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The Supercomputer Industry Development, Government Involvement, and Implications For The Future

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ABSTRACT

This research paper examines the supercomputer industry from the perspective of U.S. Government involvement. The last ten years of Legislative and Executive branch action relative to the supercomputer industry are discussed. In addition, the current state of the industry is analyzed, as well as how Government involvement has influenced its evolution. Finally, recommendations regarding the future role which should be played by the Federal Government in the supercomputer industry are made. The specific areas requiring future action in this industry which are presented in this paper are as follows:

* establishing a coherent supercomputer policy;
* dealing effectively with foreign competition;
* technology transfer issues; and
* acquisition issues

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INTRODUCTION

Supercomputers. In todays rapidly evolving world of information systems technology, the word itself still implies something almost futuristic. It also implies something very large, very powerful, very complex and very expensive. Both of these images contain a great deal of truth.

The supercomputer industry is an industry that has undergone a great deal of transformation in the last ten years or so; from one of essentially U.S. domination to one of a globally competitive environment. This has serious implications for our national security as well for our continued technological development.

In this paper, I will examine how the industry has evolved, within the United States and elsewhere, and what role the U.S. Government has played to date in helping to shape the industry. Additionally, I will explore the industry today (including how it evolved), as well as the prospects for the future for American supercomputer firms. Finally, I hope to identify areas where the U.S. Government should play a different, or perhaps expanded or lessened role in this industry in the remainder of the 1990's.

The paper is organized into several sections, beginning with a description of what a supercomputer is and a delineation of the commercial and Government uses for them. Next, the involvement of the legislative branch of the Government for the last ten years is discussed. A short history of the development of the supercomputer is provided, followed by a discussion of the condition of the two major portions of the industry; 1) conventional supercomputers, and 2) massively parallel processors. Finally, current Government policies towards supercomputers are discussed as well as supercomputer and supercomputer industry issues for today and the future.

WHAT IS A SUPERCOMPUTER?

Although supercomputers have been in existence for many years, and the term is used universally, the definition of what a supercomputer is remains rather nebulous. It has also remained this way for many years. In a 1983 hearing before the House Committee on Science and Technology Dr. John Gibbons, at the time Director of the Office of Technology Assessment stated, "In short, supercomputers are the largest, most powerful computers currently available."[1] This basic definition has been maintained over the years, as evidenced by the definition in the 1987 book **The Supercomputer Era**; "A supercomputer is the most powerful computer available at any given time."[2] This definition, however, has caused confusion over the years because it necessitates comparisons. This problem is becoming more prevalent today with the advent of minisupercomputers, high-performance workstations, and special-purpose computers. Such a vague definition also can cause problems when policies for the industry are defined. It is important to ensure that the appropriate policies target the right component of a very diverse industry; i.e., the information systems industry.

Even though there are potential problems, there isn't a better definition of supercomputers. When discussing supercomputers in this paper, I will be referring to the fastest and most powerful computers in terms of performance -- i.e., speed, accessible memory, etc. Speed is most often the identifier of a supercomputer as well as a comparative measure of its performance. "One basic measure of computer performance is the rate at which it carries out floating point operations, essential for accurate, high speed mathematical calculations. The counter for this is FLOPS, which stands for floating point operations per second. Any computer likely to be compared seriously with supercomputers is capable of at least a million such operations in one second, so performance is measured in megaflops."[3] Using this context, I will be examining only those companies which produce supercomputers which operate in the megaflop range, and above.

WHAT ARE THE USES FOR SUPERCOMPUTERS?

Because of the extreme speed of todays supercomputers, it would seem that they would be everywhere and used for almost everything requiring a large capabiblity for compute power. However, "it is important to remember that supercomputers are not universally superior and not always the most cost-effective tool. For many purposes, computers with more limited capability are as good, or better, and are likely to be easier to use."[4]

Even though they are not suitable for all purposes, supercomputers have many varied uses and in todays world are an absolute necessity for many tasks. "First used for cryptography and nuclear physics, supercomputers are quickly becoming indispensable to virtually every branch of science and engineering. Their ability to simulate all physical phenomena provides a new scientific method that joins theory and experimentation."[5] Future applications in science alone are immense and the potential is almost limitless. "The hyperfast machines can model virtually any phenomena in the physical world that can be described with mathematical formulas -- from subatomic collisions, to the Earth's warming atmosphere, to quasars at the end of the universe."[6]

COMMERCIAL SUPERCOMPUTER USES

In various testimony in 1991 before the Senate Committee on Commerce, Science and Transportation, many current supercomputer uses and applications were described. Some of the commercial uses are;

- supercomputers test advanced aircraft design, proposed new drugs, new manufacturing techniques, understanding of the Earth's climate and weather, and evolution of the galaxy,
- supercomputing could lead to a better understanding of AIDS, cancer and many other diseases,
- supercomputers are now used routinely for design and crash tests by auto companies; they are also used for handling and braking simulation, fuel economy, emissions and aerodynamics testing;their use allows auto companies to explore several designs before selecting one for use in prototyping, thereby saving on both design, testing time and cost,
- supercomputers are used by energy companies to analyze seismic data and prospect for oil, and by financial markets

for real-time analysis of market behavior and trading opportunities,

- engines on the Boeing 737 were designed by a supercomputer and became 30% more efficient than earlier models,

- future library and communications uses are possible since supercomputers can store and sort through tremendous quantities of data -- and can then electronically retrieve the data in a matter of seconds,

- other potential uses in the fields of biochemistry, physics, chemistry, geology, medicine and engineering will undoubtedly emerge.[7]

GOVERNMENT SUPERCOMPUTER USES

The Federal Government has been perhaps the most extensive user of supercomputers since their emergence onto the market. Some of the absolutely essential uses for supercomputers in the Government sector are:

- the National Security Agency (NSA) relies on the fastest and most most sophisticated supercomputers for use in signals analysis, codebreaking, and communications security;

- supercomputers are essential for use in anti-submarine warfare and for the design of many advanced weapon systems, as well as for supporting the scientific computational needs of other defense weapon systems development;

- many aspects of the Strategic Defense Initiative (SDI) and other military research and development projects rely heavily on supercomputer modeling;

- the National Aeronautics and Space Administration (NASA) utilizes supercomputers to simulate the aerodynamics of aircraft and spacecraft; and

- supercomputers have played a major role in the design and analysis of nuclear weapons, most prominently at the Department of Energy's Los Alamos National Laboratory (LANL), and Lawrence Livermore National Laboratory (LLNL).

