configured in a single HEP

system. Because of the HEP's unique architecture and it's scalar capability, Denelcor plans to market this supercomputer in a target market niche providing substantial value added products.(109)

Mr. Hill has set a corporation objective of fast growth over the next several years of 30% to 50%. He believes that Denelcor's value added, niche marketing strategy will result in a significant market share (20% to 50%). A longer term corporate strategy is use of their unique MIMD architecture products to gain a dominate supercomputer market share.(110)

As a small entreprenurial firm, Denelcor provides it's key executives with equity in the firm and the associated benefits of shared growth. In addition Denelcor is emphasizing technical excellence to provide incentives for creative technical personnel.

Denelcor operates in only one business segment. The strategic posture of the firm is really one-in-the-same with the business level strategy.

<u>6.3.2 Denelcor Supercomputer Business Level Assessment</u>

The internal analysis of the strengths and weaknesses of Denelcor's supercomputer business should be coupled with the supercomputer industry attractiveness assessment discussed in earlier sections. The key factors for this analysis are

market position, technology capability, financial performance, and manufacturing/management capability.

6.3.2.1 Market

In 1982, Denelcor delivered its first HEP processor to the Army BRL, a four-PEM system. During 1983, they reported the delivery of two additional single-PEM systems. Denelcor has yet to establish themselves in the supercomputer market. Denelcor projects sales of 16 PEMs in 1984. Denelcor's sales projections have been optimistic, 1984 sales will be an indication of Denelcor's future. Without an established HEP-I base, Denelcor can not hope to make a significant penetration in the supercomputer market with its HEP-II.

One of Denelcor's market strengths is their low price to performance ratio. A single-PEM system can be obtained for about $1.5 million. Additional costs for memory and I/O systems will raise the lowest cost system to about $2.5 million. This cost is significantly below Cray and CDC supercomputers. Since the cost of a HEP system is directly related to the number of PEM's, a sixteen-PEM system would provide 160 MIPS at a cost of over $20 million! While the performance is impressive, cost limits practical systems to four or less PEMs. Therefore the market niche for the HEP is in the low end of the supercomputer performance spectrum.

One early criticism of the HEP is its operating system. During 1983, Denelcor developed a UNIX-based operating system for the HEP. This operating system is expected to be available for delivery in the first quarter of 1984 and should substantially enhance the attractiveness of the HEP for scientific users.

Denelcor markets its own products in the U.S. They have established wholly-owned subsidiaries to sell and service their products in Europe. Denelcor has already delivered one HEP to Messerschmitt-Bolkow-Blohm, in Germany. During 1983, discussions were begun for a joint venture with a Japanese firm to market of Denelcor's products in Japan. Denelcor views international marketing a key ingredient in their future success.(111)

6.3.2.2 Technology

Dr. Burton Smith has played a key role in the development of Denelcor's HEP architecture. The HEP provides 1 to 16 PEM's operating in a true multiprocessor architecture. Processors, memory and input/output are connected with a high-speed switch network. While previous computers have provided SIMD capability, the HEP is the first commercial product to provide true MIMD capability.

Each PEM in the HEP-I system has a scalar speed of 10 MIPS. Four PEM's in parallel provide 90% of the rated speed of four

individual PEMs. Denelcor is developing the HEP-II, for availability in 1986. This system will utilize much faster PEMs and provide a maximum speed of 12,000 MIPS in a 16 PEM configuration.(112) As with the HEP-I, the cost of a HEP-II system is proportional to the number of PEMs, and therefore the largest economic HEP-II system would probably be about 4 PEMs with a maximum speed of about 3,000 MIPS.

In developing the HEP, Denelcor has focused on the unique architecture and used rather pedestrian component and packaging technology. Technologists have criticized the ultimate speed and reliability of Denelcor's switch network as it is expanded to the upper end of supercomputer performance levels. Denelcor does not have inhouse semiconductor capability or resources to fund special purpose semiconductor development. They are dependent on U.S. and Japanese semiconductor firms to supply their basic components. As they advance the HEP architecture they will be constrained by available semiconductor technology.

Software is the key to obtaining the true power of supercomputers. The ability to vectorize code for use on the Cray and CDC vector machines has been found to be an art. Over the past four years, users of vector machines have begun to better understand how to efficiently generate vectorized code. Similarly, it is an art to examine a computational problem and develop parallel code for operation on the HEP.

Denelcor has developed a parallel Fortran 77 programming language for the HEP. They believe the extensions offered to be easy to learn and use. More importantly, to fully exploit the benefits of parallel architecture systems, the initial algorithms to be solved should be reexamined for more fundamental methods of using the power of a parallel computer. Programmers with this talent are just now emerging. This more than any other factor may influence the speed with witch Denelcor can introduce the HEP system.

6.3.2.3 Financial

Funding for the completion of HEP development and marketing have been obtained from placements of roughly $30 million of equity since 1980. In addition, the firm entered into a $8.5 million R&D agreement with a limited partnership to fund development of advanced HEP products.(113) This financing should carry the firm through 1984. While Denelcor has sold three HEP systems since 1982, it has yet to register a annual profit. Until a larger sales volume is established, the profitability and the related rate of sustainable growth of the firm is at question. This situation is similar to Cray Research, which had four years of losses until the introduction of the Cray 1 supercomputer. If projected HEP sales for 1984 do not materialize, then Denelcor could have substantial problems raising capital for 1985.

6.3.2.4 Manufacturing/Management

In 1982, Denelcor opened a new corporate headquarters and manufacturing facility in Aurora, Colorado. The manufacturing facility provides excess capacity for the production of HEP-I systems, and should provide adequate capability for the next several years of projected growth.

Perhaps the major strength of Denelcor is their management. James Hill came to Denelcor with extensive experience in the Gould/SEL superminicomputer business. More importantly, his management skills are derived from his experience at International Telephone and Telegraph ("Geneen U.") and Texas Instruments where strong financial control and strategic planning concepts were developed. Mr. Hill has brought several key individuals from the Gould/SEL management organization to provide a close management team at Denelcor. Evidence of the capabilities of this team is their ability to raise the necessary financing to meet 1983/1984 working capital requirements.

6.3.2.5 Denelcor Supercomputer Business Level Summary

A summary of Denelcor's current market strength is given in Figure 6. The discussion in the proceeding sections can be summarized by the following comparison of the relative strength of Denelcor to its major competitor (Cray Research):

Factor	1983	1987
Market performance	Low	Medium
Market capabilities	Low	Medium
Manufacturing/Management	Medium	Medium
Technology	Medium	Medium
Overall assessment	Low	Medium

Based on this assessment it is projected that Denelcor will obtain a minor market share in the supercomputer market. It is estimated that their total market share may be as high as 10% (primarily within their market niche). However, this success is highly dependent on the sale of HEP I systems in 1984.

6.4 U.S. Supercomputer Business Level Strategic Analysis

Control Data/ETA Systems, Cray Research and Denelcor are following similar strategies to provide startup and growth with the industry with aggressive steps to penetrate the market:

Initial Market Development: CRI plans to invest $90 million over the next three years to develop the Cray-2 and Cray-3. ETA Systems plans a similar investment of $60 million by 1986 to develop the GF-10. Denelcor's investment plans on the HEP-II are estimated at about $25 million. These offensive technology development strategies are aimed at obtaining and

maintaining a clear technological lead on competitors. All three U.S. manufacturers are developing UNIX-based operating systems which should have the impact of reducing their differentiation. The plans for U.S. government acquisition of prototype and early development units eases the technology development risks.

Excess Capacity: Cray Research has approximately 350,000 square feet of design and manufacturing space. This strong commitment represents efforts to provide excess capacity to meet projected needs. Both ETA/Systems at Energy Park, St. Paul, MN and Denelcor at Aurora, CO have excess capacity to produce supercomputers at a rate to meet the needs of the next five years.

Market Penetration: A segmented approach to the supercomputer market was introduced by Cray Research in September, 1982. CRI offers the low-end Cray 1/M, and the high-end Cray X/MP with performance of two to five times that of a Cray 1/S for customers requiring maximum supercomputer speed. In announcing these new products, Cray established new price/performance levels for supercomputers. In January 1983, CDC was forced to lower its prices on the Cyber 205 to remain fully competitive. CDC will focus on marketing the current Cyber 205, with upgrades to memory and peripherals. ETA Systems will develop and market the GF-10 and GF-30 solely for the high end of the supercomputer market. Therefore,

CDC/ETA Systems together are following a similar strategy to CRI. Denelcor is targeting it's systems only at the low-end price-to-performance market niche.

While CDC/ETA Systems, CRI, and Denelcor have followed these three elements of a startup strategy, they have also been pursuing the following elements of a grow with the industry strategy and aggressively maintain market share:

Backward Integration: CRI is moving aggressively on expansion of its integrated circuit capabilities in 1983. These steps are aimed at backward integration to reduce dependence on outside component suppliers. In an effort to gain future access to gallium arsenide components, CRI has invested in a venture to develop this component manufacturing capability. CRI is the only U.S. supercomputer manufacturer following this strategy.

Export/Same Product: CDC/ETA Systems, CRI and Denelcor have focused on foreign sales of it's supercomputers. CRI and CDC currently market their supercomputers through wholly-owned foreign subsidiaries in Europe and the Far East. Denelcor is developing its international sales capability, with established offices in Europe and a potential joint venture in Japan. Foreign sales amount to roughly a third of all sales for the three U.S. supercomputer firms.

Same Products/New Markets: Applications for supercomputers are growing constantly. The U.S. government is a primary user of supercomputers However, marketing efforts at CRI are now focused at new users. A primary target is american industry. Of the sixteen CRI supercomputer sales planned for 1983, thirteen are with new users. Similarly, CDC has sold/leased systems to petroleum, aerospace, graphics, and automotive companies. Denelcor is focusing on the image processing niche.

New Products/New Markets: The CRI segmented marketing approach indicated in an earlier strategy is coupled with the development of new products (Cray 1/M) intended for new users. The Cray 1/M is aimed at low end supercomputer users that can not step up to the cost of a high end supercomputer. CDC plans to provide new products also. CDC is enhancing the Cyber 205 with lower cost memory technology.

CRI has been the leader in developing supercomputer industry strategies, and CDC/ETA Systems and Denelcor have followed this lead. Two areas where the strategies of U.S. supercomputer firms differ are: backward integration and segmented markets. Cray Research following a backward integration strategy through construction of a semiconductor fabrication facility. Neither CDC/ETA Systems nor Denelcor have the resources to follow a strategy of backward integration. Cray Research's segmented market strategy is

unique among U.S. firms. ETA Systems plans to develop the GF 10, aimed at the high-end supercomputer market, while Denelcor plans to remain in the low-end supercomputer market niche. By following these strategies, CRI should retain a leadership role. A key element in future market share of CDC/ETA Systems and Denelcor is the speed with which they can develop and market their next generation of supercomputers. If these firms do not meet their performance goals or are not first to hit the market window, they could suffer substantial loss of market share.

6.5 Summary of U.S. Supercomputer Industry Analysis

This summary addresses the industry attractiveness and the relative strength of the three leading U.S. firms in the supercomputer industry. The relative strength of leading Japanese firms will be added to this analysis in the next section. Figure 16 presents the current and projected market performance of CDC/ETA Systems, CRI, and Denelcor. These market projections are based on the individual strengths and weaknesses of the three firms given in the proceeding sections. In addition a traditional graphical representation of the industry attractiveness and relative strength of CRI, CDC/ETA Systems and Denelcor is given in Figure 17. Each firms location on the graph is based on the assessments given earlier. The size of the market is based an an assessment that growth over next four years will continue at 28%. It was projected that the size to the supercomputer market would be

