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Fifth Generation Super Computers - An International Competition

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SUMMARY

FIFTH GENERATION SUPER COMPUTERS - AN INTERNATIONAL COMPETITION

This report is a deliberate mixing of two technologies within the advanced computing world. The Japanese have preserved the distinction by initiating two national projects; the "Fifth Generation Computer Project" and the "Super Speed Computer Project". The super speed computers are used for numeric computation as have all super computers of past generations. Government, science and industry have expressed a need for super computers 100X to 1000X faster than current machines. Many scientists believe that this is possible by 1990. The competition to develop this technology is the primary emphasis of this report.

The "Fifth Generation Computer" technology is concerned with non-numeric computing. This technology is less well developed, includes the mystical art of artificial intelligence (AI) and the goal is "Machines Who Think". In some respects the potential benefits and commercial value of non-numeric computing may be greater than for numeric computing. As the non-numeric technology develops, super computer advances will have a major accelerating effect.

Two U.S. companies, Cray Research and CDC (now ETA systems) have dominated the world super computer market. A third company, DENELCOR has begun to market a radical new parallel computer design. Three large Japanese companies, Fujitsu, Hitachi and NEC have recently entered the market. The 1985 world market for super computers is estimated at $600M and expanding. An individual computer costs $5-$20M. A small market, perhaps 60 computers for the year. U.S. technology and experience is strong, but the Japanese have the advantage of long term planning and they have correctly identified the critical computer technology for the future.

The either/or proposition for the U.S. government is very difficult. Either the leading edge of the U.S. computer industry must be commercially profitable or the U.S. government must take steps to support/protect markets to make it so. There is almost unanimous agreement that U.S. technical dominance in the field must be maintained for national security reasons. The Japanese have entered the market in ernest. Past experience in other industries leads one to worry about the outcome.

The Japanese may have done a great service. Their computer projects have focused world attention on the need for rapid technological advances in both the super-speed and fifth generation computers. The U.K., France and the FRG separately and within the EEC have research projects. Within the U.S. both numeric and non-numeric computer research is proceeding in universities and private companies. Noteably, industrial research consortia such as MCC and SRC, add impetus to private research. The recently initiated DARPA, Strategic Computing Program, NSF university advanced computer centers program, other NASA, DOE and DoD research projects add a sizeable amount of money and personnel. Tremendous advances in computer technology and applications <u>will result</u> by the early 1990's. The outcome for domestic industries and international trade is far less certain.

16 April 1985 Carl A. Miller

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CHAPTER ONE

INTRODUCTION

The interest and imagination of the American public was captured by "Megatrends" in October 1982. The widely acclaimed book was on the New York Times best seller list for 60 weeks. It simply claimed to describe "the ten new directions transforming our lives." Whether attributable to the book's organization, style or timing, it was apparent that the American public was intensely interested in this picture of the future. The first, and according to the author, most explosive of the ten major tranformations is "From an industrial to an Information Society".

A related and potentially more significant event was occurring in late 1982. The Japanese, through their Ministry of International Trade Industries (MITI), announced their plan to achieve "Fifth Generation" Computer capability by 1990. As an over simplification, one might suggest that while the American public was becoming interested in a new trend that would transform their lives, the Japanese were explaining in detail what kinds of technology were necessary to make this transition and committing their resources to an ambitious timetable for making it happen. This was no hastily assembled set of grand statements but a carefully described set of goals and objectives which drew much favorable commentary from the U.S. university, commercial and government experts. There were actually two National Projects, a National Super Speed Computer project and a related but separate Fifth Generation Computer project. It was obvious that much careful study and planning had been done before the international conference at which the project was presented. It was also apparent that a national committment to these goals was a prerequisite to their international publication. Nor is there much question about the ability of MITI to guide government/ industrial efforts. An impressive track record in earlier projects including the Very Large Scale Integrated (VLSI) circuit development project provided valuable experience for the Japanese in how to cooperatively advance R&D results while preserving the individual competition between companies at the product level. As a result of the successful VLSI project, the Japanese companies regained a respectable share of the world market in fourth generation computers.

In the view of many experts, the Japanese have the ability, the will and the plan to make major advances in computer technology by the 1990's. In so doing, they could leap-frog their nearest competition, the U.S. computer industry and thereby dominate the most advanced segment of the world computer market of the 1990's. Computer technology, the heart of the information society, is very much a moving target. The U.S. has dominated the industry until now and is not idle. Tremendous computer advances in relatively short periods of time have been the rule. The Japanese have <u>advocated</u> a continued rate of advance which may not be attainable but does none the less represent a challenge. Even

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without this particular timetable, there are other forces/demands for advancement which could continue a rather remarkable rate of progress.