FEDERAL GOVERNMENT INVOLVEMENT IN THE SUPERCOMPUTER INDUSTRY

In the earliest days of supercomputer development there was little active involvement by the legislative branch of the Federal Government. However, as new needs were identified, the ability of U.S. firms to meet these needs were questioned, and foreign competitors announced far-reaching programs emphasizing high-performance computer development, the U.S. Federal Government began to get involved in the supercomputer industry in ways other than simply buying machines. Some of the more significant issues which were addressed at the Federal level over the last ten years follow.

1983

Almost ten years ago, in hearings before the U.S. House of Representatives Committee on Science and Technology, two broad concerns of the United States relative to supercomputers were summed up by Representative Larry Winn of Kansas. They were:

> "One, the use of the supercomputer in the United States is not necessarily widely distributed. Access to supercomputer facilities is limited primarily to weapons research with its necessary security, to one or two fundamental research programs within the Department of Energy, to environmental forecasting, and to proprietary usage in petroleum exploration. So a large number of basic, fundamental research projects progress at inefficient rates due to lack of adequate computational capability. I strongly feel that we must explore the avenues by which we make this needed computer capability available to our scientists in industry, colleges and universities."

> "The second area of concern is that the United States leadership in supercomputer development and marketing is being challenged by foreign countries, particularly the Japanese. That country has established a joint Government-Industry program with a commitment that extends into the next decade. The effort of the program is clear cut and well defined. This strong program definition and commitment of nearly one-half billion dollars exceeds any coordinated program in this country at this time."[8]

The first concern identified by Rep. Winn also implied that the United States was fostering a future of little expertise in the supercomputer field. Because of the limited number of supercomputers, their predominance in specialized areas of the Defense and Energy Departments, and little availability elsewhere, the U.S. was not developing a future cadre of professionals capable of either developing new supercomputer systems or of using existing ones to their fullest extent. Dr. Paul Schneck, representing the Scientific Supercomputer Committee of the United States Activities Board of the Institute of Electrical and Electronic Engineers expanded on this important issue. "The United States is educating and training a generation of scientists and engineers with no experience in the use of supercomputers. We are not preparing the science and engineering community to work with the most advanced machines that are available. The Committee believes that much broader use of supercomputers is essential and can be accomplished only if more trained people are available."[9] Recommendations were made to establish supercomputer centers at various sites around the country to allow access to scientists, engineers and students.

The second concern centered around the emergence of an outside threat, that of a strong Japanese interest in becoming the leader in the supercomputer industry. Ironically, this concern has steadily increased over the last ten years. Even in 1983, however, the implications were clear concerning the viability of the Japanese threat. As stated by George Kozmetsky of the University of Texas at Austin, "Only Japan has firm and dedicated funding for ten years. The U.S. firm funding is dependent upon the market and the individual firm's ability to generate earnings."[10] In addition, it was observed that while U.S. firms targeted technological breakthroughs, the Japanese targeted specific markets. As will be discussed later, these two differences have definitely affected the look of the supercomputer industry today.

As a result of the hearings in 1983, the National Science Foundation (NSF) received $6 million in their fiscal year 1984 budget to begin the establishment of a network of supercomputers to provide access to researchers in many fields. Supercomputer centers founded under this program are still in existence and are receiving Government funding today.

1985

In 1985 hearings before the U.S. House of Representatives Committee on Science and Technology, the same concerns which were expressed in 1983 were resoundingly reaffirmed. For example, Mr. Henry Zanardelli, manager of Engineering and Product Data Systems at Ford Motor Company testified that the, "use of supercomputers in American industry may be restricted not by hardware or software limitations, but by the limited number of people that have the know-how to use them. More students have to be graduated with an understanding of the supercomputer."[11] Federal dollars were given to the NSF beginning in FY1984 to initiate this very concept. But Mr. Zanardelli summed up his and others' concern in this area when he stated that, "while the Government is to be congratulated for its recent initiatives to foster supercomputer research at a few large, prestigious schools, I believe more is needed in the way of aid to the smaller institutions who together produce the bulk of our engineering graduates."[12] These hearings also summarized the results of three major studies which all pointed to the need for greater supercomputer access. These were the LAX report, which examined the computational needs of those in the science and engineering fields; the NSF Working Group on Computers in Research; and the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET).

The concern of increased emphasis by the Japanese in the supercomputer industry was also reinforced. For example, it was pointed out that universities in Japan were always the recipients of the first supercomputers produced by any Japanese Company. By doing so, the Japanese were making an early commitment not only to have extensive applications run on their machines, but also to get as much access to them as possible for future scientists, engineers, and computer scientists.[13] The future threat of Japanese competition was also seen to be potentially severe. Many in the U.S. industry felt at this time that it would be easier for

Japanese companies to enter and even increase their position in the world market than it would be for U.S. firms. Finally, the Japanese Government was continuing to fund a portion of the R&D costs of the industry.[14]

These hearings also emphasized the fact that the generation of supercomputers in the United States to date, had largely resulted from a private sector undertaking. Even though the Government was the greatest user in the 1985 time frame, purchasing or leasing greater than 50% of the machines in service in the U.S., private industry had essentially borne all of the R&D costs themselves.[15] Relative to this issue, perhaps the most telling argument for Government involvement was made by George Kozmetsky of the University of Texas at Austin when he said,

> "The supercomputer is the single greatest impact on world communication, automated factories, health care delivery, biotechnology production, renewal of basic industry, and heightened productivity of the service industry, including Government. The real task is to develop appropriately integrated policies, regulations and support mechanisms that extend the U.S. computer/communications industry. The commercialization of supercomputers for the global market is so tightly structured from scientific exploration to ultimate use, regeneration time is so short, investment so large, and risks so great, that we cannot leave policy consideration to evolve accidentally and independently as in the past."[16]

Yet, as will be shown later, there is still a lack of a definitive policy on supercomputers, even though it is being actively pursued by some.

During this time frame, three major initiatives were in the formative stages regarding Government sponsorship of programs supporting supercomputer concerns in the United States:

1. The National Security Agency announced the establishment of the

Supercomputer Research Center to be built at the Maryland Science and Technology Center by the Institute for Defense Analysis (IDA). The center would conduct supercomputer research as well as develop future applications for supercomputers. This center is still in operation today.

2. The National Science Foundation, using funds appropriated by Congress beginning in FY1984, was in the process of establishing the first three supercomputer centers in the U.S. The intent was to establish a network of supercomputers which could be accessed by researchers, engineers, and scientists in many fields. As stated previously, four of these centers are still in existence today.
3. The Defense Advanced Research and Programs Agency (DARPA), had begun a program for the Strategic Computing Initiative (SCI), also utilizing funds appropriated by Congress for this purpose. This program was designed to develop artificial intelligence applications using university supercomputer research.