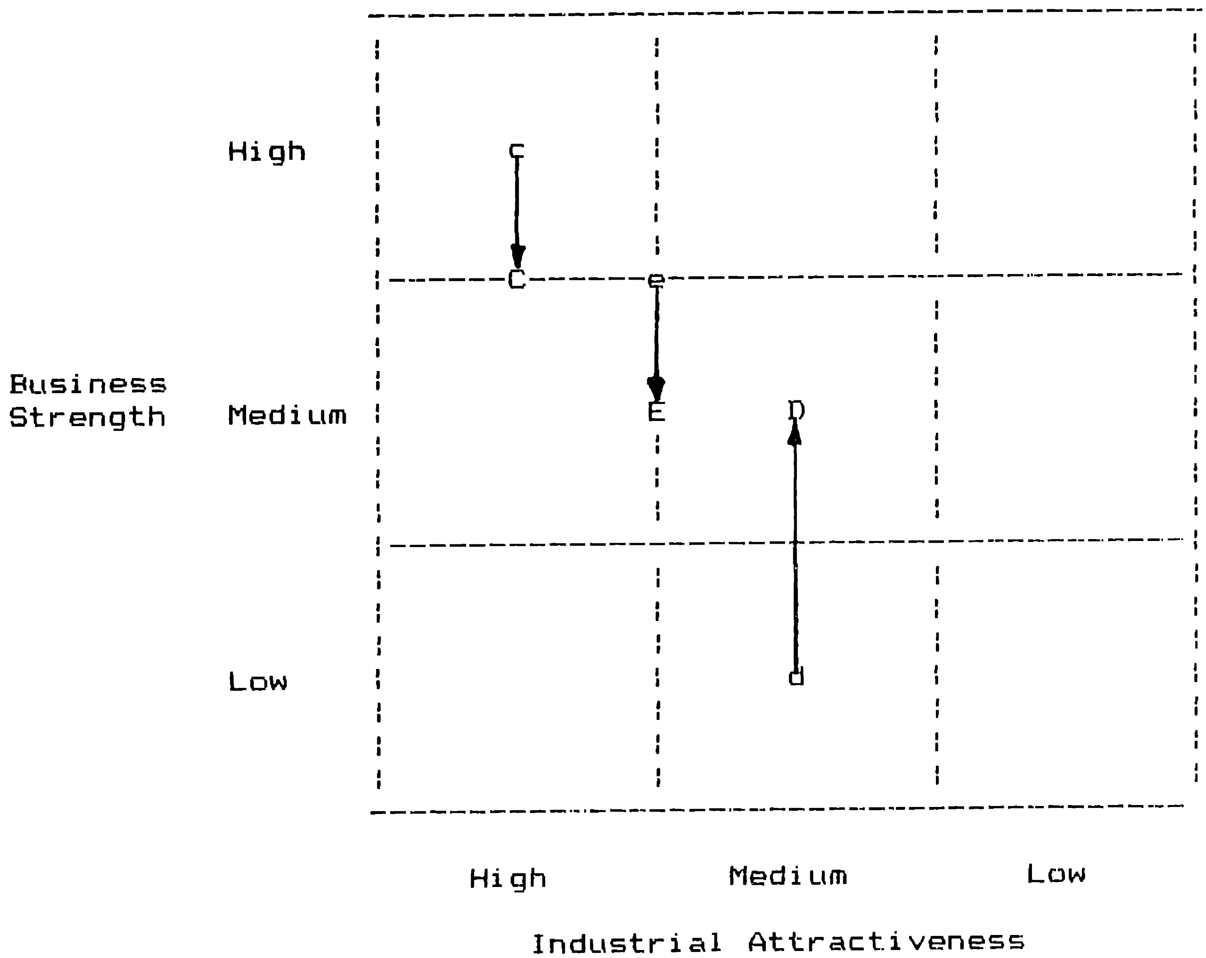
about $700 million in 1987. With the introduction of lower priced machines to attract new markets, and repurchases in mature markets, continued growth for at least the next four years is considered a reasonable assumption. The lower performance limit for supercomputers is expected to increase by 1987 to a level in excess of 100 MFLOPS.

The supercomputer industry exibits high entry and exit barriers. Therefore, it is inevitable that development and introduction of new supercomputers by Japanese firms will cause a general weakening of U.S. firm positions. These introductions are expected to initially impact the Japanese and European markets. These impacts will be discussed more fully in the next section. However the result should be a total reduction of market share for U.S. firms of about 25%. Finally, the strength of the U.S. firms is closely tied to government policy decisions. It is anticipated that government policies with respect to supercomputers will be implemented. Failure to implement these policies could severely change the outlook for U.S. firms, particularly ETA Systems.

Competitors	Growth 1981–1983 (%)	Profitability 1981–1983 (%)	Sales 1983 (M)	Market share 1983 (%)	Sales 1987 (M)	Market share 1987 (%)
Cray Research	42	20.5	175	68	410	58
CDC/ETA Systems	30	15.0	80	30	91	13
Denelcor	–	–	4	2	35	5

Figure 16. Summary of the market performance of the leading U.S. supercomputer firms.

Source: Author estimates based on interviews with CRI, CDC, ETA Systems, and Denelcor conducted in January, 1984.



<u>Legend</u>:

c Cray Research 1983
C Cray Research 1987
e CDC/ETA Systems 1983
E CDC/ETA Systems 1987
d Denelcor 1983
D Denelcor 1987

Figure 17. Business strength - industrial attractiveness of the domestic U.S. supercomputer firms.

CHAPTER 7

JAPANESE SUPERCOMPUTER INDUSTRY ANALYSIS

This chapter provides an overview of Japanese computer industry policy and specific actions aimed at stimulating supercomputer development. The three Japanese firms competing in the supercomputer industry are examined. Corporate vision, key strengths and weaknesses, and supercomputer business strategies are examined to develop a projection of each firm's 1987 market position. These projections are combined with industry attractiveness estimates given in Chapter 5 to form a traditional industry matrix.

7.1 MITI and Japanese Computer Industry Policy

MITI's role in the development of the Japanese computer industry can be traced to the late 1950's, with the enactment of the Temporary Law for the Promotion of the Electronic Industry. This law provided the charter to begin the development of a Japanese computer industry. In 1961, MITI began support of the Japan Electronic Computer Co.,Ltd. (JECC). JECC was a joint effort between seven Japanese computer companies. JECC would purchase computers outright from Japanese manufacturers and lease them to users. This allows Japanese firms to register the sales and profits at time of sale. Similarly in the early 1960's Fujitsu, Oki, and NEC formed the Electronic Computer Technology Research Association, with Y700 million subsidy from MITI. Their first

project was the development of the "FONTAC" computer. Like government sponsored support of computer research in the U.S., the "FONTAC" did not become a commercial success.(114)

In an effort to make inroads into the U.S. mainframe computer market, MITI began, in 1970, an effort to reorganize the Japanese computer industry into three groups - Fujitsu-Hitachi, NEC-Toshiba, and Mitsubish-Oki.(115) Each group was formed to carry out the design and development of separate implementations of an IBM 370 compatible mainframe computer - M Series (Fujitsu-Hitachi), COSMO (Mitsubish-Oki), and ACOS (NEC-Toshiba). MITI funding for these ventures was a 50% subsidy, Y 4.5 billion in 1972, Y 14 billion in 1973, and Y 15.2 billion in 1974. The sharp increase in funding was tied to the governments decision in 1973 to completely liberalize foreign capital investment in Japan by the end of 1975. These joint ventures lasted through the design and development cycles of the machines. Once production began, each of the member firms began independent marketing. Out of this MITI funded program came the basic technology for each of the major Japanese mainframe computer manufacturers. It is interesting to note that the Hitachi and Fujitsu systems were designed to use IBM compatible software. Current Hitachi and Fujitsu computers continue to utilize IBM compatible software. On the other hand NEC has developed a line of mainframe computers with non-IBM compatible software. MITI has followed these computer development efforts more recently with three

important technology development projects - the Very Large Scale Integrated Circuit Project, National Superspeed Computer Project, and the Fifth-Generation Computer Project.

In 1976, MITI established the Very Large Scale Integrated (VLSI) Circuit Technology Research Association, with a four year set of objectives to enable the manufacture of the next generation of semiconductors.(116) The association was funded at about Y 70 billion of which Y 30 was from the government. The five industrial members were Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba. Research efforts included microfabrication, crystal science, circuit design, processing, testing, and device development. The program involved considerable infighting among the managing director, the member firms and among the research sites (one cooperative laboratory and two group labs). The Association was ultimately successful and the VLSI program goals were achieved. Sakakibara has compared the program to efforts conducted by individual U.S. companies and found significant benefits from the cooperative Japanese VLSI program.(117) The initial success of the program is evidenced in the rapid growth of Japanese manufacturers in the overall semiconductor market. Much of this growth has been in the random access memory (RAM) segment of the market. Critics point out that this was a segment of the semiconductor market which the U.S. manufacturers could not fully satisfy in the late 1970's. A longer term measure of success will be their ability to penetrate the semiconductor logic market.

The National Superspeed Computer Project was initiated in 1982 with six industry participants (Fujitsu, Hitachi, NEC, Mitsubishi, Oki, and Toshiba), in coordination with the Electo-Technical Laboratory (ETL).(118) Technical direction is provided by Hiroshi Kashiwagi of ETL. The total funding for this program is about Y 23 billion ($ 96 million). The project is aimed at developing by 1989, an experimental computer capable of an execution rate of 10 billion floating-point operations per second (BFLOPS), one billion bytes of memory, and based on distributed parallel-processing architecture. Key to the success of this project is the development of high-speed electronic devices. Research is being conducted by each industry participant as shown in Figure 18. A major research topic is the development of a parallel architecture supercomputer. The Japanese favor multiple-instruction, multiple-data stream (MIMD). New methods of interconection of processors are being studied, with emphsis on data-flow techniques. It is interesting to note that Japanese computer manufacturers have been experimenting with multiple processor architectures and have available a large number of products with two to 16 multiprocessors (e.g. Fujitsu M382, NEC ACOS-1000, Toshiba 16-microprocessor system). This long term research effort has clearly had significant spin-off for the near term supercomputer introductions of Fujitsu, Hitachi, and NEC. These efforts will be discussed in greater detail in the following sections.

Device Technology: Company	Josephson-Junction	Gallium-Arsenide	High-Speed Silicon
Oki		X	X
Fujitsu		X	
NEC	X	X	
Mitsubishi		X	X
Hitachi	X		
Toshiba		X	

Figure 18. High-speed logic device research in Japan under the National Superspeed Computer Project.

Source: Buzbee, B.L. et al. "Japanese Supercomputer Technology", Science, Vol 218, December 17, 1982, p. 1189.

The third major computer effort initiated by MITI is the Fifth-Generation Computer Project.(119) This project was initiated in April 1982. At the core of the Fifth-Generation Computer Project is the Institute for New Generation Computer Technology (ICOT), headed by Kazuhiro Fuchi. ICOT is supported by funding from MITI and eight manufacturers - Fujitsu, Hitachi, Matsushita Electric Industrial Co., Mitsubishi Electric, NEC, Oki, Sharp, and Toshiba. Two short term hardware goals are the development of a parallel inference machine and a knowledge-based machine. Inference machines follow a line of reasoning to arrive at a conclusion. The goal is 100 million to 1 billion logical inferences per second (LIPS). The knowledge-based machine will enable the

automatic organization, control, retrieval and update of the contents of a knowledge base of 100 billion bytes. The final stage of the project will involve the merge of the knowledge-based machine with the inference machine. In addition a significant effort is devoted to the development of the necessary software for these systems. Prolog has been selected as the kernel language, for the fifth-generation computer project. The data-flow concept is currently being studied for both the parallel inference machine and the knowledge-based machine. The objectives of the fifth generation project should be differentiated from the goals of the supercomputer program which is aimed at using faster more complex integrated circuits and computer architectures to achieve fast number-crunching capability. The end objectives of these two programs may bring the efforts together at the end of the decade. However, today these efforts are clearly differentiated.

MITI has imposed tariffs to protect it's domestic computer market from the weight of IBM's market share. Until 1980, these protective measures amounted to a 15 percent direct tariff and 12 percent non-direct tariff (total tariff of 27%).(120) Under pressure from non-Japanese manufacturers, the direct tariff is being reduced to about 8% by the mid-1980's. Indirect tariffs are not expected to be removed. The effects of the JECC to allow all purchases of Japanese manufactured computers to be treated as sales (leases on

JECC's accounts), further exacerbates the problems of non-domestic Japanese manufacturers. With the introduction of new computer models, a trade-in of leased machines occurs. For example, with the introduction of the IBM 3081 in Japan, IBM was forced to announce additional computing power for the IBM 3033 to avoid large scale cancellation of previous orders (via return of leased machines). In addition the sale of foreign manufactured computers to the Japanese government is prohibited.

The results of this overall policy are evident in the domestic Japanese computer market sales given in Figure 19. In 1979, Fujitsu surpassed IBM as the leading overall computer manufacturer in the Japanese domestic market. This is the only computer market in the free world where IBM does not have the dominant market share. It is interesting to note that the mainframe segment of the Japanese computer market is only 28% and growing at a rate of about 18% while the minicomputer/personal computer segments comprise 48% of the market and are growing at over 30% per year.(121) The Japanese manufacturers have been most successful in the small personal computer segment of their domestic market, and this is the fastest growing segment. The outlook for IBM in the domestic Japanese computer market is exacerbated by the declining share of the market for mainframe computers and the efforts of MITI to support mainframe computer development.

Company	Computer Revenues (billions of yen) 1981	1980	Ratio of Computer Exports to Computer Revenues 1981	1980	Ratio of Computer Revenues to Gross Revenues 1981	1980
Fujitsu	454	382	13	10	68	66
IBM Japan	429	338	25	20	100	100
NEC	328	258	12	6	24	24
Hitachi, Ltd.	288	250	10	7	14	13
Oki	109	94	12	7	51	51
Toshiba	101	82	8	6	5	5
Nippon Univac	91	79	2	2	100	100
Mitsubishi Elec.	90	77	12	10	7	6

Figure 19. The eight leading Japanese computer manufacturers.

Source: Computer World Japan, January 1982

Under the program for the liberalization of foreign capital investment in Japan, MITI began to encourage foreign investment in the Japanese computer industry in the early 1970's. IBM has been successful in the U.S. domestic and world computer markets by providing value added service to it's customers. Other computer firms have found to successfully compete in the worldwide computer market, comprehensive sales and service expertise must be provided worldwide. Japanese computer firms sought joint ventures to share or acquire expertise (technical, sales, or service) in order to provide necessary sales and service capability in

foreign markets. In the early 1980's a number of joint ventures were initiated including: Fujitsu's tie-ups with Amdahl, TRW, ICL, and Siemens; Hitachi's tie-ups with Itel (now National Advanced Systems), ICL, and Olivetti; NEC's recent agreement with Honeywell, and Mitsubishi's tie-up with Sperry Univac. These joint ventures have been to a large part to provide distribution channels to Japanese firms in the U.S. and Europe. Fujitsu's joint ventures have been more successful than Hitachi's in large part due to the bankruptcy of Itel in January 1980. Japanese joint ventures with American computer firms have not been highly successful.(122) Japanese joint ventures with European firms may provide earlier signs of success. The Fujitsu-ICL tie-up provides ICL with supply of systems technology, LSI components, and mainframe computers. In return this joint venture provides Fujitsu a foothold in the English computer market without the difficulty of setting up its own sales and service systems in world markets. During this period ICL has maintained a 35% share of the English computer market against a strong onslaught by IBM.