It is difficult to form an accurate perspective of the computer industry. It is multi-faceted and its history has been extremely short. Within little more than thirty years, we have progressed from a first generation of vacuum tube computing machines, through the second generation transistor (solid state) machines, to the third generation integrated circuit machines of the IBM 360 variety. The VLSI circuit technology has begun to move us into the fourth generation with the Cray XMP, Cyber 205 and IBM 3080. These generation levels may mean little to those who are still trying to decide which personal computer is best for their family. Yet this in itself illustrates the ubiquitous nature of the industry and its many commercial facets. We have, with almost no individual exceptions, entered the realm of the computer revolution. We accept as a matter of course that a wristwatch can perform a wide range of basic computer functions flawlessly with a tiny battery for power. We are not alarmed, probably reassured, that our new auto has electronic ignition or that other functions such as no locking auto brakes are computer operated. After all, the computers can fly the space shuttle. There is tremendous commercial wealth in the computer and related consumer electronics field.

The National Research Council panel on Advanced Technology Competition identifies within advanced technologies -- core technologies. These technologies "have far-reaching influence upon the state of the American economy. The rapidly improving performance and falling costs of these advanced technology products are key to rising productivity. In 10 years, productivity in advanced technology industries has risen 5.6 percent, compared to 0.9 percent for business generally -- a sixfold difference. In addition, productivity in mature industries may be increased through the applications of advanced technology throughout the manufacturing and distribution processes." "Electronics is one core technology arena in the form of integrated circuitry of increasingly higher density, digital devices for communications, an enlarging array of computers, and increasing sophistication in "user friendly" software."

Then advancing computer technology carries with it a significant multiplier effect at a number of levels as a function of core technology. It is therefore a critical part of the Hi-tech industries upon which we hope to base the economic future of the U.S.

A major component within the computer line is called the main frame computer. These are large capacity, (however, substantially less powerful than super computers) fast general purpose computers which can perform a variety of functions from personnel and payroll to accounting and engineering calculations for a large corporation. These computers in combination with small remote computer terminals and the necessary telecommunications can provide worldwide information services very quickly and efficiently. These mainframe computers form the backbone of the computer industry through all of its generations and are tremendously valuable in a direct commercial sense and also for the many ancillary lines of equipment and services which they promote. The world leader in this mainframe computer arena has been and continues to be IBM. The Japanese have been increasing their share of the mainframe market, and in addition are producing a range of IBM compatible equipment.

Finally, in each computer generation, there have been a relatively few often custom engineered super computers produced. These super computers have largely been used by governments in advanced R&D and weapons design programs and to a limited extent shared with a few universities who support these efforts. Much of this work has been classified. This top end or super computer portion of each computer generation has been judged a commercial failure in two thirds of the machines produced, according to the manufacturers. The numbers of machines sold, the performance requirements and the technical difficulties have made this market segment so unattractive that most large U.S. manufacturers are not competing and this high end of the computer market is the exclusive domain of a few very small U.S. companies. Most recently, two or three large Japanese Computer Companies have marketed super computers with capabilities roughly equivalent to those available in the U.S. Therefore, the standing market for super computers in the U.S., in particular, the Federal government is faced for the first time with the question of whether or not to buy Japanese. There are complications of both a technical and security nature involved.

Hopefully, this very sketchy description provides some perspective of where we are now with computer technology. However, none of what has been described above begins to approach the capabilities of the Fifth Generation computing world. There are a wide range of technical advances necessary. These include natural language capability, high speed input and output, the application of artificial intelligence, microelectronics technologies and new super computer architectures. These areas of R&D are each important and in many ways integral to the achievement of the capabilities described as "Fifth Generation". While not ignoring the others, this study will focus on the super computer technology, relating it to other technologies as necessary. Of particular interest will be the international relationships which influence both technology advances and market access.

CHAPTER TWO

SUPER COMPUTERS

The state of super computer development in the world today presents a mixed picture. At one end of the spectrum the Japanese are describing a plan to develop a new super speed computer technology by 1989. In addition, they propose to develop intelligent machines by the 1990's. These machines will use the latest in the developing science of "Artificial Intelligence" (AI) applied to these immensely powerful (large and fast) computers to perform expert tasks which can only be generally described today. At the same time it would appear that most of the U.S. computer industry is only mildly interested in developments at the outer edge of super computer technology. This is not surprising since super computers represent only 1% of the computer business today and two thirds of the previously built super computers were judged to be commercial failures. This of course does not consider the future spin off from super computer technology. Two U.S. companies, Cray Research and CDC have been successful. But the total world market has been extremely small.

In 1982, fifty U.S. super computers were in operation worldwide --38 in the United States, ten in Europe and two in Japan. Government labs operated 25 of the 38 installed in the U.S. and another three were in operation in Universities. By late 1983 the total was estimated at 70 worldwide. Growth in U.S. government direct use is expected to approach 80 installations by 1990. Precise comparison between 25 in 1982 and 80 in 1990 are not meaningful because the lower threshold of super computer definition is shifting upward. Estimates of increases in universities, in U.S. industries and in foreign markets were not available, although most experts are optimistic that commercial applications will expand substantially by the 1990 timeframe. These totals are comprised of as few as two and at most six different machines produced by CDC and Cray Research. To a certain extent, the initial entry of the Fujitsu and Hitachi machines should have little effect on the world market since their early installation will be in Japanese labs and universities which have been a very small fraction of the market available to the U.S. manufacturers.