1991

Hearings before the Senate Committee on Commerce, Science, and Technology in May, 1991, surfaced many of the same concerns relative to high-performance computing and supercomputers as in prior years. Once again, there was a great deal of testimony which centered on the Japanese focus on supercomputer development and their desire to be in the forefront of the supercomputer industry.

In April, 1990, for instance, Japan launched a major research program to accelerate R&D on the newest technology, parallel processing supercomputers.[17]

In addition, other emerging supercomputer programs were identified as threatening the United State's preeminence in the industry. In March, 1990, the European Community announced a $1.3 billion per year high-performance computing program to fund high-speed network development, supercomputing centers, supercomputer hardware and software development, supercomputer applications, and education.[18]

During these hearings, also, success in the high-performance computing and supercomputer arenas was discussed as a key to future U.S. well being in other areas. The 1990 White House Science Council report stated, "any eountry which seeks to control its future must effectively exploit high performance computing. A country which aspires to military leadership must dominate, if not control, high performance computing. A country seeking economic strength in the information age must lead in the development and application of high performance computing in industry and research."[19] The President's Science Advisor, Allan Bromley added, "high performance computing must be a high priority because it has a catalytic effect on just about any branch of research and development and will eventually transform industry, education, and virtually every sector of our economy, bringing higher productivity and enhanced competitiveness.[20]

During this time period, high-performance computing and supercomputers are being viewed as instrumental in fostering the economic well being of the U.S. as well as being a key ingredient to the U.S.'s current and future technological competitiveness. In addition, the case was being made that without additional federal and private investment, the U.S. risks losing its superiority in the $2.4 billion world supercomputer market and would then have to rely on foreign suppliers for enhancing U.S. competitiveness and ensuring national security.[21] The case for federal involvement was summed up by the Office of Technology Assessment of the Congress in April 1992 when it provided the following reasons:

1. First, researchers cannot consistently obtain needed information resources because of the cost. High-end scientific computers cost several million dollars to purchase and millions more per year to operate;

2. Second, information resources -- computers, databases, and software -- are being shared among disciplines, institutions, and facilities. A need has grown for better coordination in the design and operation of these systems;

3. Third, although the U.S. computer industry is relatively strong, there is concern about increasing competition from foreign firms, particularly Japanese. During the last two years there have been difficult trade negotiations between the United States and Japan over supercomputer markets in the respective countries. This has raised concern about the economic and strategic importance of a healthy U.S. high-performance computing industry; and

4. Fourth, concern for the Japanese challenge in high-performance computing goes beyond the competitiveness of the U.S. supercomputer industry. It is in the availability and application of high-performance computing to increase productivity and improve product quality where the greatest future economic benefits may lie.[22]

DEVELOPMENT OF THE SUPERCOMPUTER INDUSTRY

With an identification of the history of the major legislative concerns about the supercomputer industry, and before evaluating current and potential future policies, it is necessary to look at the state of the supercomputer industry. The first step is to examine the evolution of the industry.

Although large, fast mainframe computers existed before, the evolution of the supercomputer probably began at Control Data Corporation with the CDC 6600. This computer, introduced commercially in 1963, was capable of executing 3 million program instructions per second. It was followed in 1968 by the CDC 7600, which was capable of executing 15 million program instructions per second. These computers were faster and more powerful than anything else available from any other manufacturer, even IBM. IBM, interestingly, made a conscious management decision not to compete in the supercomputer arena.

Another important early contributor to the development of supercomputers (especially during the 1960's and 1970's) were U.S. universities. Perhaps the major player at this time was Dr. Daniel Slotnick at the University of Illinois. He developed a supercomputer called the ILLIAC IV by using many processors in order to achieve high performance. He thus demonstrated an early version of a parallel processor even before the traditional vector processors emerged as the standard. In fact, the ILLIAC IV was used at NASA's Ames Research Center during the early to mid 1970's.

Other university researchers also had a significant impact on the development of the industry.

However, the introduction of the Cray 1 supercomputer in 1976 marked the true beginning of the supercomputer era. The Cray 1 was, "the first commercially successful vector processor which executed not one, but 32 arithmetic operations at a time. The result; a computer one-fourth the size of the CDC 7600 that could do ten times the work."[23] The Cray 1 has long since remained the benchmark by which supercomputers and their performance have been rated. Since that time, also, Cray Research Inc., the company which designed and introduced the Cray 1, has remained the leader in the supercomputer industry that, until recently, has been dominated by the vector processor design.

Since 1976, there have been very few new entries into the supercomputer business and some notable failed attempts. During the 1983 House of Representatives Hearings, the supercomputer market was defined as the following manufacturers: Cray Research, Control Data Corporation, and Denelcor in the United States; and Fujitsu, Ltd. and Hitachi Data Sytems Corp., in Japan. In 1985, the market was virtually the same, but for two changes. Control Data had spun off its supercomputer business to a susidiary Corporation, ETA, and a new Japanese entrant to the market had emerged, Nippon Electric Corp. (NEC).

CONVENTIONAL SUPERCOMPUTER MARKET

Today the market for traditional vector type supercomputers shows some significant changes. Both Denelcor and ETA have closed their doors, each having sold only a handful of machines. Cray Research, Inc. remains the world leader in the conventional supercomputer arena, however several changes have occurred. The founder of Cray Research, Inc., Seymour Cray left the company to pursue his current project, the Cray 3, and formed Cray Computer Corporation. Another former Cray Research designer, Steve S. Chen left Cray Research, Inc. in 1987 and formed Supercomputer Systems Inc. (SSI). SSI was being backed by IBM (along with several other minor corporate investors), both with financial assistance as well as with component technology. To date, neither Cray Computer Corporation nor SSI has delivered a single product. Convex Computer Corp., which began as a producer of minisupercomputers has entered the market by producing some higher powered machines, but their market share remains quite small. The Japanese companies, Fujitsu. Ltd., Hitachi Corp., and Nippon Electric Corp. (NEC) are all still involved in the supercomputer business and are actively seeking an increased position in the industry, apparently with strong Government backing.

Additionally, both Cray Computer Corp. and SSI appear to be in serious financial difficulty. In December, 1991, "Lawrence Livermore National Laboratory, tired of delays, canceled Cray Computer Corp.'s one and only order for a Cray 3 supercomputer.