The primary focus of MITI has been in the development of Japan's mainframe computer segment and more recently in the development of the supercomputer segment. The strategic focus of these efforts must be toward the U.S. and world market, since the Japanese <u>mainframe</u> market is small and declining in size. The largest Japanese computer firm (Fujitsu) has only a

1.9% share of the world computer market. The long term significance of MITI's efforts in the Japanese computer market will be registered in their impact on the world computer market. The first signal of the success or failure of the Japanese worldwide strategies will probably come in the European market area.

7.2 Fujitsu Limited

7.2.1 Corporate Vision: Mission, and Philosophy

Established in 1935, Fujitsu Limited has become Japan's number one computer manufacturer. They currently conduct business in four industries - computers and data processing; communications; semiconductors and electronic components; and consumer electronics. Computer and data processing is the single largest business unit with over 60 percent of sales. Fujitsu has stressed high reliability and value engineering throughout the company. These corporation objectives are vital for the foreign export of high technology computer, communications and semiconductor systems. Without high reliability foreign distribution and service costs can skyrocket. Fujitsu believes it has established a good reputation for high reliability systems and has recently began to turn the corporations focus on "new technology for tomorrow's information age". Fujitsu has pioneered new unique technologies such as gallium arsenide high electron mobility transistor (HEMT) and field effect transistors (FET's).

Fujitsu maintains a full line of mainframe, medium-scale, M Series (IBM Plug Compatibles), CAD/CAM, terminals and office automation systems. In July 1982, Fujitsu announced the FACOM VP-100 and VP-200 supercomputers. This announcement was the first official entry into the supercomputer market by a Japanese computer manufacturer. Since the domestic Japanese market for supercomputers is modest, and IBM doesn't market supercomputers, the move by Fujitsu to enter the supercomputer market is viewed as an effort to expand it's share of the IBM dominated world computer market. Fujitsu's supercomputer business segment strategy is coupled to their overall computer business strategy.

7.2.2 Fujitsu Supercomputer Business Level Assessment

This internal analysis of the strengths and weaknesses of Fujitsu's supercomputer business should be coupled with the supercomputer industry attractiveness assessment discussed in Chapter 5. The key factors for this analysis are market position, technology capability, and manufacturing capability.

7.2.2.1 Market

Fujitsu's first supercomputer was installed at Nagoya University's Plasma Research Institute in December, 1983.(123) Initial delivery was the smaller VP-100 model. Fujitsu currently has no significant market share. No rental or price data for the VP-200 is currently available for the U.S. market. The price for a VP 200 in Japan with 64 MB memory is

Y 2,760 million ($11.5 million). Fujitsu's U.S. supercomputer prices are expected to be slightly below CRI and CDC prices.

Fujitsu's greatest supercomputer market success will be the domestic Japanese market. Since Fujitsu is the leading domestic Japanese manufacturer of computers, they are expected to capture a major portion of the domestic market. It is interesting to note that Cray Research has recently been successful in selling a Cray supercomputer to Nippon Telegraph and Telephone(NTT) in the domestic Japanese market.

A key factor in Fujitsu's worldwide marketing capabilities are joint ventures. Fujitsu markets supercomputers in Europe through ICL and Siemens.(124) Siemens has been quite active in calling on Cray Research prospects in Europe. Futitsu will penetrate the European market in part due to political reasons of lessening dependence on U.S. technology and in part due to the successful joint ventures with ICL and Siemens. Fujitsu is also selling mainframe computers to Singapore, Malaysia, Australia, and Brazil. These world markets may serve as future targets for Fujitsu supercomputer sales.

Amhdal is Fujitsu's marketing arm in the U.S. Fujitsu has just increased its ownership in Amhdal to 49.5%. Because Amhdal has a significant position in the U.S. scientific computing market, this joint venture should provide Fujitsu a good supercomputer marketing capability. This link up is

consistent with other U.S. computer manufactures who are experimenting with joint ventures to strengthen their competitiveness against IBM.(125) Based on national security reasons, the U.S. government will not become significant users of Japanese supercomputers.

7.2.2.2 Technology

The Fujitsu VP-200 supercomputer has been a significant development effort. Benchmark performance data given in Figure 11 suggest that peak performance rates may approach publicized performance rates of 500 million MFLOPS for the VP-200 and 250 MFLOPS for the VP-100 for long vector applications. The VP-200 performance is comparable to current U.S. supercomputers.

While the VP-200 is not attractive for upgrades of existing CRI or CDC facilities, it is a good system for new supercomputer users. The FACOM VP-200 is built around IBM compatibility, with the potential of converting current high-end IBM mainframe users to supercomputer users. This advantage is particularly important for the introduction of new applications into the supercomputer market. Fujitsu has developed a very capable vector FORTRAN compiler which should enhance sales of its supercomputers.(126)

Fujitsu has a strong inhouse semiconductor and electronic

component business. They are currently funded under the Japanese National Superspeed computer Project to advance the state-of-the-art in high-speed logic components. A major goal of Fujitsu research is to reduce the minor-cycle time for gallium arsenide high-electron-mobility transistors (HEMT) to 1 nanosecond, which would allow a single processor execution rate of 1 billion instructions per second (see Figure 20)! They believe that by the 1990's that levels of integration equaling conventional silicon technology can be equaled by HEMT's.(127)

Fujitsu's R&D investment is about 9% of sales in 1983, up from about 8.5% in 1982.(128) Total company investment in computer, communications, and electronics R&D was about $360 million in 1983. The specific portion devoted to supercomputer R&D is not available, but these funds are augmented by MITI funds and cooperative research under the National Superspeed Computer Project. Fujitsu's computer and component research effort differs from the rather narrow scope of R&D conducted by U.S. supercomputer firms. Fujitsu's R&D program has the advantages of broader perspectives, however, the size of the U.S. supercomputer firms may allow them to make more radical technological changes without altering the strategy of the firm as a whole.

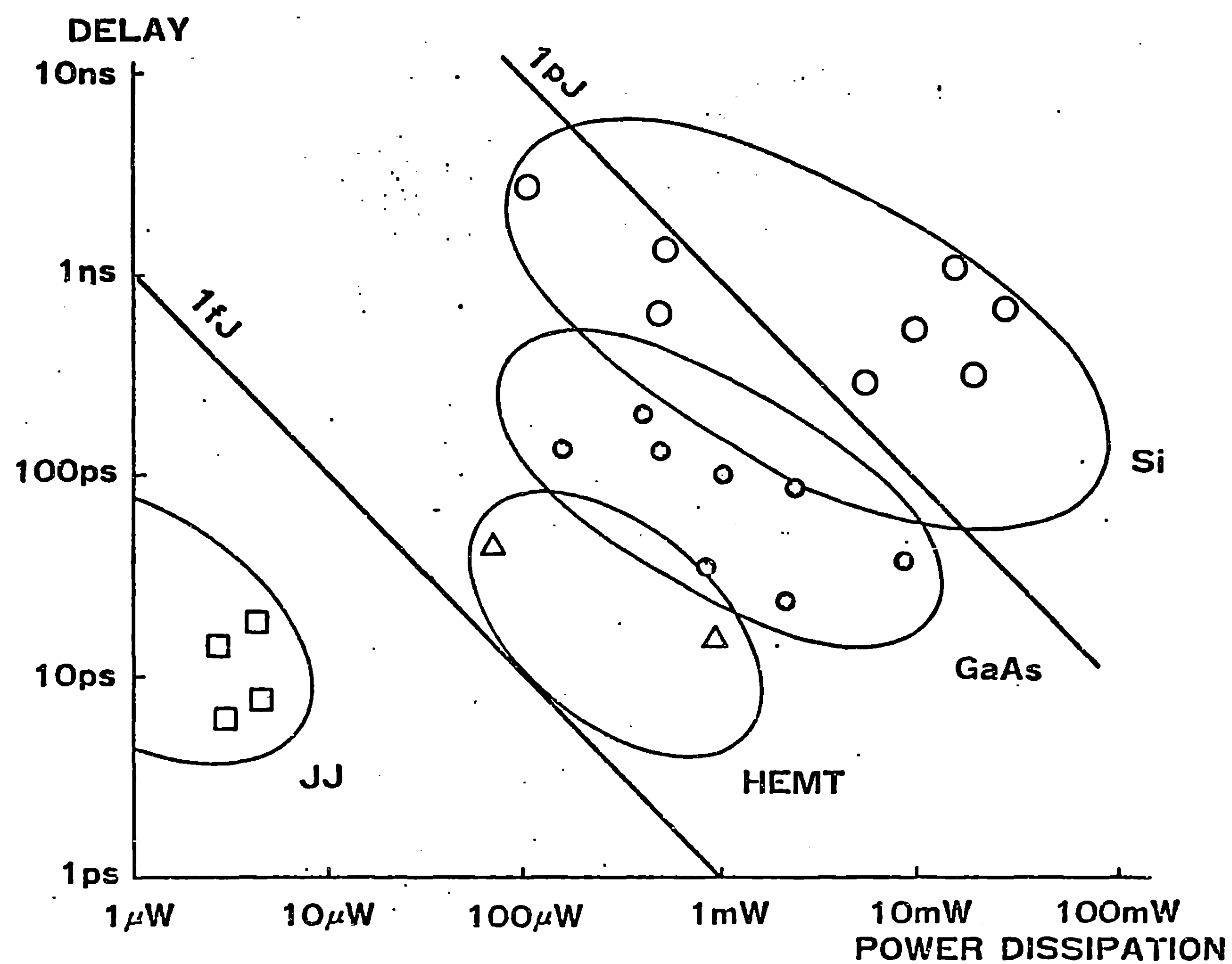


Figure 20. Supercomputer device performance

Source: Tsuchimoto, Takamitsu (Tokyo, Japan: Fujitsu, Ltd., January 26,1984).

Key to Fujitsu's competitive strength will be the capability of the next generation Fujitsu supercomputer family compared to it's U.S. competition. Both CRI and CDC/ETA Systems are developing supercomputers in the 2 to 10 BFLOP range for the mid-1980's time frame. If Fujitsu technology advances allow their next generation machine to provide say 15 to 30 BFLOP capability they could capture a major portion of the high-end of the future supercomputer market. Fujitsu's chances of making such technology breakthroughs are low-to-moderate.

A second major key to Fujitsu's future competitive strength will be their ability reduce the cost/performance ratio for supercomputers, through higher levels of circuit integration. Fujitsu will introduce lower cost/performance capability for low-end supercomputer users.

7.2.2.3 Manufacturing and Research Facilities

The prototype FACOM VP-200 was developed at Fujitsu's Kawasaki factory, just south of Tokyo. Production units of the VP-200 will be fabricated at the Numazu City Fujitsu plant in Shizuoka Perfecture near Mount Fuji.(129) Fujitsu has recently opened a new facility in Atsugi for microelectronics R&D. The financial base of Fujitsu is considerably greater than U.S. supercomputer competitors. With annual sales approaching $4 billion, Fujitsu invested over $450 million in new plant and equipment in 1983. These capabilities provide a competitive advantage to Fujitsu over the smaller U.S. firms.

5.2.2.4 Fujitsu Supercomputer Business Level Summary

A summary of Fujitsu's current financial strength is given in Figure 12. The discussion in the proceeding sections can be summarized by the following comparisons of Fujitsu to its major competitor (CRI):

Factor	1983	1987
Market performance	Low	Medium-Low
Marketing capabilities	Low	Medium
Manufacturing	High	High
Technology	Low	Medium
Overall assessment	Low	Medium

It is anticipated that Fujitsu will obtain a 10% share of the supercomputer market by 1987. Fujitsu will obtain its world market position through sales in Japan and Europe. They will not achieve a major penetration the U.S. supercomputer market. Fujitsu supercomputers are expected to outsell Hitachi supercomputers in Japan due Fujitsu's higher supercomputer performance and their stronger domestic Japanese marketing system.

7.3 Hitachi, Ltd.

7.3.1 Corporate Vision: Mission, and Philosophy

Hitachi is Japan's largest diversified manufacturer of electronic and electrical products. Their major product lines

include: power systems & equipment (17%); consumer products (23%); semiconductor, and information & communications systems (22%); industrial machinery (18%); and wire, cable, metals (21%).(130) Much of Hitachi's recent growth has come from the semiconductor and computer segments of their business. Hitachi is the leading Japanese manufacturer of 64K random access memories (RAM) with over 70% of the world market. This success in large part due to their participation in the MITI semiconductor project. In addition they are currently the first company delivering large production quantities of 256K RAMs. Hitachi is the fourth largest Japanese computer manufacturer (see Figure 19). Only about 14% of Hitachi's gross revenues are derived from the computer business. On August 30, 1982, Hitachi announced its intention to market supercomputers. At that time it announced the S-810/20 and S-810/10 supercomputers. The S-810/20 is rated at a maximum speed of 630 MFLOPS, making it the world's fastest supercomputer (the Cray 2 will not be available until third quarter 1984).(131)

The admission of guilt and legal settlement of the IBM spy case has proven highly embarrassing to Hitachi. In 1983, Hitachi agreed to payment of $300 million in exchange for IBM's dropping its suit charging Hitachi with stealing confidential technology. At the heart of this suit is a claim that the Hitachi VOS 3/SP2 software infringes on IBM's MVS/SP software. All users of Hitachi VOS 3 software will be asked

to sign licensing agreements with IBM. Hitachi is currently paying IBM between $2.1 and $4.2 million a month for use of IBM software. It is further rumored that Hitachi has agreed to pay IBM annual fees which may amount to as much as $26 million.(132) In December 1983, it was reported that operating system software for its S-810/20 supercomputer infringes on IBM's software. Tokyo University has been asked to sign an IBM software contract for operation of the first Hitachi S-810/20 supercomputer. Hitachi plans to develop new software for its supercomputers by March 1984 to avoid the IBM licensing problem.(133) This incident has significantly impacted their computer business prospects.