The challenge to build larger, faster computers in the U.S. has been the arena of a few in industry and government who see a need for the future. Some industry managers assert that the majority of breakthroughs are inevitably achieved by small research teams. The inflexibility imposed by large corporate structures tend to stiffle the very creativity necessary to follow technical break throughs and adjust direction of effort quickly. Clearly, a number of large manufacturers in Japan and the U.S. are content to concentrate on commercial applications well within the state of the art, relying on their powerful engineering and marketing capabilities to assimilate new technology when it is profitable to do so.

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The small market size for super computers to date must be understood in the context of their potential use and productivity. Clearly, there are large, scientific and engineering applications today which require greater computational force than the computer industry has been able to provide. The increased speed and size of machines will help these problems but the expansion of markets also requires an increased capability to use them effectively. Only a relatively few government and university research facilities presently have the capability to adapt increasing computer capacity to productive use. By comparison, the producers of the large mainframe computers have provided the necessary software (operating instructions) to make these machines productive for users without requiring large user investments in computer skills. Therefore, software development looms large in the commercialization of super computers for the future. A large sphere of cooperation between the computer industry and the user community is necessary so that the computer industry understands the problem sufficiently to adapt the super computer to the industrial need. This process is ongoing today and must grow in the future. As will be seen in Chapter Three, the Japanese are developing some super computers with IBM software compability to improve flexibility of use with existing software.

Closely related to the software development question is the nature of design for future super computers. While research is finding ways to increase the speed with which individual operations are performed, there is also a basic departure from past sequential operating methods to parallel processing schemes which can vastly increase the number of operations carried out simultaneously thereby decreasing the time for completion of a particular task. While this research appears very promising, it will require different construction of operating instructions to use the parallel feature. This methodology has not been developed. For that matter, the whole science of software development is also in a developmental stage. These problems are obviously not trivial and their successful addressal is key to large scale advance in the super computer field as well as the advancing computer field in general.

There are no national or international industry performance standards. The number of possible variables in an application are such that the only true measure for an individual user is the speed of execution of the particular application of interest to that user. This method of measurement is in fact used by individual vendors. One step less specific are standard programs which have been developed by large users such as Government labs so that comparisons can be made between computers. These results are useful to the extent that the test programs tend to resemble the applications of interest to a particular user. Finally, each vendor is prepared to describe a theoretical maximum performance which is optimized to the features of his computer design. These values are useful to the extent that a particular application may coincide with the strengths of a particular computer design.

Computer capability is generally measured in millions of instructions executed per second (MIPS). This coupled with some measure of storage capabilities in millions of bytes of memory are the general yard sticks of the current computers. Thus a typical mainframe computer may execute from 8-20 MIPS. Super computer speed today is measured in the more complex unit, millions of floating point operations per second (MFLOPS). Each operation refers to the equivalent of one arithmetic operation between two numbers. Typically super computer ranges of 100-400 MFLOPS are being achieved with 4-8 million words of memory. The latest terminology has already escalated to a billion floating point operations (BFLOPS) or (GFLOPS), as will be seen later in this paper.

Over the last decade the rate of advance of super computers has been by a factor of 4-5 every 4-5 years. The Japanese in their super computer project propose a magnitude increase of 100X in 10 years or less (according to the FCCSET super computer panel report.) Prospects for the success of parallelism in architecture as well as improvements in the electronics show much potential. Microelectronic technologies well beyond the scope of this brief paper are proceeding apace. Suffice it to say that these efforts will continue to make the integrated circuit units faster and more compact thereby substantially reducing the size of increasingly more powerful units. While this activity will continue, there are many who argue that the outer limits of this particular line of advance are being approached and the more promising work is really in new methods of organizing multiple processing units which can concurrently work on different segments of the same problem. An interesting example which illustrates parallel operation is used by Robert Kahn of DARPA. "----an hours worth of (recorded) speech may be broken into 100 segments of 36 seconds apiece, and each may be processed simultaneously for a potential hundredfold improvement over realtime processing." The idea is interesting but the knowledge necessary to build the machines and use them has not been perfected yet. Also the experience necessary to know what kinds of problems lend themselves to high degrees of concurrent processing are only now being studied. Super computer technology of the fifth generation faces many challenges but most experts are optimistic about progress if not agreed on method.