Then on April, 16, Neil Davenport, the company's president and chief executive, up and quit. With no sales, no orders on hand, no working prototype, and no CEO, Cray Computer's short run looks as if it's about finished."[24]

At Steve Chen's SSI, the problem is even worse. At the end of January, 1993, IBM announced that it was terminating the financial support which it had been providing to Supercomputer Systems,Inc. for the past five years. At the time it appeared that SSI was already more than two years behind its original development schedule and significantly over budget. According to some industry estimates IBM had provided SSI with more than $100 million.[25]

Less than a week after IBM made its announcement, SSI closed its doors and left its approximately 300 employees jobless. "We were left with no alternative but to terminate our project at this point," said Steve Chen. Mr. Chen added that he could not find an investment banker willing to raise money through an SSI stock offering, and a worldwide search for new investors willing to provide the $60 million needed for continuing operations through 1993 was also unsuccessful.[26]

Both of these cases are illustrative of the difficulties involved in establishing a company in the conventional supercomputer business. There are extremely high start up costs and very long design and production times, not to mention complex technical problems that must be solved. Yet throughout the initial development time sales are rarely generated because the market is waiting to see if the supercomputer will work at all, will be affordable, programmable, etc. These two cases are also particularly disturbing since they involve two of the United State's preeminent supercomputer designers. If they cannot succeed, who can? Finally, if they fail, as now appears likely, the United States will have only two viable competitors in the traditional supercomputer industry, Cray Research, Inc. and Convex Computer Corp. This hardly seems optimal, considering the importance many are giving to high-performance computing in the future and how it could impact our nation's economic outlook and national security in the years ahead.

MASSIVELY PARALLEL SUPERCOMPUTER MARKET

Perhaps the biggest recent change to the supercomputer industry has been in the evolution of the massively parrallel processor (MPP) version of the supercomputer. "In essence, MPP calls for ganging together dozens, hundreds or even thousands of cheap, powerful microprocessors to attack large computing problems en masse. Choregraphed with the right software, 100 small processors can often execute large programs in a fraction of the time it would take even the fastest traditional supercomputer to run them in serial fashion, one instruction at a time. And they can do the work in a tenth or even a twentieth of the cost of mainframes and traditional supers."[27] The market for MPP's however is still in its infant stages even though the technique has been around for at least ten years. "At present, there is not much difference between the performance that the most powerful massively parrallel processors (MPP's) and the most powerful conventional supercomputers can sustain on actual problems."[28] The industry has also made slow improvements in providing software that will allow customers to use the machine's capabilities effectively. Regarding MPP's, "many agree that, despite recent improvements, programming them to run efficiently remains a challenge."[29] Only certain special kinds of problems seem to lend themselves to a massively parallel approach. Some of these applications are extremely important, however.

To date the MPP market has been dominated by American firms although there is clear evidence that both Japanese and European firms are actively pursuing parallel processing technology. Currently, the major U.S. players in the MPP arena are Intel Supercomputers, Thinking Machines Corp., Maspar, Inc., N-Cube Corp., Kendall Square Research, and Wavetracer, Inc. In addition, Cray Research, Inc., Convex Computer Corp. and IBM, Inc. have all announced major efforts which are underway in the parallel processing arena. In the European market, Meiko Scientific Corp., and Parsytec have introduced successful MPP supercomputers. Finally, in Japan, all three of the major traditional supercomputer manufacturers (Hitachi, Fujitsu, and NEC) have active programs to produce their own versions of MPP supercomputers.

It is worth noting, however, that, as with the traditional supercomputer industry (and even though startup costs and potential development timeframes may be less), the MPP arena is also quite risky. "A number of ventures have already failed, even though MPP's as an industry segment are only about six years old. The failed efforts include MPP ventures at Alliant Computer Systems, Bolt, Beranek and Newman, and Ametek in the United States; Suprenum in Europe; and Myrias in Canada. In July, Active Memory Technology Inc., an Irvine, Calif.-based MPP company, filed for protection under chapter 11 of the bankruptcy code."[30]

Charts depicting the market shares held by the major supercomputer companies in both the traditional and massively parallel portions of the industry (for 1990 and 1991) are shown in attachments 1 and 2.

CURRENT GOVERNMENT INITIATIVES INVOLVING SUPERCOMPUTERS

Current U.S. Government activities and sponsorship in the supercomputer area involve several initiatives. They include the High Performance Computing and Communications Intitiative (HPCCI), the National Science Foundations' continued funding of supercomputer centers, the Cooperative Research and Development Agreement (CRADA), and the involvement of the United States Trade Representative (USTR) in attempting to open Japanese markets to U.S. supercomputers.

HPCCI

The High Performance Computing and Communications Act was passed in late 1991. "This bill will provide $2 billion over the next five years to fund supercomputing research and training to solve the so-called grand challenges of big science and engineering. Supporters have likened this infrastructure investment to the interstate highway construction program of the Eisenhower years."[31]

The program is also expected to provide significant economic benefits to the country. For instance, a study performed by the Gartner Group in Stamford, Connecticut, "estimates that newer, faster computers and networks could increase annual productivity in the aerospace, chemical, electronics, petroleum, and pharmaceutical industries by up to five percent a year, and boost the Gross National Product by slightly more than $500 billion in the 1990's."[32]

The program calls for a multi Agency effort and five years of funding for high-performance computing, hardware and software development, networking, and education and training in high-performance computing and supercomputers. The Agencies involved include: the National Science Foundation (NSF), the Defense Advanced Research and Projects Agency (DARPA), the National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE). In addition, the bill encourages other federal agencies and departments to procure early production or prototypes of new high-performance computer systems.[33]

Finally, the HPCCI has as one of its major goals, the establishment of a National Research and Education Network (NREN).

Specifically, the NREN is, "the future realization of an interconnected gigabit computer network system supporting HPCC. The NREN is intended to revolutionize the ability of U.S. researchers and educators to carry out collaborative research and education activities, regardless of the physical location of the participants or the computational resources to be used. As its name implies, NREN is a network for research and education, not general purpose communications."[34]

This program will allow access to all university users, not merely those students and researchers physically located at the supercomputer centers. However, it will also require the development of quite sophisticated networks because of the high data rates involved.

SUPERCOMPUTER CENTERS

"In February, 1985, the National Science Foundation selected four sites to establish national supercomputing centers: Cornell University, the University of Illinois at Urbana-Champaign, the University of California at San Diego, and the John Von Neumann Center in Princeton. A fifth site, Pittsburgh was added in early 1986. Funding for Princeton's Von Neumann Center was later dropped."[35] The centers have been quite successful in bringing together scientific and industrial researchers as well as academicians to work problems in many areas and to become educated about supercomputer technology. The NSF continues to fund the centers (to the tune of about $60 million in 1991), but it is not adequate to keep up with rapid technology advances. For example, "the four supercomputer centers supported by the NSF are struggling to find the money to invest in faster types of supercomputers, perhaps even at the risk of doing away with some of their well-used traditional machines."[36] In response, the NSF has said that it cannot increase significantly its support for the supercomputer centers. This dilemma may cause the centers to choose between competing technologies. Having to do so at this critical juncture (when the MPP market is just beginning and the traditional market is in some trouble) may in fact undermine the reasons the centers were established -- to provide access by a wide range of users to a wide range of technology.