7.3.2 Hitachi Supercomputer Business Level Assessment

This internal analysis of the strengths and weaknesses of Hitachi's supercomputer business should be coupled with the supercomputer industry attractiveness assessment discussed in Chapter 5. The key factors for this analysis are market position, technology capability, and manufacturing capability.

7.3.2.1 Market

Hitachi delivered an S-810/20 supercomputer to Tokyo University on November 1, 1983. This marks the first delivery of a Japanese supercomputer. While this first delivery is very important, Hitachi does not currently have a significant share of the supercomputer market. In their press release on the S-810/20 supercomputer, Hitachi indicated a rental charge

of about Y 70 million ($3.5 million) per month for a core S-819/20 without extended storage.(134) This rate reflects a slight cost savings over CRI or CDC supercomputers.

Hitachi should obtain a significant share of the domestic Japanese supercomputer market. A key factor in Hitachi's worldwide marketing capabilities are joint ventures. Hitachi has been exporting its mainframe computers (e.g. M-280H) in Europe through BASF of Germany and Olivetti of Italy. Hitachi is expected to have a limited success in marketing its supercomputers through these distribution channels in Europe. Hitachi has used a joint venture with National Advanced Semiconductor (NAS) to market its products in the U.S. Hitachi must seek a more substantial U.S. computer manufacturing distribution channel. Over the past year, there have been reports of a Burroughs and Hitachi joint venture.(135) Lack of a strong U.S. joint venture, coupled with the IBM spy settlement should result eliminating Hitachi from the U.S. supercomputer market.

7.3.2.2 Technology

Hitachi has completed development of the S-810/20 and S-810/10 supercomputers. Hitachi's estimates of supercomputer performance are given in Figure 21. Benchmark performance data for the S-810/20 are given in Figure 11. The S-810 supercomputers use the standard IBM M-series architecture and operating system. This allows any applications programs for

IBM computers to be easily converted for use on the S-810.(136)

Since Hitachi is the world-leader in RAM memory production, they have the unique potential to drive down the cost of supercomputer memory.(137) For example, the S-810 is provided with a new extended secondary memory system with up to 1,024 MB capacity. This advantage could be very important for supercomputer users, with large applications data sets. A key to Hitachi's future success will be their ability to reduce the cost/performance ratio for supercomputers. Because of the size of the supercomputer market, economies of scale are not available. However, it is feasible for Hitachi to bring costs down as a side benefit of its corporate strategy in the semiconductor business.

<u>7.3.2.3 Manufacturing and Research Facilities</u>

During 1983, Hitachi invested $786 million (about 5% of sales) in R&D corporate wide. Much of Hitachi's R&D is targeted on strategic areas. Supercomputers and semiconductors are two key strategic areas. Hitachi maintains a central research laboratory, the Musashi Works, and also has encouraged several subsidiaries to conduct engineering and software R&D. Hitachi has excess computer manufacturing capacity for supercomputer manufacture. The research and manufacturing resources of Hitachi are significantly larger than U.S. supercomputer firms.

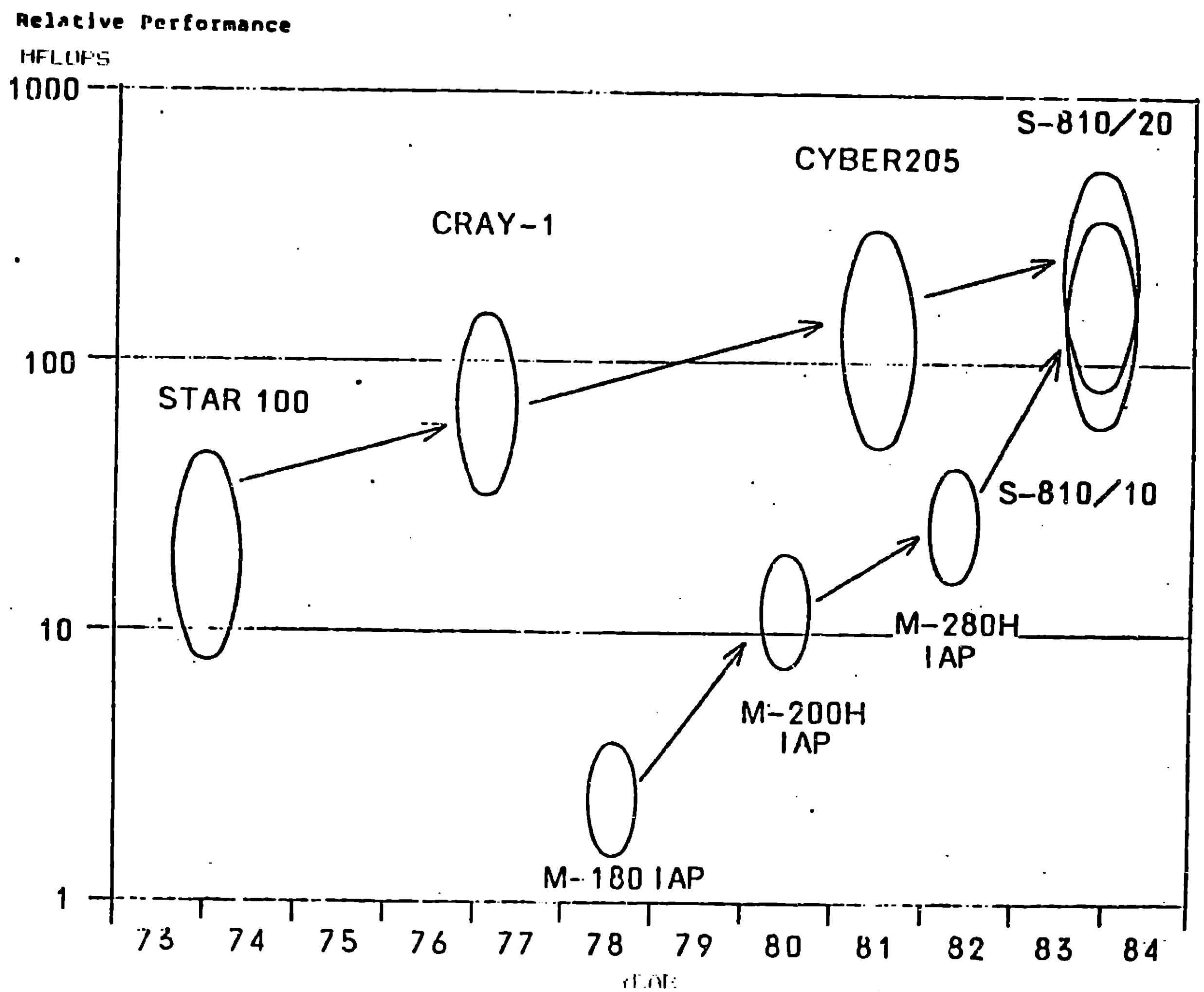


Figure 21. Hitachi estimates of supercomputer performance improvements.

Source: (Tokyo, Japan: Hitachi, Ltd., 1983).

7.3.2.4 Hitachi Supercomputer Business Level Summary

The discussion in the proceeding sections can be summarized by the following comparisons of Hitachi to its major competitor (CRI):

Factor	1983	1987
Market performance	Low	Low
Marketing capabilities	Low	Low
Manufacturing	High	High
Technology	Low	Medium
Overall assessment	Low	Medium-Low

Hitachi has projected sales of 30 supercomputers over the next four years, or about 10% market share in 1987.(138) I project Hitachi will obtain about half this value (5 % share of the supercomputer market by 1987). Hitachi will obtain this minor world position through sales in Japan and Europe.

They will not be successful in penetrating the U.S. supercomputer market.

7.4 Nippon Electric Co.,Ltd.

7.4.1 Corporate Vision: Mission, and Philosophy

NEC was incorporated in 1899 as the first American joint venture in Japan to produce telephone equipment for the new Japanese telecommunications industry. Today NEC conducts business in four major areas - communications, computers,

electronic devices, and home electronics. Communications is the largest business group. Computers comprise about 25 percent of the corporations sales.

Dr. Kobayashi, Chairman of NEC, has been advocating the communications and computer (or"C&C") concept as a central theme for NEC strategy since the mid-sixties. His philosophy is to concentrate on the technologies of information handling. The key technologies are communications, computers and electronics as shown in Figure 22. Unlike IBM or ATT which have previously specialized in either communications or computers, NEC has developed strong businesses in both fields. More recently, NEC has extended this concept to include the third dimension of the "man" with emphasis on technologies associated with the man-machine interface. (139)

NEC produces a full line of computers and peripheral devices, including general-purpose, business, minicomputers, and personal computers. NEC has a leadership position in the Japanese domestic personal computer market (with a 45% share).

In April 1983, NEC announced its plans to enter the supercomputer market with the SX-1 and SX-2. The first supercomputers are projected to become available in 1985. (140) The SX-2 is projected by NEC to operate at a speed of 1300 MFLOPS.

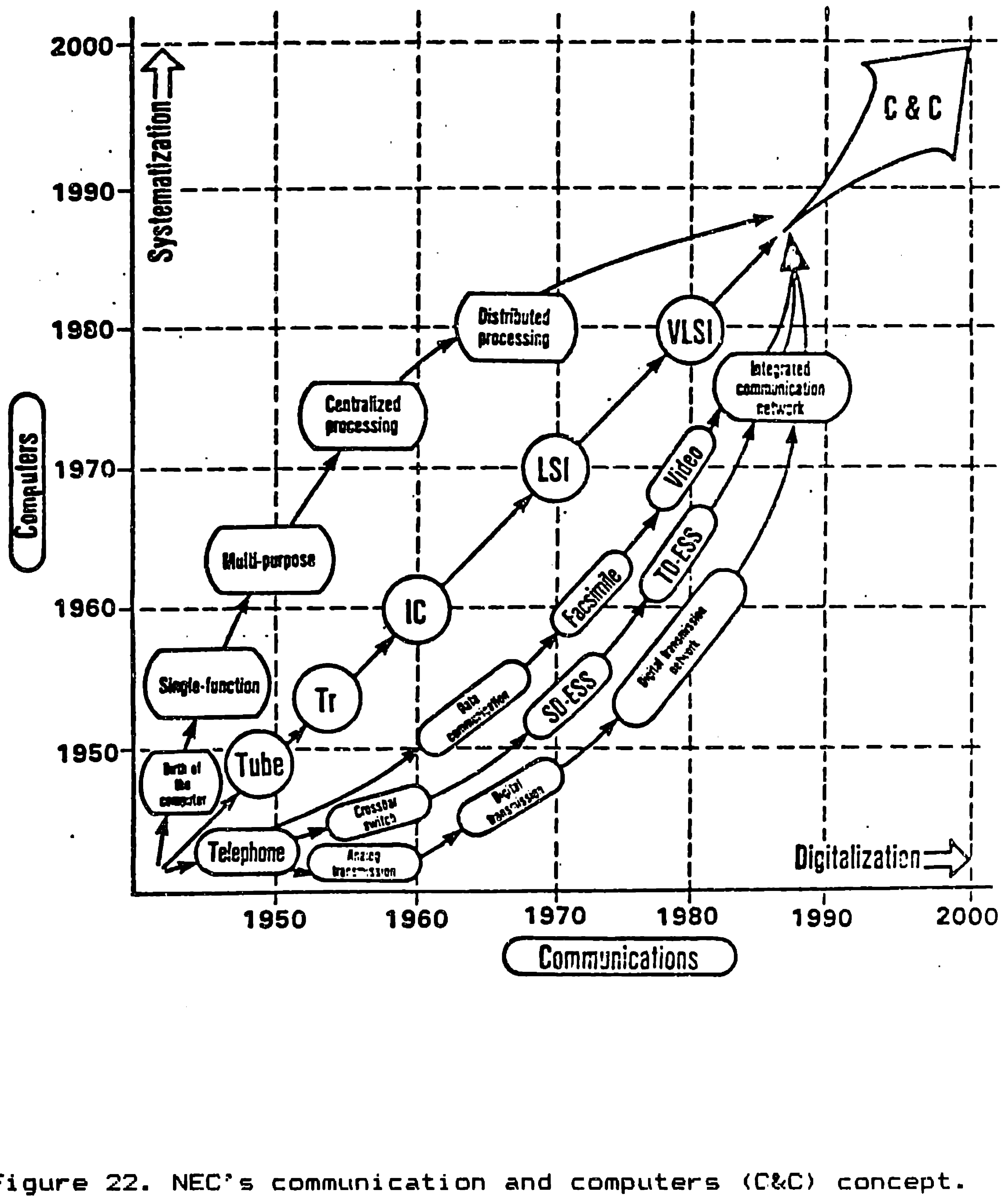


Figure 22. NEC's communication and computers (C&C) concept.

Source: Kobayashi, Koji "NEC's Management and ITs 'C&C' Strategy", (Boston, MA: Graduate School of Business Administration, Harvard University, December 1982).