CHAPTER THREE

JAPANESE PROJECTS

The present Japanese developmental efforts in future computer technology may be categorized in two major separate, but interrelated areas. The first and more explicit is called the "National Superspeed Computer Project", whose goal is the production of a super computer with capabilities 100 times more powerful than present super computers. The second, much broader and futuristic, is called "The Fifth Generation Computer Project". This 10-year project, described as innovative, even revolutionary, is to produce systems that offer new capabilities in problem solving, man machine interfaces and cognitive processes. The project both nationally and internationally is designed to address the needs of an information society in the developed nations of the world. The two national projects, both separately funded, bear the obvious relationship that more powerful computers may aid a number of the problems associated with the fifth generation project. In simpler terms one may think of the superspeed computer for solving numeric problems and the fifth generation for solving non-numeric problems.

Perhaps the best starting point for describing the Japanese initiatives is 1975. (William Ouchi in "The M-Form Society" describes the scene.) "The race was on to develop the fourth generation computer. One of its key components would be the memory unit, which was to be the 64K RAM (64,000 Bit Randon Access Memory Chip), a large step ahead of the 16K RAM then in use." The Japanese computer industry had suffered through a difficult 10 years during which various government/industry efforts had managed to save an industry which appeared doomed by the power and ability of U.S. manufacturers; IBM in particular. A combination of foreign trade restraints, government loans and joint industry development ventures had managed to salvage, although not totally revive the industry. These protective measures were to be lifted in 1976. The Japanese manufacturers hoped that they were strong enough to survive this increased competition.

"On July 15, 1975 (the Japanese government and industry) all parties agreed to the formation of a new joint research and development venture that was to become the most celebrated of all such attempts in the Japanese computer industry." Beginning in 1976, the VLSI (Very Large Scale Integrated Circuit) Research Association was formed with capital contributed by five leading companies; NEC, Toshiba, Hitachi, Mitsubishi and Fujitsu. In addition, two industrial labs (NTIS and CDL) and two government facilities (ETL and NTT) would join in the effort to focus on basic research. All parties would provide scientists to a joint laboratory. The results would be passed to the industrial labs to develop useable technology. Finally the technology would be passed to all five participating companies who would compete among themselves and with foreign companies for business. The project was conceived as a four year project. (1976-1979).

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The decision to proceed with the joint project in July 1975 was a compromise solution worked out by MITI. The companies wanted direct government subsidies without collaboration and only reluctantly yielded their individual research expertise when MITI insisted that direct subsidies were politically impossible. Even after agreement in principle, there were questions of recruitment of scientists from the five companies, organization of the research work, accountability for results and so on. All of the problems of teambuilding under this collaborating scheme with divided corporate loyalties had to be overcome.

The results seem to speak for themselves. The project applied for 1000 patents of which 300 to 500 were approved. The break down included 59% representing the work of independent inventors, 25% by several inventors from the same company and 16% from inventors from several companies and the government lab. Whether the project yielded truly significant joint scientific achievement is not clear. Many suggest the project was a success because timing was good; everyone recognized that VLSI would be a competitive issue in four or five years. Also, the joint lab stayed away from trying to invent commecial products, thus avoiding the inevitable refusal to share know-how but instead concentrated on basic research, with applied research done by the industrial labs. Finally, all agree that major impetus was the perception of IBM as a technically superior competitor, so highly regarded that no one company could imagine successfully overtaking it.

The VLSI project was completed on schedule in 1979 and the lab was disbanded. Its success may be best measured by competitiveness of Japanese mainframe computers in the marketplace. By 1978 the basic technology of the 64K RAM had been mastered. Fujitsu and Hitachi each announced new computer versions which exceeded the capacity of the largest IBM model available at that time. As the fourth generation entered the marketplace both the Japanese and IBM were nearly simultaneously introducing models based upon the same VLSI technology. By 1982 Fujitsu replaced IBM as the largest seller of computers in Japan. The Japanese had closed the technology gap from ten years behind to within months of currency with the worlds leading computer company.

As an added incentive to potential customers who may have already invested in IBM systems for other purposes, at least two Japanese super computers currently on the market are capable of running IBM-compatible software. There is an estimated $200 billion worth of IBM compatible software available in the world making a software rich environment available to super computer users for the first time since no U.S. manufacturer offers an IBM-compatible super computer.

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As described at the outset, there are two major projects in progress relevant to the future of computer technology in Japan. There are also others, including the Electronic Computer Basic Software Technology Research, begun in 1979, that are of interest but will not be considered here.

The National Super Speed Computer Project and the Fifth Generation Computer Project are two of nine or more national projects in progress at this time. In order to qualify for this designation and support, projects must provide R&D on technology urgently needed for industrial progress where the development cannot be undertaken by individual firms because of high risk and high investment. The National Super Speed Computer Project which will be funded at $200M over the period 1982-1989 seems very much a formula to build upon the successful methods of collaboration between government and industry developed in the VLSI project. The players are virtually the same. Fujitsu, NEC, Hitachi, Mitsubishi, Oki and Toshiba will cooperate with the government Electro-Technical Laboratory (ETL) in the project. The goal is a superspeed computer capable of 10 BFLOPS, one billion words of memory with a parallel processing architecture. The parallel processing is specified on the premise that maximum performance of a single processor is unlikely to exceed 1 BFLOPS in this century. Interestingly enough, Fujitsu has just announced their VP-400 computer with performance of 1 GFLOPS. The earlier comments about accuracy of performance measurements apply. It is too early to know how well these machines will actually perform across a range of general applications.