CRADA

The Cooperative Research and Development Agreement allows the Department of Energy to release some of its previously classified advanced technology to the commercial sector. The hope is that the release of this information will spur additional commercial uses for specific applications that have already been developed. "The benefits are obvious, not only to the end user. The technologies transferred from the laboratories to the commercial sector is clearly important to U.S. competitiveness in the world economy."[37] However, many have reservations about the release of the information since much of it was geared toward the development and testing of nuclear weapons.

UNITED STATES/JAPAN SUPERCOMPUTER TRADE AGREEMENTS

The disputes about the acquisition of Japanese supercomputers by Americans and vice versa generally represent a microcosm of Japanese/U.S. trade tensions. United States manufacturers have claimed a lack of access to the Japanese market. In response to these complaints, "the US Trade Representative (USTR) has negotiated two agreements with Japan to open the Japanese market to US supercomputers. The first, in 1987, was generally ineffective, despite an attempt by the Japanese Government to ease tensions by hurriedly buying three machines. The 1990 agreement is considered better, but since then US companies have won only three of nine Japanese public-sector bids, despite the generally accepted technical superiority of US machines."[38] This issue, as well as that of easing export restrictions and potentially allowing supercomputer sales to China, Russia and other eastern European countries, will be discussed in greater detail in the next section

SUPERCOMPUTER INDUSTRY ISSUES OF TODAY AND FOR THE FUTURE

POLICY

Without a doubt, the most pressing issue regarding supercomputers, both today and in the future, is the role (or nonrole) that should be played by the Government. Once again, this is only a subset of a larger question; i.e., should the Government play a role at all in establishing a technology policy? The passage of the HPCCI notwithstanding, many still argue that the development of information services and products should be left entirely up to the private sector. The uniqeness of the industry, both from a cost standpoint as well as from the standpoint of potential uses, I would argue, calls for Government involvement.

The strong support within Congress for the HPCCI emphasized that the federal Government will have a role in the further development of the supercomputer industry. Those who support the continued involvement of the Government point out that, "the dominant position of the U.S. supercomputer industry has historically resulted from heavy federal investments in computing for research and that the future health of the industry will require continued federal attention."[39] In addition it is argued that, "U.S. economic growth and societal strength can be assisted by the development of a national information infrastructure that couples a high-speed data communication network with a wide range of powerful computational and information resources."[40] With federal involvement in the continued development of the supercomputer industry this particular goal will be enhanced and its achievement time significantly shortened. With many more potential uses for supercomputers, as well as a fragile industry in the U.S., the words of George Kozmetsky in 1985 ring more true today. We cannot leave supercomputer policy to evolve accidentally or independently.

In order for the Government to have an effective impact in the policy area, though, there must be more. Representative George E. Brown Jr., the Chairman of the House Science and Technology Committee summed up the concern when he called for increased understanding of the implications of the HPCCI. Merely "stapling together of several agencies' budget requests does not necessarily make a coherent technology policy."[41] What is needed is a concrete policy on Government involvement in the supercomputer industry as well as a focal point within the Federal Government to coordinate and act upon that policy. This policy should in no way restrict the ability of individual Agencies to pursue the acquisition of specific supercomputers which meet their needs, but should provide oversight for implementation of the Government's overall supercomputing needs. Specifically, the Government policy focal point on supercomputing should deal with pertinent issues such as preventing the HPCCI from being used by individual Agencies to promote their own parochial interests, ensuring that all promising architectures are explored, helping in the transfer of technology between Government, industry, and academia, and ensuring that critical defense technologies are protected.

This policy would decrease the role which the Department of Defense will play in the future development of supercomputer technology. And it should. No one would argue that the uses for supercomputers probably began with the needs of weapons systems designers and intelligence users. But now their uses transcend many industries and the future possibilities are virtually limitless. In addition, declining defense budgets will reduce the ability of the DOD to continue to be the champion of supercomputer development as it has been in the past. Yet we must not lose sight of the continued importance supercomputers have and will continue to have to the DOD world and of their potential value to those who harbor intentions of major weapons development.

Finally, in this area, a policy must address the uniqueness of the industry itself. Guaranteeing that different technologies are pursued is one aspect. Recognizing the difficulty of entry into the market and low survival rates of potential companies is another. High start-up and operating costs, state-of-the-art development in many technologies simultaneously, extremely long development time frames (many years), and the potential of a limited quantity of sales even if successful, make this industry truly unique. Any successful supercomputer policy must deal effectively with these facts.

FOREIGN COMPETITION

Over the last decade, the Japanese Government has supported several programs designed to support and strengthen the Japanese position in the supercomputer marketplace. Perhaps the best known was the "Fifth Generation Computer Systems Project." This project was, "initiated to conquer the challenges of artificial-intelligence-based parallel computing, and to put Japan on the advanced research and development map."[42] The program was sponsored by the Japanese Government through the Ministry of International Trade and Industry (MITI). Although unsuccessful in its attempt to develop the next-generation computer or supercomputer, the program certainly illustrates Japan's willingness to provide strong Government sponsorship of its high performance computing initiatives. In addition, prominent individuals in Japanese industry have made the following observation about the fifth generation program: "because it was Government-sponsored, we were able to participate in pre-competitive R&D that we wouldn't have been able to do on our own." [43]

At the same time foreign competition in the supercomputer market is becoming more fierce. Fujitsu "has announced its reentry into the U.S. supercomputer market after a three year absence. Fujitsu computers were available in the United States through Amdahl in Sunnyvale, Calif. but that distribution agreement terminated in 1989."[44] This time the company will sell directly through its American operation. Thomas Miller, vice president of sales and marketing for Fujitsu America's supercomputer group said, "we've been hearing a lot from supercomputer users about how the U.S. market needs competition and that we ought to be here. We see things that we can do that will bring considerable success. We can give any of the established vendors pretty good competition."[45]

Nippon Electric Corp. (NEC) has entered into a teaming arrangement with Control Data Corporation to market their line of supercomputers in the United States. This move is obviously intended to access new U.S. markets for NEC machines. NEC was also successful in becoming the first foreign supplier to bid on a U.S. Federal Government procurement for a supercomputer when it bid on a supercomputer for NASA's Ames laboratory. "Competition for the Ames contract was opened to foreign suppliers by the GSA Board of Contract Appeals, which upheld a NEC bid protest challenging NASA's restricting that buy to U.S. companies."[46]

These trends certainly suggest a marked increase in interest in the U.S. supercomputer market by Japanese supercomputer manufacturers. This increase cannot be ignored and to date the issue has received piecemeal consideration by the U.S. Government. Once again, the issue is related to others of technology policy; i.e., protection of free trade, and access to foreign markets. A clear strategy and comprehensive Government policy for the future are musts, however, as part of the U.S.'s high-performance computing program of the future.