7.4.2 NEC Supercomputer Business Level Assessment

This internal analysis of the strengths and weaknesses of NEC's supercomputer business should be coupled with the supercomputer industry attractiveness assessment discussed in Chapter 5. The key factors for this analysis are market position, technology capability, and manufacturing capability.

7.4.2.1 Market

NEC has not yet received an order for either its SX-1 or SX-2 supercomputers.(141) Benchmark performance data is currently not available. NEC currently has no share of the supercomputer market.

NEC has not disclosed its marketing plans for the SX-1 and SX-2. It is anticipated that they will market these supercomputers in Japan, Southeast Asia, Europe and in the U.S. NEC and Honeywell have had a strong relationship, with Honeywell providing technical assistance to NEC since the early 1960's. NEC has recently signed a joint venture agreement with Honeywell to market the S-1000 mainframe computer in the U.S. which would be designed to run Honeywell's GCOS operating system. It is expected that NEC will use this distribution channel for the SX-1 and SX-2 supercomputers.(142) NEC's success will be tied tc the speed with which they develop the SX-1 and SX-2 supercomputers and actual performance capability.

7.4.2.2 Technology

The SX-1 and SX-2 are rated at 650 MFLOPS and 1300 MFLOPS respectively. In order to achieve these levels of performance, a cycle time of 6 nanoseconds is projected for the SX-2. NEC designs are based on VLSI levels of integration, including 256K memory chips. NEC supercomputers are still under development, so they should be compared to the capabilities with the Cray 2 supercomputer (available 3rd quarter 1984). The Cray 2 is estimated to have a cycle time about two thirds that of the SX-2 and about twice the computational speed. Without benchmark performance data these comparisons are of limited value.

Like other NEC computers, the operating system will not be IBM compatible. NEC is developing a powerful vectorized FORTRAN compiler for the SX-1 and SX-2, which should be very attractive for potential users.(143)

NEC has strong semiconductor capability. Its gallium arsenide technology is state-of-the-art. This is evident by the recent award to NEC of a contract to provide gallium arsenide components for the Intelsat VI satellite. While the current design of the SX-1 and SX-2 supercomputers are based on silicon technology, NEC is well positioned to exploit gallium arsenide technology for its next generation of supercomputers. Of the three Japanese supercomputer manufacturers, NEC is the best positioned to achieve high-end supercomputer performance.

To make this commitment, NEC will need to invest heavily in R&D. NEC invested only 5% of gross revenues in R&D in 1983. However, this amounted to about $300 million.(144) The central issue will be how important supercomputers are to the core strategy of NEC. Supercomputers could play the central control function in a large "C&C" system much the way Cyber 205's play this role in the CDC Cybernet. With NEC's architecture of distributed computing it should be pointed out that only a few central supercomputers would be needed.

7.4.2.3 Manufacturing and Research Facilities

NEC has been committed to research since 1927. Unlike many Japanese research organizations, NEC began concentration of in-house research in the early 1930's. NEC inaugurated a new central research facility in the suburbs of Tokyo in 1975. NEC uses a complex process of interaction between marketing, operating and R&D groups to set research priorities for each year. In addition NEC uses extensive inhouse technical exchanges to transfer technology from the central laboratory to the operating groups.

The financial base of NEC is considerably greater than U.S. supercomputer competitors. Annual sales in 1983 were over $6 billion. NEC invested over $800 million of new plant and equipment in 1983. These capabilities provide NEC with competitive advantage over smaller U.S. supercomputer firms.

7.4.2.4 NEC Supercomputer Business Level Summary

The discussion in the preceding sections can be summarized by the following comparison of the relative strength of NEC to its major competitor (CRI):

Factor	1983	1987
Market performance	-	Medium-Low
Marketing capabilities	-	Medium
Manufacturing	-	High
Technology	-	Medium-High
Overall assessment	-	Medium

It is anticipated that NEC will obtain a maximum of 8% of the supercomputer market by 1987. This share is projected to be high-end supercomputer users. If NEC is late in hitting the market window with he SX-2, then U.S. supercomputers like the Cray 2 and GF 10 will continue to dominate the market. NEC will be successful in minor penetration of the U.S. supercomputer market by 1987. Similarly NEC is expected to obtain a minor share in the world supercomputer market, primarily from sales in Japan and Southeast Asia.

7.5 Japanese Supercomputer Business Level Strategic Analysis

Fujitsu, Hitachi and NEC are following similar strategies to provide startup and growth with the industry with aggressive steps to penetrate the market:

Initial Market Development: Fujitsu, Hitachi and NEC have been investing heavily in R&D over the past three years to develop their latest supercomputers. Fujitsu and Hitachi IBM compatible supercomputer developments are a remarkable achievement in only three years. Participation in the National Superspeed Computer (NSC) Project will provide each firm advanced devices, architecture and systems for their next generation supercomputers. MITI is committed to funding the NSC project through 1990. Key to this strategy will be Fujitsu, Hitachi and NEC capability to take cooperative research results and rapidly apply to their unique next generation supercomputers.

Excess Capacity: As a producers of a full line of computer systems, Japanese supercomputer manufacturers has ample capacity to produce large volumes of supercomputers. Fujitsu's decision to move production of the VP-200 to their new Numazu City plant is evidence of their commitment to the project. Hitachi's strategies of greatly expanding their semiconductor production facilities to maintain its leading position in the RAM semiconductor market will benefit their participation in the supercomputer market.

Market Penetration: Fujitsu, Hitachi, and NEC introductions of two supercomputer models each, is aimed at segmenting the supercomputer market. Key to the penetration of the supercomputer market will be the ability of all three Japanese

manufacturers to utilize their superior component technology to reduce the cost/performance ratio for supercomputers. They will be successful in following this strategy over the next four or five years for the low-end of the supercomputer market.

Seek Foreign Joint Ventures: Over the past several years Fujitsu, Hitachi and NEC have sought joint ventures with foreign computer firms to provide an OEM market, and more importantly to rapidly acquire distribution and service capability for their own products. This strategy has been successful for Fujitsu and Hitachi, particularly in Europe with ICL, Siemens, BASF, and Olivetti and in the U.S. with Amhdal. NEC's joint venture with Honeywell should provide them with a good basis for marketing their supercomputer in the U.S. Hitachi will seek further joint ventures in the U.S.

Backward Integration: The Japanese manufacturers maintain a strong semiconductor businesses for the computer, communications, and electronic product markets. This capability makes backward integration a logical strategy, and a key element in their future success. It is interesting to note that the Japanese supercomputer manufacturers are currently suppliers to their U.S. supercomputer competitors!

Export/Same Product: Fujitsu and Hitachi has begun to market their supercomputers both domestically in Japan and in Europe.

Fujitsu and NEC plan to market their supercomputers in the U.S. However, NEC's first supercomputers will not be available until 1985. Hitachi has not yet begun to market its supercomputer in the U.S. These moves are aimed at capturing a significant portion of the world market. The potential size of the Japanese supercomputer market through the 1990 dictates a need to follow a policy of foreign sales.

Same Products/New Markets: Since the Japanese computer manufacturers are established in the mainframe market, one of their strategies is to attempt to expand the supercomputer market down to include mainframe computer users. Their use of IBM compatible software (Fujitsu and Hitachi) allows low cost transfer of software for their current mainframe user base.

Because the supercomputer business segment is coupled to the overall computer business, it is anticipated that poor market penetration by the Japanese computer manufacturers will not be sufficient reasons for abandoning the supercomputer business. A position in the supercomputer market provides company prestige, and strategic advantage over IBM in the world computer market.

7.6 Summary of Japanese Supercomputer Industry Analysis

This summary addresses the industry attractiveness and the relative strength of the three Japanese supercomputer firms in comparison with the leading U.S. firms. Figure 23 presents a

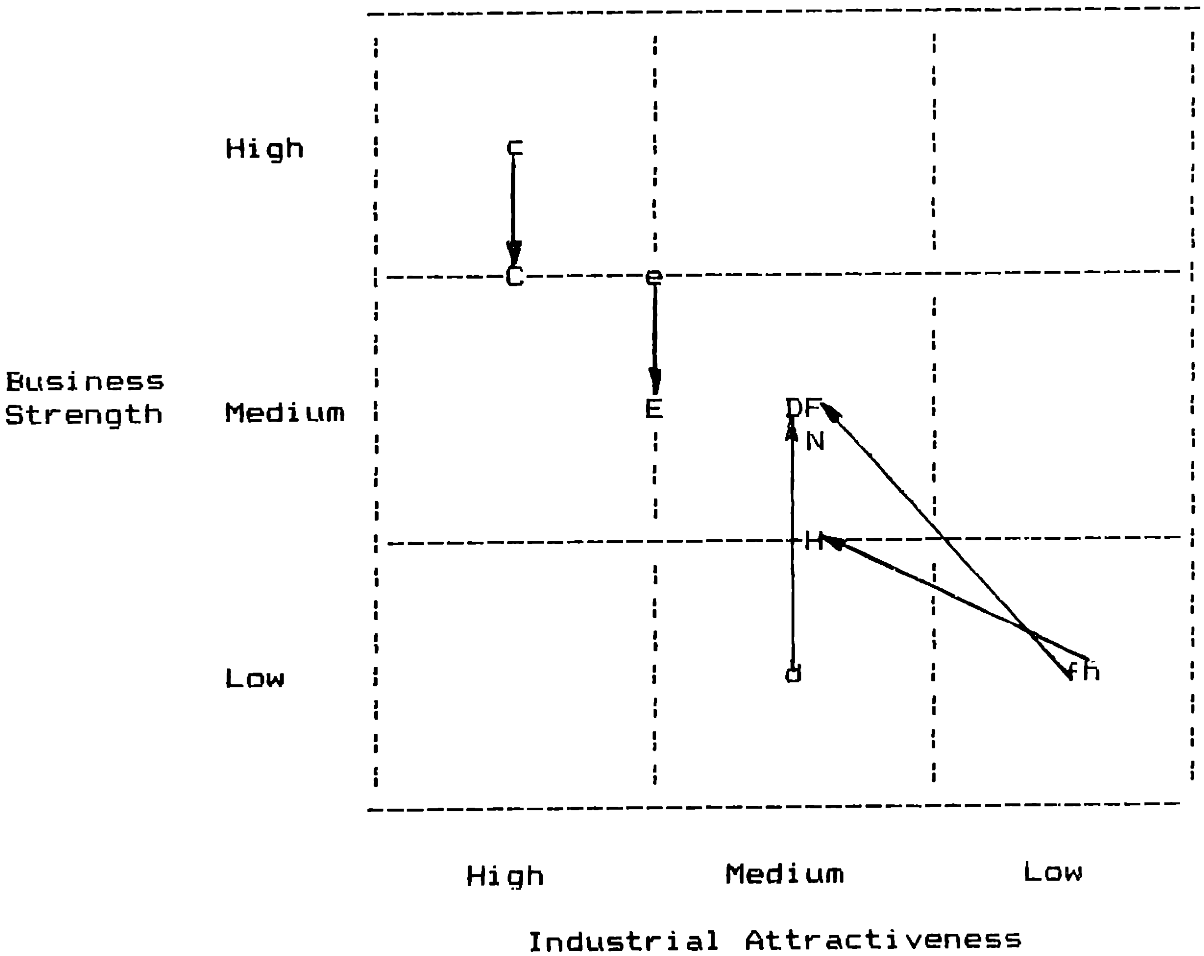
representation of the historical and projected market performance of the U.S. and Japanese supercomputer firms. These market projections are based on the individual strengths and weaknesses of these firms given in the proceeding sections. In addition a traditional graphical representation of the industry attractiveness and relative strengths is given in Figure 24. As before, each firms location is based on the previous assessments. It is projected that the supercomputer market will be about $700 million in 1987.

The Japanese firms are estimated to hold a combined worldwide supercomputer market share of about 25% in 1987. Introductions of Japanese supercomputers is expected to impact most strongly the Japanese and European markets. Fujitsu should be the strongest Japanese manufacturer in these markets. NEC should be the strongest Japanese competitor in the U.S. supercomputer market and should capture about 8% share.

Competitors	Growth 1981–1983 (%)	Profitability 1981–1983 (%)	Sales 1983 (M)	Market share 1983 (%)	Sales 1987 (M)	Market share 1987 (%)
Cray Research	42	20.5	175	68	410	58
CDC/ETA Systems	30	15.0	80	30	91	13
Denelcor	–	–	4	2	35	5
Fujitsu	–	–	–	–	70	10
Hitachi	–	–	–	–	35	5
NEC	–	–	–	–	60	8

Figure 23. Summary of the market performance of the leading U.S. and Japanese supercomputer firms.

Source: Author estimates based on interviews with CRI, CDC, ETA Systems, and Denelcor conducted in January 1984; and information supplied by Fujitsu, Hitachi, and NEC in January, 1984.



<u>Legend</u>:

c Cray Research 1983
C Cray Research 1987
e CDC/ETA Systems 1983
E CDC/ETA Systems 1987
d Denelcor 1983
D Denelcor 1987

f Fujitsu 1983
F Fujitsu 1987
h Hitachi 1983
H Hitachi 1987

N NEC 1987

Figure 24. Business strength - industrial attractiveness of the U.S. and Japanese supercomputer firms.

CHAPTER 8

CONTRAST U.S. vs. JAPAN: SUPERCOMPUTER INDUSTRIES

The following section contrasts the differences in the structure of the U.S. and Japanese supercomputer industries and the external reasons for these differences. The implications of these differences on U.S. supercomputer strategy are explored. In addition, the differences in the corporate strategies of the U.S. and Japanese supercomputer firms are contrasted. Finally, the implications of Japanese supercomputer firm strategies on the future strategies of U.S. supercomputer firms is examined.