The "Fifth Generation Computer Project" is designed to move computer use from mathematic computational use into the automated reasoning realms of the future. The tools of the information society, where natural language will instruct the computer and logical, inferential functions will be performed on information to give intelligent results. Moving far beyond the need for more powerful computers, this project will concentrate on natural language interface, symbolic (rather than numeric) data and artificial intelligence applications to dramatically advance the ease of use and value of the result. For example, today's computer may select and order stored data for human analysis according to written instructions (in computer language), the fifth generation envisions spoken or written natural language instructions which cause the computer to provide analytic results together with the supporting data if supporting data is required.

A government Institute for New Generation Computer Technology (ICOT) within MITI has been formed to oversee the project which has been organized around the same set of industry/government participants as the superspeed computer project and has been funded at $430 million for the first five years of a ten year project. The total expenditure by the end of the project in 1990 has been estimated at $1.35 billion of which two thirds will be furnished by industry and one third by the government.

CHAPTER FOUR

U.S. ENTERPRISE

U.S. Computer companies have dominated the super computer segment of the industry through each succeeding generation of computers and into the present fourth generation. Some say it has been a domination by default. Other countries have not had the technology and even within the U.S., some industry leaders have chosen to ignore this segment because of the small market potential.

At the moment there are only three U.S. companies who are actively developing and marketing super computers. In a sense, Control Data Corporation (CDC) might be considered the genesis of the present day industry. Seymore Cray was a CDC employee involved in the development of the Cyber 7600 before he decided to form Cray Research in 1972. Since that time his company has become the acknowledged industry leader. More recently, CDC has spun off a subsidiary, ETA, to continue marketing of their latest super computer, the Cyber 205 and develop the new ETA-10 super computer. ETA is largely owned by CDC and is staffed with CDC researchers. The newest and most revolutionary of the three is DENELCOR, a small company built around the scientific expertise of a chief scientist who is a proponent of parallel architecture. DENELCOR hopes to gain a market share through development of a new and more flexible architecture built upon the principles of concurrent processing. Their Heterogeneous Element Processor (HEP) offers a distinctly different architectural approach to super computing. A number of HEP 1 installations have been made in the U.S. and a significant foreign commercial sale to Messerschmitt-Bolkow-Blohm in the FRG occurred in 1983. DENELCOR is currently developing the HEP-2.

Most recently, three Japanese companies Hitachi, Fujitsu and NEC, have announced super computers which claim to meet or exceed the performance of the Cray machine. Performance claims, counterclaims and measurement or validation methods are sufficiently vague as to make precise comparison difficult. However, for discussion purposes the Cray-2 claims an operation rate on the order of 800 MFLOPS. Fujitsu has produced VP-200 with a claimed rate of 500 MFLOPS. Although these rates are far short of those projected for fifth generation machines, it shows continued incremental progress. More importantly it demonstrates that the super computer market is no longer the exclusive purvue of the U.S. industry.

Super computer development in the U.S. has been largely supported by the U.S. government and continues to be so. Particularly during the 1950's and 60's there was a very productive collaboration between, government, universities and industry. There was a general decoupling from the university segment during the 1970's as government funding for computers was removed. As a result, none of the super computers of the 1970's were installed at U.S. universities and today only three universities have on-site super computers. The reasons for this trend during the 1970's will not be examined here. However, it has been identified by several government studies as one of the national problems of super computer development requiring change. The National Science Foundation has already begun to rectify this shortcoming. A $200 Million program will fund University Super Computer Centers. Each will provide multiple access by participating universities. The first announced centers are to be located at Princeton, Cornell, University of California, San Diego, and University of Illinois. The network is expected to increase the high speed computing power available to thousands of university scientific researchers.

Over half of the super computers installed in the U.S. today are owned or leased by the U.S. government. These machines are used to model many complex physical phenomena from nuclear weapons design, weather prediction, aerospace, magnetic and inertial confinement fusion, fundamental physics and many other fields of R&D. Significantly, as modeling capabilities improve, increased uses for super computers will replace expensive experimental testing and increase the government demand.

While the government demand for super computers continues to grow, there are at the same time increases in the private sector. The oil, automobile, electronics, chemicals and aerospace industries are beginning to apply super computers to technical problems. This, of course, represents an international market with significant future potential.

In the last two years there have been several government studies performed by committees and advisory groups made up of government, industry and academia leaders to assess where the U.S. is in the super computer/advanced computer development and what steps might be taken to further U.S. efforts. Depending on the orientation of the particular group, the emphasis may be on super computer technology leadership for national security or scientific purposes. In over simplification it might be said that all are convergent on the need to foster rapid U.S. advancement of super computers and related technology of the Fifth Generation ilk. There is divergence as to what should be done and by whom.