It is interesting to note that the U.S. fear of increasing competition from the Japanese in the supercomputer industry has been a topic of discussion since the first Congressional supercomputer hearings in 1983. But specific strategies and policies to deal effectively with the issue have been relatively few and, at times, at odds with each other. Two of the more basic issues have recently reemerged in two separate cases involving the preeminent Japanese and American supercomputer companies, NEC and Cray Research.

The first involves the Government's decision to allow NEC to bid on a supercomputer acquisition for NASA's Ames laboratory. "The prospect of a Japanese supercomputer at the heart of one of the last areas where America enjoys a technological advantage raises sensitive issues of national security and trade policies."[47] If the U.S. Government is going to allow the Japanese to bid on U.S. Federal Government supercomputer requirements, specific circumstances must be defined when it is acceptable and when not due to security constraints. So far, no foreign competitor has succeeded in supplying the U.S. Government with a supercomputer (the Ames contract mentioned above was awarded to Cray Research Inc.). But with the Japanese commitment to supply them in the U.S. continuing to get stronger, it is only a matter of time. If we allow foreign competitors to bid, we must be in a position to accept the consequences when they win. To date, it appears that we are not. This issue will continue to grow in importance in the near future as the Government spends more money on supercomputing in accordance with the HPCCI.

The second issue relates to the aspect of free trade. According to Representative John Conyers of the House Government Operations Committee, "the Japanese Government supercomputer market remains closed to U.S. companies even though the administration is protecting the rights of Japanese companies to participate in the U.S."[48] The current example involves the decision by Japan's National Institute for Fusion Research to lease a NEC supercomputer instead of one from Cray Research, Inc. Cray protested the award but it was sustained by a panel of Japanese experts. Yet Cray's contention that, in a fair competition they win everywhere but in

Japan, is borne out by statistics. "Cray is the undisputed leader in large supercomputers, holding 67% of the world market. Fujitsu Ltd. comes in second at 20%, and NEC third at 6%. But look at Cray's track record in Japan. Thanks to the 1990 supercomputer trade accord, its market share in commercial installations there has inched up to 25%. Yet in the public sector, which includes government-funded universities and research labs, Cray is stuck at a trivial 8%."[49] But put the shoe on the other foot and the Japanese percentage in the United States is 0.

It is clear then, that the U.S. Government should continue to press for access to all markets in Japan for supercomputers. In doing so it can continue to focus attention on Japan's continuing reluctance to open its markets to imports of any high-tech products. But the U.S., relative to supercomputers, must also be prepared to respond to similar allegations from the Japanese in the future. To do so, a comprehensive strategy and associated policies on future Federal supercomputer acquisitions here in the U.S. is essential (including how and where foreign competitors fit in for acquisitions, in the federal sector in particular).

TECHNOLOGY TRANSFER

Another area in which current policy has not been completely clear is that of technology transfer. The Government has recently taken steps to further encourage technology transfer, as evidenced by the CRADA agreement discussed earlier. In addition, the Bush administration has relaxed some of the criteria for exporting supercomputers. Specifically, the new rules for exporting supercomputers, "eliminate virtually all paperwork for shipments of these machines to Canada and Japan and will require only minimum safeguards for deliveries to other western nations with a proven record for protecting high-technology assets. More stringent safeguards will be required for some Eastern European and Middle Eastern nations where the unauthorized use or reshipment of such products is still a matter of concern."[50] These are both encouraging steps which should help the competitiveness of U.S. firms not only domestically (by promoting the transfer of previously classified technology) as well as globally (easing the restricitions on many overseas sales).

However, the debate on sales to other markets, specifically to countries in Eastern Europe, continues. At least two U.S. companies have recently been involved in potential sales of supercomputers to countries which, only a few years ago, would have never even been considered. The first involved the sale of a $7 million machine to the newly independent ex-Yugoslav republic of Slovenia by Convex Computer Corp. The second involved the potential sale of a similarly priced machine by Cray Research, Inc. to China. Although both sales would represent low-end-performance machines, they both would provide performance close to a billion theoretical operations per second. These two sales also provide both sides of the issue in real-time terms. First, Convex officials stated that, "though military clients would remain off limits, for civilian buyers in most Eastern European countries the threat that these computers would be misused (for weapons research) is gone."[51] On the opposite side of the debate, the proposed sale of the Cray supercomputer to China prompted the following response from Senator Jesse Helms, the senior Republican on the Foreign Relations Committee; "there is every reason to believe that a supercomputer in the hands of Communist China would inevitably be used for ballistic missile targeting, regardless of any stated...purpose."[52]

As new machines become available (via MPP technology or the continued success of traditional supercomputers) this issue will become more paramount and in need of a concrete U.S. policy. The policy must deal with the issues of potential military use as well as improving U.S. trade through the export of supercomputers. Indeed there will be promising markets in the very near future in other formerly forbidden territories. The U.S., in fostering its own supercomputer industry must recognize that, "in products like supercomputers the first company to install a machine often gains a real advantage over late-comer competitors. As third country markets grow in importance and as Japanese companies become stronger, it is increasingly important that U.S. firms not be prohibited from competing by export restrictions, especially when the Cold War justification for such restrictions no longer exists."[53]

ACQUISITION ISSUES

There exist several acquisition and contracting concerns related to the supercomputer industry which are also in dire need of attention. As discussed earlier, DOD, NASA and DOE have, in the past, helped stimulate the development of supercomputers. In some cases, contracts for the acquisition of certain machines were written before the machines were manufactured. As pointed out by Congress's Office of Technology Assessment, "This cooperative approach was one key to advancing high-performance computing in the 1960's and 1970's. Unfortunately, the process has become more difficult as federal procurement regulations for computing systems have become tighter and more complex."[54] Specifically, the Brooks Act, with its restrictions on federal purchases of computer equipment, makes it difficult for Agencies to buy supercomputers without production having been completed. With the exhorbitantly high start up costs and long lead times involved in the supercomputer industry, this makes it more difficult for new companies to enter the market and effectively cuts off one potential source for capital.

Another complicating factor is the fact that most, if not all, supercomputer companies in the United States have strictly commercial accounting systems. This basically excludes them from being able to negotiate any cost type, developmental contracts with any DOD Agencies because the companies have no way to allocate costs to specific contracts. Tradtionally, this is the method used to fund R&D effort for the development of other advanced technologies (i.e. weapon systems) within DOD. Supercomputer companies have also been reluctant to change their accounting systems to comply with Government regulations because of data rights restrictions. If they were to develop new technology under a cost type development contract the Government would own the data rights to that technology. This could destroy any competitive advantage on a unique design -- the mainstay of the industry.