8.1 Structure of U.S./Japanese Supercomputer Competition

In both the U.S. and Japan, key roles are played by government, industry and universities in the development and use of supercomputers. A contrast of these roles in each country provides insight into the most appropriate U.S. government-industry supercomputer strategic policy.

8.1.1 Government-Industry Relationships

The relationships between the U.S. government and the supercomputer industry dates to the 1940's. These relationships have been implicit, primarily driven by the mission needs of key government agencies. By contrast, Japanese government-supercomputer industry relationships are relatively recent, dating from the late 1970's; although,

Japanese government-computer industry relationships date back to the 1950's. The Japanese government-supercomputer industry policy is explicit, driven by the goal of achieving worldwide economic competitiveness.

The historical U.S. government-supercomputer industry relationships were traced in detail in Chapter 4. These relationships have shifted over the past four decades. In the 1940's and 1950's, the government supported research and development, and placed supercomputer orders in advance of their development. The government underwrote R&D and became a friendly buyer. During the 1960's, government support of R&D declined. However, it remained a friendly buyer. During the 1970's, the government began to purchase supercomputers at arm's length from established suppliers. This led to a departure from the friendly buyer relationship to fly off or try before buy relationships. This departure ultimately slowed the rate of technical progress. Most recently, the government has begun to return to the friendly buyer relationship with supercomputer suppliers. Currently, the primary U.S. government-supercomputer industry relationship is one where the government is a buyer of supercomputers, but does not provide the industry with financial assistance or guaranteed loans for supercomputer development.

By contrast, the Japanese government does not currently purchase or use supercomputers, but, as detailed in Chapter 7,

provides a broad base of support for the domestic Japanese supercomputer industry through tariff and non-tariff trade barriers, favorable financing, computer leasing through JECC, and support of long-term R&D. Two examples of cooperative long-term R&D support of the supercomputer industry are the National Superspeed Computer and the Fifth Generation Computer Projects.

8.1.2 Industry Structure

In addition to different government-industry relationships, the U.S. and Japanese supercomputer firms differ in their approaches to technological innovation. The three current U.S. supercomputer competitors are monolithic in structure -- each competitor is a small entrepreneurial single business firm. They have not established ties to the newly emerging computer industry cooperative research groups, like, the Microelectronics and Computer Technology Corporation (MCC).

The three Japanese supercomputer firms are also somewhat monolithic in structure. In contrast, however, each Japanese competitor is a large firm engaged in multi-products, multi-markets, and multi-divisions and these firms are engaged in cooperative supercomputer research efforts sponsored by the Japanese Ministry of International Trade and Industry (MITI). Using Horwitch's terminology of technological innovation, U.S. firms follow Mode I, while the Japanese firms follow a combination of Modes II and III.(145) Japanese supercomputer

development is based solely on independent Mode II innovation. Japanese cooperative supercomputer efforts (Mode III) focus on component and advanced architecture research. This distinction is important because the Japanese supercomputer firms participate in cooperative research and perform independent product development simultaneously. Differences in U.S. and Japanese technological innovation can be traced to different social and structural systems.

8.1.3 University Relationships

Historical relationships between university-industry-government in the U.S. supercomputer industry are traced in Chapter 4. During the 1940's and 1950's, U.S. universities were partners with both industry and government in the development of the nation's first computers and supercomputers. Today, U.S. universities do not play a significant role in the development of supercomputers. In fact, there are signs of antagonism between university computer scientists and industry development teams. In a similar fashion, Japanese universities have not played a significant role in the development of Japan's supercomputers. However, they are involved with industry and MITI in cooperative research on "experimental" supercomputer architectures. Only three U.S. universities have supercomputers, and these facilities are underutilized. Japanese universities were the customers for the first two supercomputers developed in Japan. University research on

these Japanese systems is adequately funded and the facilities are fully utilized. Finally the contrast between U.S. and Japanese universities in computer science education is quite dramatic. In 1982, U.S. universities produced only 225 Ph.Ds in computer science and computer engineering. In Japan, computer science is the most popular science and engineering subject.

8.2 Reasons for U.S./Japanese Supercomputer Industry Structural Differences

Social differences between the U.S. and Japan contribute toward differences in each country's approach to cooperative research. The U.S. is made up of many races, histories, languages, religions, and cultures. Americans emphasize individualism. According to Ouchi, traditional American companies exhibit individual decision making, individual responsibility, and segmented concern.(146) Lewis believes that adversity and social discord in American firms inhibit technological innovation and cooperative research.(147) Japan's national character derives from having homogeneous race, history, language, religion, and culture. Japanese history illustrates a tradition of people working together and placing needs of the group above those of the individual. They use a consensus form of decision making, involving government, political parties, and leaders of industry. The Japanese possess a unique, culturally derived capacity for cooperation and this social philosophy encourages cooperative

research efforts.

Structural differences between the U.S. and Japan account for differences in technological innovation. The U.S. possesses the world's most aggressive venture capital market. Recent changes in U.S. tax laws have led to rapid expansion of the U.S. venture capital market and the ability of this system to produce a large number of technological entrepreneurs (Mode I technological innovation). Japan also has specific structural strengths which contribute to its mode of technological innovation. Key among these strengths are their "sacred treasures": a lifetime employment system, seniority wage system, and enterprise unionism. After graduating from colleges, scientists and engineers in Japan seek employment through a rationed system of recommendations from their university professors. Graduating scientists and engineers compete for the most prestigeous jobs, which are considered to be positions in the Japanese government or employment in one of the large Japanese firms. As a result of this recommendation system, the lifetime employment system, and the lack of a Japanese venture capital market, small entrepreneurial firms are hard to fund and staff with qualified scientists and engineers. Therefore, the majority of technological innovation in Japan is produced by large firms (Mode II).

Because of these cultural and structural differences, it is

not surprising to see contrasting modes of technical innovation in the U.S. and Japan. Both modes will work in their respective systems. An attempt to copy the Japanese method of technical innovation in the U.S. is doomed to failure without the attendant cultural and structural supports.

8.3 U.S. Strategy Implications

Technical innovation is the key strategic factor in the success of commercial supercomputer ventures. Government, industry and universities play important roles in technical innovation. Different methods of technical innovation have evolved in the U.S. and Japan, largely as a result of structural and cultural differences.

The Japanese approach to supercomputer R&D is explicit government (MITI) - sponsored cooperative research and independent firm-sponsored product development. Other successful Japanese R&D-intensive industries, such as semiconductors, robotics, and flexible manufacturing systems, have followed this same pattern of government-sponsored cooperative research and independent firm-sponsored product development. The Japanese government provides explicit assistance for independent product development through favorable loans from the government-controlled Long-Term Credit Bank. In addition, Japanese universities play a central role in MITI sponsored cooperative research programs

like the National Superspeed Computer and the Fifth Generation Computer Project.

By contrast the U.S. approach to supercomputer R&D is less comprehensive. Technical innovation in American supercomputer firms lacks university involvement and cooperative research. The primary form of government development assistance is through guaranteed purchases. The U.S. government must work with American supercomputer firms to (1) strengthen government assistance of independent supercomputer development; (2) restore long-term research relationships with American universities; and (3) foster cooperative research. The U.S. supercomputer strategy recommendations in the next chapter address these three points.

Alternative U.S. research and development strategies include both direct government R&D support as well as indirect R&D support measures. Direct government R&D support is appropriate for large, high-risk development programs such as space projects, advanced aircraft, and major defense systems. Direct government R&D support is also appropriate for long term research. Successful direct government R&D endeavors have usually involved cooperative efforts among universities, industry and government laboratories. The Reagan administration has supported direct R&D for selected industries. For example, the OSTP has recently completed a study supporting direct government R&D in the aircraft

industry.(148)

Indirect R&D support is appropriate for industries where product development can be undertaken with reasonable risk by individual firms. Policy efforts which provide indirect R&D support include: 1. guaranteed purchases, 2. legislation to stimulate private sector financed collaborative research, and 3. R&D tax incentives. The National Innovation and Productivity Act of 1983 (proposed by the Reagan administration), supports and encourages private sector financed collaborative efforts like the Microelectronics and Computer Technology Corporation and the Semiconductor Research Corporation.

A central issue in <u>independent supercomputer development</u> policy is whether direct government R&D support is desirable. There have been proposals to establish a "National Supercomputer Program" to provide direct R&D support to the industry. The policy developed by OSTP and the recommendations received from key U.S. supercomputer firms favor indirect R&D support for the development of commercial supercomputers. I believe the perspectives gained over the past forty years of U.S. supercomputer development clearly support the indirect R&D approach for <u>independent supercomputer development</u>. As discussed in Chapter 4, the <u>friendly buyer</u> approach of indirect support has proven the most successful.

On the other hand, direct government R&D support can play a central role in restoring long-term research relationships with universities. Direct government R&D support can take the form of long-term basic resr rch efforts, such as evaluation of new "experimental" supercomputer architectures, research access to supercomputers and support of university computer science education.

Public and private sector financed alternatives exist for fostering cooperative research. U.S. experience with private sector sponsored cooperative research is limited. The Electric Power Research Institute (EPRI) was formed fifteen years ago to perform cooperative energy research sponsored by competing electric power companies. During this period, the productivity and significance of EPRI sponsored research does not indicate that private sector alternatives are superior to public sector alternatives.

An American response to the lack of cooperative research in the computer industry has been the formation of the Microelectronics and Computer Technology Corporation (MCC). MCC is a private sector initiative involving twelve U.S. competitors in semiconductors and computers: Control Data Corporation, Motorola Inc., Honeywell Inc., NCR, National Semiconductor Inc., RCA, Sperry, United Technologies, Harris, Digital Equipment, Advanced Micro Devices, Inc., and Allied Corp. Unfortunately, none of the current U.S. supercomputer

firms is directly involved in MCC. ETA Systems, through its parent firm, will have loose ties to MCC. Small entrepreneurial American supercomputer firms feel that MCC cooperative research efforts are better suited to large computer firms. John Rollwagen of Cray Research has expressed his concern that young researchers sent to MCC for a period of two to three years will be motivated to form their own entrepreneurial firms and not return to their sponsoring firms. This process he believes will contribute toward MCC's ultimate success, but will limit the technology transferred back to the sponsoring firm. Other small supercomputer firms are simply not able to pay the cost of MCC membership. It has been proposed that MCC establish an "Associate" member status with reduced membership and personnel requirements to enable the participation of small supercomputer firms.

I fully support private sector cooperative research at MCC. However, poor coupling between MCC and U.S. supercomputer firms dictates that additional efforts are needed to strengthen cooperative research. Since the gap between U.S. and Japanese cooperative supercomputer research is so large, I believe both private and public sector alternatives should be sought to fill this void.

8.4 U.S./Japanese Supercomputer Business Level Strategy Comparison

Japanese supercomputer business strategies differ from the

"traditional" Japanese strategic approach to the world marketplace. In his analysis of Japanese strategic planning, Particelli suggests "traditional" strategies include: 1. development of the protected Japanese market, 2. focus on the low-end industry segment, 3. volume production to exploit economies of scale, and 4. product imitation with process and production innovation.(149) While Particelli's model is accurate for the radio, television, motorcycle, automobile, and zip fastener industries, these strategies do not fit the supercomputer industry. The characteristics of the supercomputer industry are high-end industry segment, no economies of scale, and the need for constant product innovation.

Supercomputer industry characteristics dictate many similar strategies for U.S. and Japanese firms. For example, all six U.S. and Japanese firms follow the important strategy of offensive product innovation. However, the strategies of these six firms differ in four major areas: market penetration, foreign participation, backward integration (or sourcing) and software compatibility. These differences derive primarily from the internal strengths and weaknesses of the individual firms.

Figure 25 depicts the marketing and foreign participation strategies of the leading supercomputer firms. Cray Research initiated a segmented market strategy in 1982. With limited

resources, ETA Systems and Denelcor have focused on niche or single supercomputer market strategies. The three Japanese supercomputer firms have followed Cray's strategy with the development of both low- and high-end supercomputers.

All three U.S. firms have favored wholly-owned subsidiaries in developing foreign markets. The use of subsidiaries to market supercomputers is consistent with other high-technology U.S. industries. This strategy is appropriate if the firm has a strong foreign marketing and technical staff. With a perceived weakness in marketing, the three Japanese supercomputer firms have sought joint ventures to rapidly provide foreign marketing capability.