In April 1982 a DoD/NSF coordinating committee organized a workshop to explore the problems, needs and opportunities in large scale computing. A panel of fifteen scientists and engineers, headed by Peter D. Lax, New York University, National Science Board, conducted a number of workshop sessions during the spring and summer culminating in a Panel report issued Dec. 26, 1982. The panel identified two basic problems:

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a) <u>Access</u> by researchers and students is too limited

b) <u>Capabilities</u> of today's super computers are several orders of magnitude too small for current problems.

Then they recommended a four point program:

a) Increase access through regularly upgraded super computer facilities with networking

b) Increase applications through research in computational scientific and engineering computing

c) Improved training in scientific and engineering computing

d) Research and development of improved super computer technology.

The panel report (Lax Report) deliberately avoided recommending specific governmental implementing actions of organization, programatic, or budgetary nature.

In January 1983, a Federal Coordinating Committee on Science, Engineering and Technology (FCCSET) Panel on Super computers was formed to examine what, if anything, the U.S. government should do. The FCCSET Panel broke the problem into three interagency working groups which roughly parallel the recommendations of the Lax report.

<u>Access Group</u> - to recommend ways to improve access by scientists

<u>Technology Base Group</u> - which considers research and development needs

<u>Procurement Group</u> - to consider what actions are necessary to develop the market for super computers.

The FCCSET panel procurement report concludes that there are a number of specific actions which the U.S. government should take. These can be generalized in two areas. The government should expand its friendly customer role by establishing a minimum government purchase level for future super computers which meet a performance standard 200X present machines. Also more money should be allocated for research to be performed by universities and other contractors. The report strongly favors a preponderance of private enterprise support.

Both the Lax report and the FCCSET foresee the need for a Federal government mechanism for coordinating overseeing, guiding or advising on the total government program in the super computer area. The Lax report specifies both an interagency Policy Committee and a interdisciplinary advisory panel.

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The Office of Science and Technology Policy (OSTP), responsible for acting on the (FCCSET) super computer panel recommendations, will very likely have the primary policy guidance responsibility. The exact form and make up of advisory and/or coordinating groups is not clear at this time.

The President's Foreign Intelligence Advisory Board (PFIAB) has for some time expressed interest and concern for the intelligence ramifications of advancing computer technology. Presumably both the significance of intelligence applications of advancing technology as well as the security ramifications of control and access to this technology by others are of concern. The PFIAB has established a group to examine this subject and a report is expected shortly.

The Defense Department and in particular the Defense Advanced Research Projects Agency (DARPA) has been an active player in computer technology advancement overtime. In October 1983 they produced a Strategic Computing Plan: A strategic plan for development and applications to critical problems in defense. The plan is directed basically at the fifth generation kinds of technology although the general relationships with super computer technology clearly apply. The approach to solving future defense problems is quite comprehensive and employs the elements of vertical integration of technology so often missing in other programs. (By vertical integration is meant the relating of various research technologies of software, microelectronics, systems architecture and specific applications such that a common result is achieved.) Three model or demonstration categories of military applications have been identified for this program; autonomous systems, pilots' associate and battle management. The selection of categories is such that a broad range of technologies across the whole computer spectrum will he developed. The commercial spin off should be substantial.

In the private sector a new and potentially significant development has been the establishment of the limited industrial research consortium Microelectronics and Computer Technology Corp. (MCC) in Austin, Texas. Formed in 1982, to work on a broad range of computer R&D technology, it is probably too soon to judge what effects this venture may have on the super computer industry. The MCC facility is associated with the University of Texas and has support from the Austin business community. It is clearly a compromise solution between the go it alone company research and the government dominated research efforts which have marked the past history of the U.S. super computer industry. In some respects the arrangement is partially analogous to the Japanese model of limited industrial cooperation in research with individual company commercialization of results and open competition for market. It is a difficult management challenge which may demonstrate the degree to which U.S. manufacturers are concerned for the future or alternately how confident they are of individual corporate strength since only a limited segment of the U.S. computer industry has chosen to join in MCC projects, although membership is growing. One of the early concerns that such a venture might violate anti-trust legislation was removed when the Justice Department ruled that private industry cooperation in basic research was permissible.

The aggressive support for MCC is a deadly ernest effort by various business/government factions in Texas to obtain a part of the high technology industries of the present and future. State/University/business affliations are also underway at the triangle complex in North Carolina and a similar pattern is developing at a number of other locations. These high technology centers with university affliations and commercial financial support should provide a significant base for technological advance and commercial development which will be beneficial for the super computer industry.

In summary, the U.S. computer industry continues to operate from a position of relative strength in the super computer technology of the present. The status has been quite thoroughly assessed and a large range of decision choices have been presented. The future technological development and their potential applications over ten years or more can only be broadly described because of the dynamic and developmental nature of computer technology generally. The Japanese competition is viewed seriously. It will continue to provide strong incentives for improving computer performance at competitive prices.