One additional area involving current acquisition regulations that continues to cause difficulties involves selling commercial items to the Government. Given the fact, as discussed above, that it is virtually impossible to contract for a supercomputer before production has been completed, most purchases are of production machines. However, to make a purchase of a commercial item, DOD requires a contractor to prove, "substantial sales to the general public at catalog prices." This precludes DOD from being able to purchase the first production of any supercomputers. Additionally, because of the small number of total machines of any one type sold, there is certainly a question almost every time as to whether the "substantial sales" criterion has been met.

The implications here are very clear. Congress and the Executive branch both are encouraging federal agencies and departments to purchase early production or prototypes of high-performance computers and supercomputers, yet today's acquisition regulations do not really permit that to be done. Acquisition regulations have not adequately kept pace with the evolution of the computer industry in general, and the supercomputer industry in particular. What is desperately needed is a reevaluation of Government procurement regulations, and changes where necessary, in order to allow federal agencies to have the ability to purchase early versions of supercomputers. Specifically, Government purchases of supercomputers ought to be exempt from the Brooks Act (although this would require an unambiguous definition of supercomputer).

One final area of concern involves the attempt by Congress to require the DOD to identify future supercomputer purchases. In 1989, the Congress requested the DOD to submit a five-year plan for supercomputer acquisitions and installations. When it was submitted in May 1992, "the U.S. Department of Defense (DOD) supercomputer master plan was criticized by Congress as too little, too late. The plan does not state how many supercomputers will be bought by the DOD over the five years nor where the machines will be installed; it does not mention how the high speed network will be purchased nor where the nodes will be located."[55] Criticism also centered around the emphasis apparently placed by DOD in the MPP arena, at the expense of the traditional vector supercomputer products.[56]

The requirement to submit a five-year plan of the type requested appears to have been misguided. It is certainly appropriate to require the DOD to think strategically about future supercomputer acquisitions. But to require a five-year commitment to specifics in this area is unrealistic. First, DOD budgets are being reduced so rapidly, that it is difficult to project specific high dollar acquisitions that far in advance. In addition, technology itself is changing very rapidly in the supercomputer area (witness the virtual explosion in the MPP world). It is impossible to project what will be available in that time frame and industry development may even be restricted if implications about the direction of specific funds for supercomputer acquisition are given.

CONCLUSIONS

The supercomputer industry, although involving a fairly small number of firms worldwide, is a complex and highly important one. It has also proven to be a very unique and fragile industry within the United States. But it remains a critical U.S. industry today which will prove to be EVEN more valuable in the future. It may well be the key to a continuing evolution of an information-dependent society.

The U.S. Government has proven in the last ten years that it can have a substantial positive impact on this industry. The establishment of supercomputer centers has exposed many more people to supercomputers and has been quite successful. The DOD, DOE and NASA have been largely responsible for the preeminence of U.S. firms in the industry today. Yet, in the same time period, several U.S. supercomputer companies have gone out of business. In addition, with rapidly declining defense and NASA budgets, it is unclear as to how well those elements will be able to impact future growth in the industry.

The Japanese, through their three major, vertically-integrated and Government-supported supercomputer companies (Hitachi, Fujitsu and NEC) are not only continuing production of traditional supercomputers, but are actively pursuing new and expanded markets. Through marketing agreements with U.S. companies they are aggressively pursuing additional business within the United States. If successful, this will be at the expense of the two remaining U.S. firms. Finally, the Japanese and the Europeans now appear committed to developing the emerging massively parallel supercomputer technology. The result: as in virtually every other industry today, competition is becoming global and much more threatening to an already weakening U.S. industry.

The supercomputer industry in the United States, both now and in the years to come, is too important to ignore. The Government has recognized the increased importance of high performance computing and is taking positive steps to encourage the future growth of the U.S. supercomputer industry. The HPCCI, CRADA, NSF and DARPA initiatives are proof. But what is lacking is a long-term vision of the future of the U.S. supercomputer industry. For that to evolve, the Government must assume an even more active role in this crucial industry.

Specifically, the Federal Government must take action in the following areas:

1. A comprehensive policy must be developed which will adequately address the concerns of the industry (and of its customers) both

today and in the future.

2. New technologies must be pursued, yet the traditional supercomputer industry must not be abandoned. These machines will continue to have important defense and domestic uses in the future.

3. Access to markets in Japan must continue to be pushed for through U.S./Japanese trade channels. However, the United States must be ready to accept and respond to similar Japanese pressure for access to our markets by their supercomputer firms.