Figure 26 depicts the sourcing and software strategies of the leading supercomputer firms. Sourcing of high-speed memory and logic components is of strategic importance to the supercomputer industry. Fujitsu, Hitachi and NEC are major suppliers of high-speed memory and logic components. They are logically following a strategy of backward integration. Fairchild and Motorola have been U.S. sources of supercomputer components to both Cray Research and CDC. However, due to the small volume of parts required and their high-speed requirements, these U.S. semiconductor companies are not currently devoting sufficient resources to meet the future needs of U.S. supercomputer manufacturers. U.S. supercomputer firms have become more dependent on their Japanese

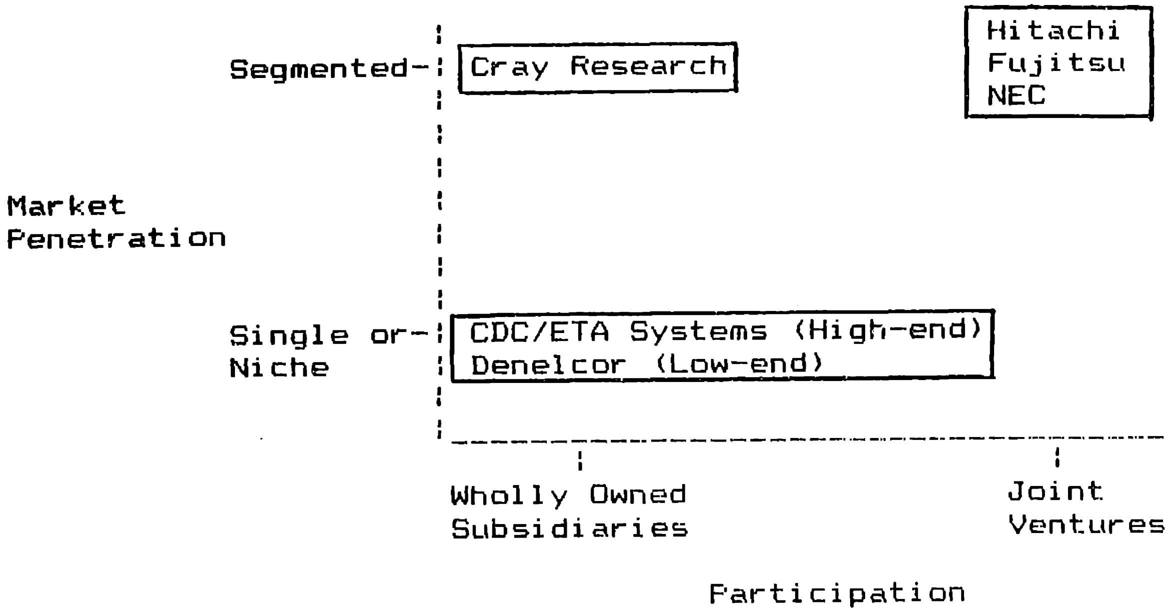


Figure 25. Supercomputer industry marketing and participation strategy map.

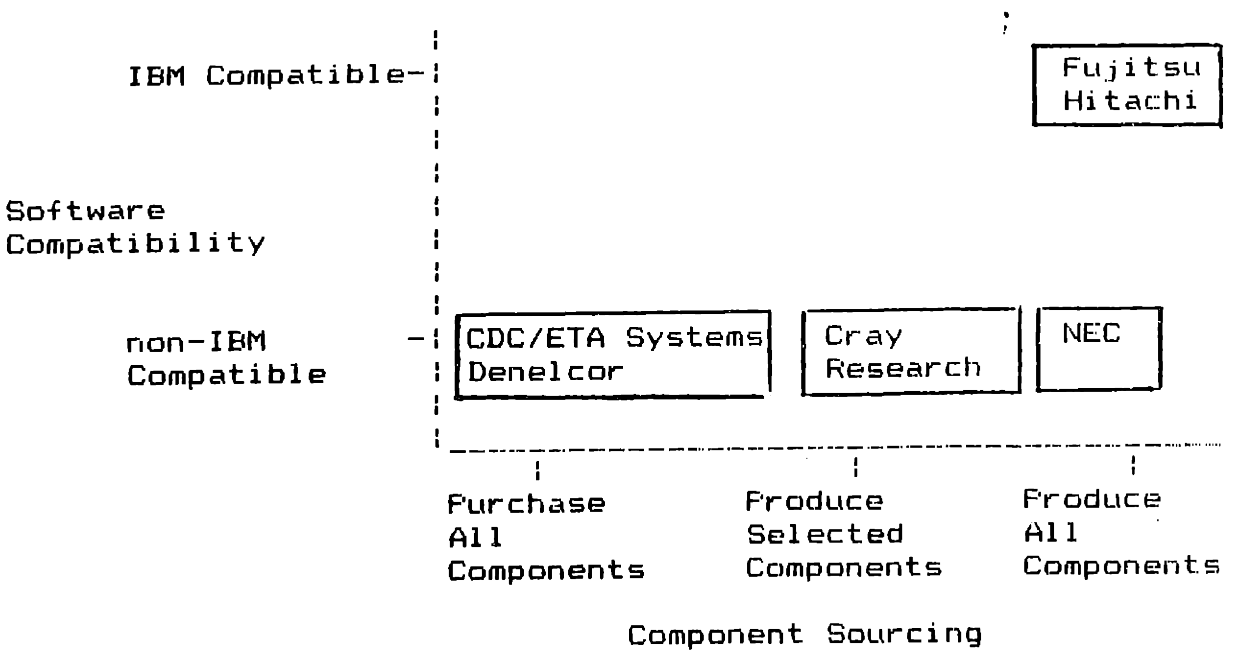


Figure 26. Supercomputer industry software and sourcing strategy map.

supercomputer competitors for supply of components. Cray Research, Inc. has established its own semiconductor operations to obviate this problem, at the expense of other important research efforts. Neither ETA Systems nor Denelcor have the resources to pursue backward integration.

Both Hitachi and Fujitsu are pursuing a strategy of IBM software compatibility. This unique supercomputer strategy takes IBM head-on in the full computer market and is of greater importance to current IBM mainframe users than to current Cray or CDC supercomputer users. The importance of the Fujitsu and Hitachi IBM-compatible software strategy will be most visible in the number of IBM mainframe computer users switching to Fujitsu or Hitachi. If this number is only ten to fifteen installations per year, this effort will not be a major market threat to IBM. If Fujitsu and Hitachi expand beyond this share of the market, then IBM will be motivated to enter the supercomputer market. At issue will be the technical ability of IBM to enter the supercomputer market rapidly. While IBM is rumored to be developing a supercomputer, this development realistically requires three to four years prior to product introduction. To position itself for rapid product introduction, IBM must perform defensive R&D.

8.3 Corporate Strategy Implications

The Japanese introduction of supercomputers has clearly added

strategic diversity to the supercomputer industry. In addition, it has served to make the supercomputer market a global industry and has stimulated defensive R&D activities at IBM. The Japanese supercomputer introductions necessitate a reexamination of the market, participation, and sourcing strategies of U.S. supercomputer firms.

8.5.1 Market Strategies

The development of a segmented supercomputer market by Cray Research is a sound strategy. The Japanese supercomputer introductions could impact Cray marketing success in the area of software. Fujitsu and NEC have developed very capable vectorized FORTRAN compilers for their supercomputers. Customers will expect Cray to provide comparable capability for both its low- and high-end supercomputers. While the U.S. government will continue to assist Cray in the development of software, Cray will need to devote a more significant effort to compiler development.

The ETA Systems strategy that focuses on a single market segment is appropriate. Market success will be based on their ability to meet projected performance levels for the GF 10. Efforts to meet these performance levels and retain compatibility with the Cyber 205 may severely strain ETA. While ETA is making radical packaging and component changes in the GF 10, additional architectural changes that compromise Cyber 205 compatibility may be necessary. ETA must also plan

on development of a user-friendly vetorized FORTRAN compiler.

With upward growth in mainframe computer capability, Denelcor will face stiff competition in the future. Denelcor's low-end niche market strategy will prove successful only if they can provide significant value added capabilities for their market segment.

8.5.2 Participation Strategies

The U.S. computer industry has generally favored wholly owned foreign subsidiaries due to the high-technology nature of the business. The Japanese have sought joint ventures to obtain rapid foreign marketing capabilities. U.S. supercomputer firms should not imitate the Japanese strategy of joint ventures for foreign distribution except for selected foreign markets such as the Japanese market.

Foreign manufacturing strategies are not appropriate for the supercomputer industry due to the low production volumes and lack of economies of scale. In fact, Control Data and Fujitsu supercomputer production is performed at their mainframe computer production facilities.

8.5.3 Sourcing Strategies

Differences in sourcing strategies place U.S. supercomputer firms at a definite disadvantage to their Japanese competitors. The development of domestic sources of high-

speed memory and logic components is critical to the U.S. supercomputer industry. This is a key area where cooperative research with semiconductor firms could yield components for Cray Research, Denelcor, and CDC/ETA Systems. Public sector funding is the most direct way to address this need. Private sector cooperative efforts, like MCC, could focus on development of memory and logic components for supercomputers. However, poor ties between supercomputer firms and MCC limit the effectiveness of this approach.

CHAPTER 9

U.S. SUPERCOMPUTER STRATEGY RECOMMENDATIONS

This chapter presents recommendations, from a U.S. perspective, aimed at maintaining U.S. preeminence in supercomputers. These recommendations respond to the strategy implications developed in Chapter 8 and include a national supercomputer policy and strategies for individual American firms. The supercomputer strategy recommended is built on a blend of the structural strengths of the U.S. free enterprise system and the government's continuing requirements for supercomputers.

9.1 National Strategy Recommendations

The key to commercial success for supercomputer firms has been the development of new products which offer significant advances in performance (factor of 5 or 10) over current supercomputers. The cornerstone of a government-industry supercomputer strategy is a system of incentives to accelerate U.S. supercomputer innovation. This strategy provides for both the government's continuing requirements for supercomputers and the continued preeminence of the U.S. supercomputer industry.

As indicated in Section 8.3, U.S. supercomputer policy recommendations must (1) strengthen government assistance of independent supercomputer development; (2) restore long-term

research relationships with American universities; and (3) foster cooperative research.

Based on the reasons stated in Sections 4.3.7 and 8.3, I believe that indirect R&D support is the best strategy for promoting independent supercomputer development. I offer the following recommendations to strengthen independent supercomputer development in U.S. firms:

1. The government should set as a goal the development of supercomputers with a capability of at least 100 GFLOPS by 1990. This capability will meet the 1990 computational requirements of key government agencies (DOE, NSA, NASA). The government should provide development incentives by guaranteeing to buy at least three of each supercomputer system that meets this goal.

2. The government should accelerate its purchase of supercomputers which represent significant steps toward this 1990 goal to ensure the health of the industry. The government should continue its <u>friendly buyer</u> policy, and provide technical assistance in the development of software.

3. The development of high performance peripherals should be stimulated by the same <u>friendly buyer</u> concept used for supercomputer development. The government should set

performance targets and guarantees to purchase a fixed number of supercomputer peripheral products.

4. The government should continue tax incentives for R&D investment.

Fundamental technology performance limits dictate a transition to parallel processor architecture to achieve the 1990 supercomputer goal. I believe direct government support is needed to bring about widespread acceptance of machine architectures which are different from traditional scalar von-Neuman machines. During the 1940's and 1950's, research relationships between government, industry, and universities proved successful in development of radical computer architectures. I offer the following recommendations to restore long-term research relationships between government, industry, and American universities:

1. The government should support university-government laboratory-industry cooperation in research and evaluation of "experimental" parallel architecture machines. These machines should be placed on networks to promote development of languages, algorithms, software and applications systems.

2. The government should increase funding for purchase and use of supercomputers within American universities, as

part of a broader program to increase support of science and engineering education. The government should take action to increase access to supercomputers at sites such as the Magnetic Fusion Network, the National Center for Atmospheric Research, and NASA's Ames Research Center. Improved access will not only bring this modern scientific tool to universities, but will help to develop new applications software and to train scientists and engineers in the use of supercomputers.

As indicated in Section 8.5.3, the reliance of American supercomputer firms on their Japanese competitors for supply of critical memory and logic components is an untenable situation. I believe cooperative research with U.S. semiconductor manufacturers and the three U.S. supercomputer firms should be conducted to develop domestic sources of high-speed logic and memory components. Private sector resources are best applied to this problem through improved technical interchange between supercomputer firms and MCC. However, I believe the efforts of MCC will be inadequate to meet the requirements of supercomputer firms. MCC and semiconductor firms are reluctant to invest significant resources in the development of supercomputer components, because of the small numbers of parts produced. I believe direct government R&D is necessary to assure continued domestic sources of advanced supercomputer memory and logic components. My recommendations in this area are:

1. The development of a domestic source of high performance supercomputer components should be stimulated by direct government R&D support of cooperative research. Memory and logic component developments should be directed by a single government laboratory, with cooperation among the U.S. supercomputer firms and semiconductor manufacturers, to produce parts that can be used by all three domestic supercomputer manufacturers. Previous supercomputer component development efforts at Motorola and Fairchild have met this criteria.

2. MCC should allow "associate" member status for small firms which are unable to meet MCC minimum funding and manpower requirements. This associate status should enhance the technical exchange between MCC and U.S. supercomputer firms and benefit the U.S. supercomputer firms with cooperative research in supercomputer components, architectures and packaging.

I believe a permanent interagency group should be established to coordinate individual agency supercomputer activities as necessary and to provide for implementation of these recommendations. This group should function at both policy and technical level, with OSTP providing the oversight function.

Policy recommendations are useful only if they can be

implemented within the infrastructure of the political system. I believe all these recommendations to be implementable. The majority of the recommendations given above are implicit, or driven by specific agency needs. The direct government support of supercomputer memory and logic components is an explicit recommendation. Unfortunately, it is the only recommendation that is not currently budgeted. I believe U.S. R&D policy should not be constrained to the implicit. The Reagan administration should support appropriate explicit R&D policy actions.

DOD, NSF, NASA, and DOE budgets for FY 1985 contain initiatives aimed at the remaining recommendations. These agency budgets are fully supported by OSTP. Guaranteed purchases of the next generation of supercomputers have already been extended to key industry participants. While the OSTP has mad major strides toward establishing and implementing these recommendations, there is concern about the continued attention of OSTP to this critical national industry. I believe it is appropriate to establish a permanent White House domestic policy office to deal solely with coordination and oversight of critical high-technology industries.