CHAPTER FIVE

OTHER PLAYERS

Great Britain, France, The Federal Republic of Germany (FRG) and the EEC are all engaged in computer development programs on some scale. Not only is their technical expertise individually and collectively important but at the same time they represent a significant portion of the world market for super computers. The history of developments in Europe, and particularly in Great Britain, has been particularly erratic. The British did some of the very early work in Artificial intelligence. During the period 1959 to 1962 the British government attempted to stimulate their computer industry by supporting the development and production of a super computer. The withdrawal of public funds in 1962 and curtailment of the project had unfortunate consequencies for the computer industry in Great Britian. It has also been cited as an early example of how government involvement in industrial development may be counterproductive. (See the Super-Computer Project: A case study of the interaction of Science, Government and Industry in the UK, Gibbons and Johnston.)

Early experience not withstanding the UK, European efforts are proceeding as follows:

EEC - "ESPRIT" (European Strategic Plan for Research in Information Technology) a 5 year precompetitive R&D program of $1.5 Billion funded half by member governments and half by participating companies. FRG, France and Great Britain plan to participate.

Great Britain - A Fifth Generation type project (ALVEY), for five years at $550 million government/industry shared costs.

France - a "Science Program Law" increasing national support from 1.8 to 2.5% of GNP by 1985 to fund and staff national research centers, provide grants, loans and tax exemption for private industry.

FRG - Increased research support by $4 million/year.

At least one writer ("The Dangers of The Fifth Generation Ballyhoo", Malcom Peltu, an article in Behavior and Information Technology) suggests that --- "Everyone is in danger of having its computing - research agenda set by the Japanese. In awe of the Japanese record in planning for information technology, the EEC and some European governments have picked on the fifth-generation computer system as a blueprint for their research programs." He goes on to point out. "In light of current paranoia about the 'Japanese threat' it is worth noting that 'the American threat' did not dictate European research trends in the past. For example, in 1972 a report in Britain for the Science Research Council virtually killed off AI and robotics research in the U.K.

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Later, when expert-systems developments emerged from American universities, there was no rush to boost research spending in this area; on the contrary, anything tainted with the AI label struggled to get recognition at all."

A further frustration for the British and Europeans is illustrated by a recent Wall Street Journal article titled "U.S. Blocks Access of Foreign Scientists to High Technology". In the Article recounting British and European difficulty with exclusion from portions of U.S. conferences and unclassified technology data, the article states that "some Europeans also suspect the U.S. of invoking national security as a excuse for guarding commercially useful information."

This is symptomatic of the much larger problem of control of computer technology and how that balances with the international nature of developing world markets for super computers.

CHAPTER SIX

INTERNATIONAL COOPERATION

International activities in the fifth generation and super speed computer areas are on going in both technology development and marketing. In the marketing area activities have been fostered for various reasons. The principle motives for international arrangements are to fill out a market line so that a more complete set of computer capabilities can be offered. These arrangements either separately or in conjunction, may provide market access which might otherwise be denied.

Fujitsu, for example, has a 49% interest in Amdahl Corporation, Santa Clara, California. Amdahl is marketing the Fujitsu VP-200 super computer in the U.S. as the Amdahl 1200. At the same time, Siemens AG is marketing the VP-200 in the FRG under a marketing agreement. In both cases the arrangement provides marketing access for Fujitsu and at the same time permits Amdahl and Seimens to go after the super computer market, thereby broadening the range of computer capability which they can offer to customers. Cray Research has successfully marketed their super computers in Japan and the FRG, through wholly owned subsidiary marketing offices.

The business strategies and counter-strategies which will drive future international marketing will probably continue to present a changing picture. The expensive and difficult R&D efforts necessary to super computer advancement will undoubtedly make this highly specialized market particularly susceptible to joint marketing arrangements.

The more interesting collaboration is in the R&D area because this is the source of the technology for the future. How this technology may develop and how it will be shared commercially in the future are large unanswered questions. The EEC ESPRIT program is probably the most completely structured international example of computer R&D cooperation today. The European experience in using a Cray computer to help design the Airbus for the aerospace industry may give them some advantage in how to turn international R&D efforts to joint commercial advantage.

MITI in announcing its Fifth Generation Computer Project, indicated that international cooperation would be welcomed. This rather disarming suggestion has been viewed with both skepticism and amazement by many foreigners. On the positive side, there are those who credit the Japanese with recognizing that their Fifth Generation project has broad use for civilization which can benefit from the cooperative efforts of foreign researchers. Such an international project increases the chances of success in a cooperative atmosphere. They apparently do not anticipate that commercial application of any newly developed technology by foreign interests will represent a particular threat to Japanese industry. On the other hand, the skeptics say that the Japanese are simply up to their old tricks. They have much more to gain because the expertise in super computers and AI related fields resides in the U.S. Some experts have voiced concern that research centers in the U.S. and Europe have an extreme shortage of research experts in the AI field. There are those that suggest that Japan may not have, in the whole country, enough experts to adequately perform the fifth generation work proposed. The benefits of added numbers of researchers, with possibly superior expertise, are powerful reasons why Japan wishes to have international help. In addition, it obviously moves an important focus of computer research to Japan.