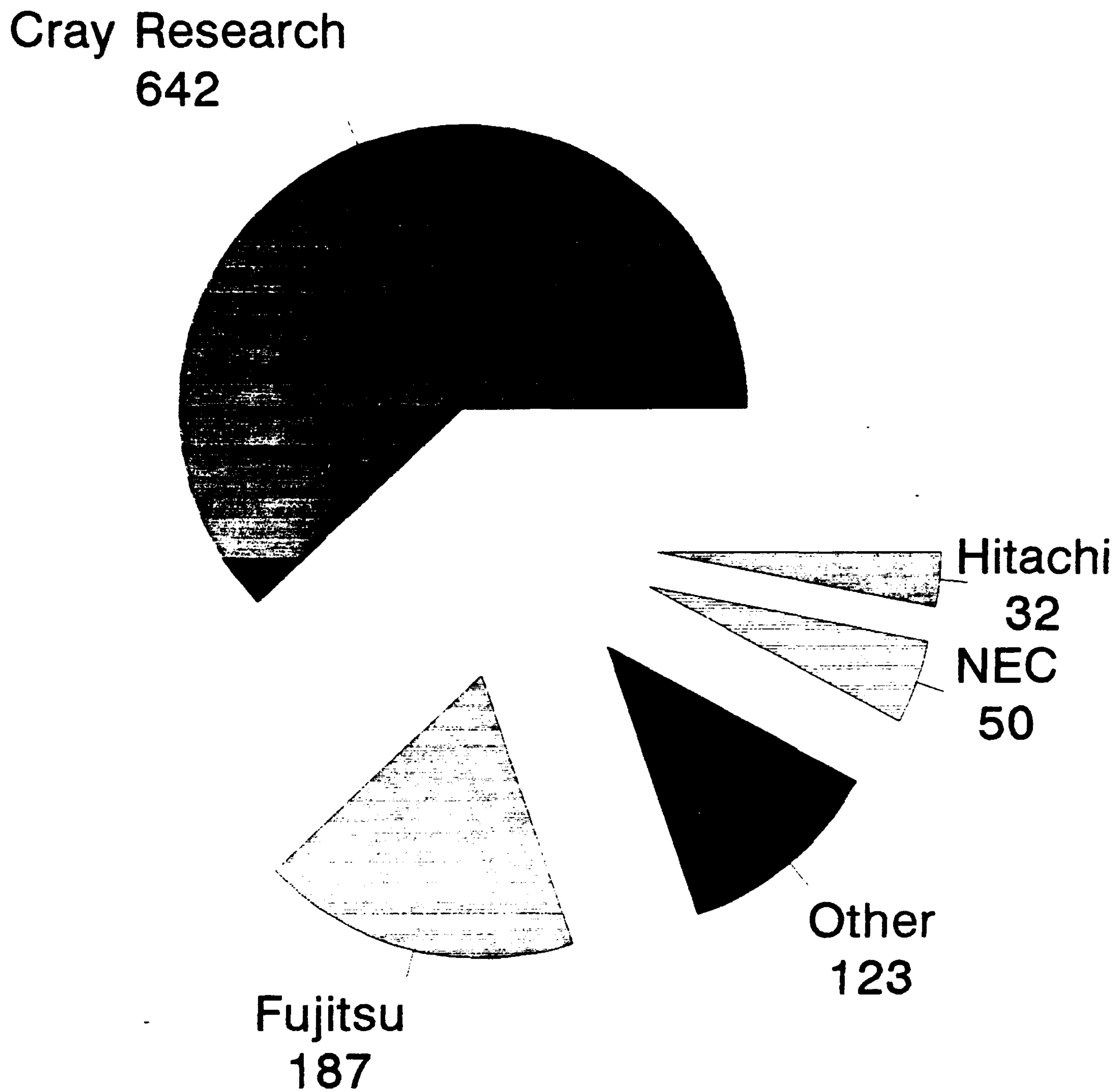
4. Export restrictions to former communist, and other areas must continue to be examined in concert with establishing a U.S. supercomputer policy. If restrictions are still needed because of defense concerns, U.S. industry should know it. If not, then export controls to these areas need to be relaxed.

5. The transfer of technology developed at Government laboratories has already begun. However, no firm groundrules have been established. This is paramount if the transfer is to be fair to all U.S. supercomputer players -- large and small.

6. A re-evaluation of pertinent acquisition regulations, as they pertain to supercomputer purchases is absolutely necessary. Without it, Federal agencies will neither be in a position to meet their own supercomputing needs, nor be able to support the HPCCI initiatives.

1991 Vector Supercomputer Market

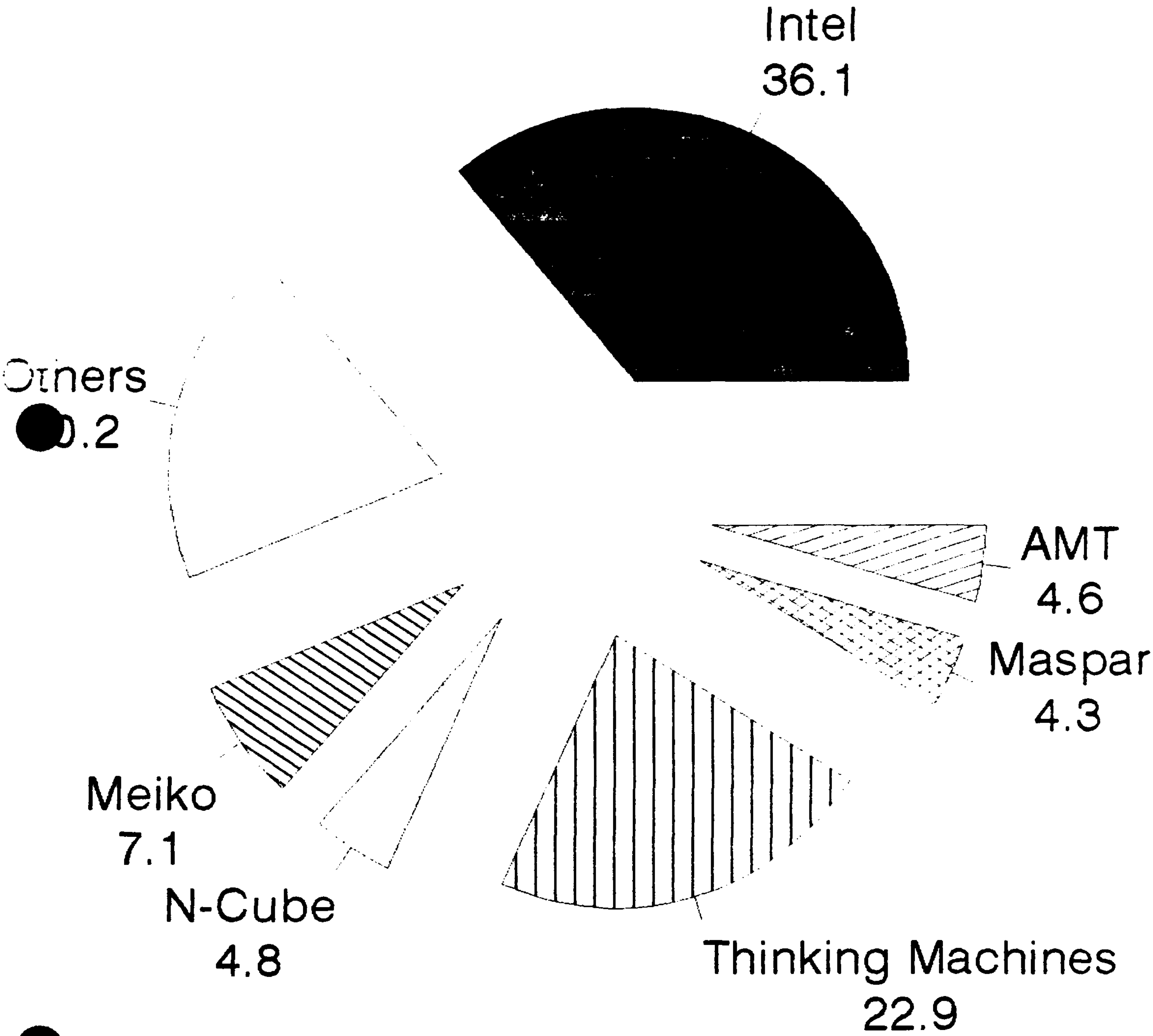
($ Millions)



Attachment 1

1991 MPP Manufacturers

Market Share (by percentage)



Attachment 2

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