The original OSTP supercomputer coordinating group recommendations included the acceleration of the export licensing process to insure that U.S. vendors are not unduly

penalized in competing for foreign customers. I agree with this recommendation on economic terms. However, the current battle between DOC and DOD on West-West high technology transfer policy will have a significant impact on any recommendation in this area. The DOC will support supercomputer export if other Western countries can produce supercomputers of capability equal to U.S. firms. The DOD believes that export of products or technology which can be used for military purposes should be closely controlled. Current export control procedures do not adequately validate end use. I believe export should be granted quickly, with an improved process to validate non-military end use.

9.2 Corporate Strategy Recommendations

In addition to public policy recommendations, the future success of U.S. supercomputer firms depends on sound corporate stategy in the private sector. American supercomputer firms have the primary responsibility for new supercomputer development, due to the indirect nature of U.S. government supercomputer policy. The successful Fujitsu and Hitachi supercomputer introductions, coupled with the reported performance advances of NEC's SX-1/SX-2 supercomputers, emphasize the need for intensified U.S. supercomputer developments. Toward this end I offer the following recommendation:

Cray Research, ETA Systems and Denelcor should continue to

pursue aggressive company funded supercomputer development efforts such as the Cray 2 and 3, the ETA Systems GF 10 and 30, and the Denelcor HEP II. Computational speed targets should be set to exceed the expected performance level of commercially available supercomputers by a factor of five or more.

Japanese supercomputer designs are architectural and technological extensions of their mainframe computers and their vertical integration strategies tie them to inhouse device technology. Radical changes in architecture and technology are difficult for Japanese firms because of impacts on other products. On the other hand, U.S. supercomputer firms have an advantage over Japanese supercomputer firms in their flexibility to accept new architectures and technology. U.S. supercomputer firms should exploit this advantage by initiating long-term research efforts to bring about radical changes in supercomputer design. This recommendation is particularly appropriate for Cray Research and ETA Systems since neither firm has begun to address the tough design challenges of a highly parallel architecture. To initiate long term research activities, I propose the following recommendation:

Cray Research, ETA Systems and Denelcor should team with American universities and government laboratories to design and develop "experimental" parallel architecture

machines. Industry should provide perspectives on user and manufacturing aspects, and stimulate architectural innovation.

For years, U.S. supercomputer firms have led Japanese supercomputer firms in software development. Now, however, the software gap has closed. U.S. firms face stiffer competition from Japanese firms that are offering improved supercomputer software tools. Early tests of Cray X/MP and Fujitsu VP-200 supercomputers reveal features of the Fujitsu VP-200 FORTRAN compiler which are unmatched as yet in the Cray FORTRAN compiler. These features indicate Fujitsu's emphasis on user software requirements. I offer the following recommendation to strengthen the market penetration of U.S. firms:

> U.S. supercomputer firms should devote increased effort toward providing enhanced vectorized FORTRAN compilers and other user requested software tools. These tools are particularly important for low-end, less-sophisticated supercomputer users.

The use of wholly owned foreign subsidiaries for marketing and distribution of supercomputers is appropriate for most foreign countries. However, Japan is a country where joint ventures are more appropriate. U.S. supercomputer firms must strengthen their focus on the Japanese supercomputer market as

it emerges as the second largest world market. IBM-Japan, a wholly owned subsidiary of IBM, has had an increasingly difficult time maintaining its leadership position in the Japanese computer market. It is turning to an increasing number of joint ventures with Japanese firms to its their penetration in the Japanese computer market. The following recommendation is offered to strengthen sales of U.S. supercomputers in Japan:

> U.S. supercomputer firms should explore joint venture agreements with Japanese firms to strengthen their marketing of supercomputers in Japan.

The corporate strategy recommendations given in this chapter provide part of the foundation for the U.S. to retain its lead in supercomputers for the next decade.

CHAPTER 10

CONCLUSIONS

10.1 Will the U.S. Remain Preeminent in Supercomputers?

Projections given in Chapters 6 and 7, indicate that the supercomputer market will remain dominated by Cray Research, Inc. through 1987. The market strength of CDC/ETA Systems will fall during the next four years to a distant second. The remaining competitors will capture only 5 to 10% of market share.

The market positions of CDC/ETA Systems and Denelcor will depend on the implementation of key policy recommendations given in Chapter 9. Failure to provide indirect R&D support in the form of guaranteed purchases could severely impact the ability of ETA Systems and Denelcor to raise the necessary capital for development. Key government agencies are in the process of providing letters of intent to purchase supercomputers from ETA Systems and Denelcor. In the final analysis, ETA Systems and Denelcor success depends on passage of FY 1985 agency budgets which provide the funding necessary to implement the proposed supercomputer initiatives.

The ability of the Japanese firms to successfully develop supercomputers of performance equal to the Cray X/MP and Cyber 205 in only three years is a remarkable achievement. The Japanese firms will successfully penetrate the supercomputer

market by 1987, gaining a combined market share of 25%. The real threat from Japanese manufacturers will be the following round of product introductions. The Fujitsu VP 200 and Hitachi S-810/20 were developed with knowledge of Cray 1 and Cyber 205 architectures. Can the Japanese firms introduce innovative new supercomputers at the same time as U.S. firms, without prior knowledge of U.S. supercomputer architectures? The second round of the supercomputer "battle" should provide insight into whether Japanese supercomputer firms imitate or innovate. It seems unlikely that the Japanese firms will beat Cray Research, Inc. to the "market window". However, they may beat other U.S. supercomputer firms and obtain greater than 25% share of the 1987 supercomputer market.

Finally, the Japanese supercomputer firms (particularly Fujitsu and NEC) have developed powerful software tools to aid in debugging, vectorizing, and optimization. These software products have benefited from their mainframe software expertise. By contrast, U.S. supercomputer firms have developed high-speed hardware systems with little concern for user-friendly software products. The Japanese supercomputer software tools may contribute toward an expansion of the supercomputer market, particularly for less sophisticated users. This market expansion and the American supercomputer response to these software tools could allow the Japanese firms to obtain a larger market share.

10.2 Implications of Supercomputer Battle

In the early 1960's, IBM transferred the technology base it had developed for the Stretch supercomputer to subsequent development of the System 360. More recently, supercomputer developments in the U.S. have been conducted by small single business firms. Since these firms don't produce lower-speed products, the opportunities for technology transfer are limited. The architectures and technologies of supercomputers tend to diverge from mainframe computers. Therefore, the "flow-down" of supercomputer technology to lower-speed products has become less significant. The first Fujitsu and Hitachi supercomputers benefited from their mainframe technology. I do not believe that supercomputer development can be justified on the grounds of technology base benefits to future lower-speed products.

Fujitsu and Hitachi are currently marketing IBM compatible mainframe computers worldwide. These systems offer about twice the scalar performance of IBM's largest machines. Even with increased performance, the Japanese computer manufacturers have penetrated only 2 to 3% of the IBM-dominated worldwide mainframe computer market. The introduction of Fujitsu and Hitachi supercomputers with 30 times the vector performance of IBM's largest machines will create a strong incentive for high-end IBM customers to consider Japanese supercomputers. Additionally, IBM faces a perceived loss of prestige with the Japanese marketing of

supercomputers. In response, IBM is rumored to be developing array and vector attachments for its largest mainframe computers to provide performance in the 200 MFLOP range. While there have been no product announcements, the Hitachi and Fujitsu supercomputer introductions will force IBM to introduce low-end supercomputer products. IBM will probably offer systems with about half the computational performance of Fujitsu and Hitachi and still be successful. IBM's value-added marketing approach should ensure retention of its loyal customers. Hitachi and Fujitsu supercomputer market shares will be most strongly affected by IBM entry to the low-end of the supercomputer market. Since IBM computers are used as "front end" processors in a few existing supercomputer facilities, some of these existing Cray and CDC supercomputer users may also select IBM supercomputer equipment when it becomes available. IBM will only enter market segments with substantial volume. Therefore, they are expected to remain in the low-end of the supercomputer market. Japanese supercomputer strategies should not significantly impact the overall IBM computer market.

The size of the domestic Japanese supercomputer market is expected to exceed the size of the total European supercomputer market by 1987. These projections are based on increased use of supercomputers by Japanese aerospace, automotive, communications, electronic, and petroleum industries. In a similar fashion, the economic

competitiveness of U.S. industries will be tied to the increased usage of supercomputers for industrial R&D. The growth of supercomputer usage in the domestic U.S. petroleum industry was paced by the development of related exploration and production applications software. Today, nearly every domestic petroleum firm utilizes supercomputers to remain economically competitive. The growth of domestic civil supercomputer markets is paced by the support of universities to develop applications software and educate supercomputer scientists. Japanese government support of Japanese universities is consistent with rapid expansion of domestic Japanese supercomputer usage. U.S. government support of American universities to develop applied supercomputer software and educate supercomputer users is currently inadequate. Edward Knapp, director of the National Science Foundation (NSF), established a task force on Advanced Scientific Computing in September, 1983.(150) The objectives of this task force are to develop plans for providing university access to supercomputers, educate a new generation of computational scientists and engineers, and support academic research in the areas of computer architecture and supercomputer applications software. Hopefully, this task force will ensure adequate support of U.S. universities and researchers.

Computers, and particularly supercomputers, are essential to national security. This thesis projects Cray's dominance of

the supercomputer industry through 1987, with weakened domestic U.S. supercomputer competitors (i.e. CDC/ETA Systems and Denelcor). This weakening of Cray's domestic competitors, coupled with the strategic impacts of Fujitsu and Hitachi supercomputers on the IBM worldwide computer market, concern the national security community.(151) This community recommends more <u>direct R&D</u> support by the U.S. government for development of commercial supercomputers to ensure continued U.S. preeminence. I believe the recommendations in Chapter 9 will prove effective. IBM is watching the supercomputer market closely and is conducting considerable defensive R&D. If the Japanese supercomputer firms succeed in penetrating the supercomputer market (e.g., greater than 10 to 15 installations per year), then IBM will enter the market. IBM's actions would aid U.S. supercomputer manufacturers, since IBM would compete with IBM-compatible Fujitsu and Hitachi offerings.

<u>10.3 Industrial Policy Pathfinder</u>

A basic challenge facing the U.S. economy today is the alarming decline in U.S. productivity compared to other leading industrial nations. Non-R&D-intensive balance of trade data (steel, automobiles, textiles, and leather products) have experienced significant decline in the past 20 years. R&D -intensive balance of trade data is more favorable for this same period with all major competitors <u>except Japan</u>. While trade barriers account for a portion of this decline,

continued negative trade balances with Japan in R&D-intensive products is most alarming.

Business, labor, and political leaders are searching for a U.S. industrial policy. Although the U.S. has not previously supported explicit industrial policy, the U.S. has taken a number of implicit industrial policy actions in agriculture, aerospace, electronics, computers, and textiles. These government policies include a wide variety of alternatives, including support of R&D, purchasing products, tariffs, quotas, and regional assistance. Current U.S. "industrial policy" is primarily a reaction to industry-by-industry requests for protection. Few high-growth segments have requested government assistance. High-growth "industrial policy" has generally been driven by government agency requirements. Efforts to develop growth industries have been more successful than efforts to protect weak industries. Generally, U.S. "industrial policy" lacks overall coordination.

The authority for government policy is decentralized and fragmented among the branches of the federal, state, and local government agencies. Badaracco and Yoffie argue that strengths of this fragmented system include the ability to examine complex issues from many positions and the ability to avoid costly single objective programs for maximum short-term impact.(152) European governments have become increasingly

committed to large single objective high-priced programs (e.g., the Concorde SST program and the $4 billion yearly subsidies to the European steel industries). Based on the strengths of the decentralized American political system, the U.S. government should respond to industrial policy issues by change from within the current political system rather than radical change.

Quinn believes a first step in U.S. "industrial policy" should be a coordinated effort among government agencies to strengthen innovation.(153) The OSTP supercomputer recommendations were developed through coordination of key government agencies to strengthen innovation in the supercomputer industry. While these recommendations address a single industry, they do serve a pathfinding role for a new era in U.S. high-technology industrial policy. The OSTP supercomputer policy is unique in the Reagan administration, because it represents an effort to stimulate a healthy high-technology industry. The OSTP has gone a long way toward formulating a national supercomputer policy. The recommendations from the OSTP group demonstrate that the government can develop responsive industrial policy for high-technology industries.

Japanese support of other "strategic" high-growth industries has proven successful in recent years. In a similar fashion, I believe the U.S. should consider a permanent White House

domestic policy office, solely responsible for coordination and oversight of U.S. high-technology industrial policy. This policy office should explore methods of stimulating high-technology industries, particularly those which do not currently have government agency support. The important role of indirect R&D support in the OSTP supercomputer policy suggests that government policy can be effective in stimulating entrepreneurial innovation without direct government investment in R&D.

In addition, direct government R&D investment should be considered for selected R&D-intensive industry situations. The Reagan administration has examined direct government R&D investment in the U.S. aviation industry. In its report on aeronautical research and technology policy, the OSTP concluded that the government role should include research and technology demonstration, while the industry role should provide for system development.(154) This report clarifies the government role in R&D support and provides a precedence for other U.S. R&D-intensive industries seeking direct government R&D investment.

Finally, the key lesson learned from the U.S. - Japanese supercomputer "battle" is that preeminent, R&D-intensive industries can be penetrated by strong foreign government-industry strategies. American industry, universities and the U.S. government must begin to work together to develop

effective industry strategies. The U.S. should support a more comprehensive "industry policy" which will provide for the strengthening of our high-growth, R&D-intensive industries. If this nation is to remain economically competitive, the U.S. can not afford to neglect its strong industries.

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