There have, from the outset of the fifth generation project, been general statements of interest by U.S. and European companies. These have lead to protracted talks about how such collaboration might be arranged.

IBM, at the apparent urging of the Japanese, informed MITI in 1982 that it wanted to participate. In addition to the very large and expert base which IBM could add to the project, MITI may have hoped that such an arrangement would help to alleviate U.S. Government demands that Japan open the door for foreign firms to participate in government sponsored projects. MITI's acceptance "In principle" of the IBM offer is attributed to the superior position of IBM in the world computer markets. Reportedly, some members of MITI are skeptical over why the world's largest computer giant would wish to expose its corporate secrets to Japan. Despite such skepticism, some MITI officials said IBM saw an opportunity to share expensive R&D costs while gaining knowledge of what the Japanese competition is doing. The public pledges by IBM and acceptance in principle by the Japanese notwithstanding, no IBM researchers have been assigned to ICOT.

Japanese talks with the U.K. about collaboration in the fifth generation project have also been ongoing since the beginning of the project. However, as late as November 1984, there had been no definite progress. The Japanese had proposed, among other things that individual British companies might cooperate directly with Japanese companies and that British academics from Imperial College and Manchester University be seconded to ICOT.

During the early stages of these discussions, the British were putting their Alvey project together. Further complicating the negotiations were the questions of government vs. private industry relationships between the two countries and the availability of researchers. According to Mr. Brian Oakley, head of the Alvey Directorate, any consideration of sending university researchers to ICOT would put them in direct competion with the Alvey project which has encountered manpower problems.

Mr. Oakley further expressed some reservations about the direction and quality of the ICOT research indicating that the Japanese had committed themselves to "too narrow a path" and were "somewhat inflexible" by U.K. standards.

It is difficult to assess the net effects of all of the talk about international cooperation in the Fifth Generation project. In terms of presenting an openness and willingness to collaborate internationally, the Japanese cannot be faulted. Their most recent conference in Tokyo was attended by 1100 researchers, scholars and other representatives from 29 countries including Japan. However, some attendees were critical of the conference on the grounds that the first two days were devoted to "Public Relations" activities. This left only two days for the presentation of a large number of technical papers in too short a time. One guest speaker, Professor Ezea Vogel from Harvard University, commented that ICOT has no foreign researchers. Another researcher observed that ICOT is not as closed as some critics suggest, despite the fact that there are no permanent foreign researchers. Other sources have suggested that the final bargain concerning foreign researchers in ICOT is not really consequential since most of the critical research is being done by member companies and is not directly accessible by ICOT researchers. It is apparent that foreign sponsors have not yet seen sufficient promise in the ICOT project to offset the cost in scarce research manpower and risk to national/company technology to make a cooperative venture worthwhile. Even if foreign participants were determined to join ICOT, the terms of participation might be unacceptable. Given the general misgivings about Japanese motives and other uncertainties, it appears doubtful that foreign researchers will be forthcoming. While the Japanese will not benefit technically from this outcome, they have gained some political advantage by continuing the dialogue with foreign governments and companies.

CHAPTER SEVEN

KEY FACTORS

William Ouchi in his book "The M-Form Society" or "How American Teamwork Can Recapture the Competitive Edge" presents the thesis that the patterns of government and industry collaboration have been successful in Japan and can work in the U.S. In advancing this thesis while discussing technology developments in the U.S. he presents the following, in part.

> "Within the Department of Defense, we have seen as a nation a clear need to place scientific advancement ahead of these concerns (of illegal collusion). As a result, the Department of Defense enjoys a nearly unique charter in the public eye, a charter permitting it to engage in bringing competitors together for the purpose of developing new defense technology. On the one hand, this anomaly allows us to see how a Japanese-like R&D process works in the United States -- it works very well. On the other hand, it should not escape our notice that we confine this benefit to very narrowly defined military procurement. The job of the Department of Defense in this area is to procure as much defense as possible for as few tax dollars as possible. The job is not to sponsor the creation of new jobs for the economy and not to advance technology in the United States. As a consequence, although, some defense projects have spun off significant new commercial technology, the vast majority have not."

Professor Ouchi goes on to examine two cases, the Photovoltaic (PV) Project under the guidance of the Department of Energy (1978-1983) and the Very High Speed Integrated Circuit (VHSIC) Project under the Department of Defense (1979-1986). While the PV project was discontinued without substantial result in 1983, the VHSIC project has been repeatedly cited as a model for how government and industry can achieve positive R&D results. Professor Ouchi commented on the success of the VHSIC project. "It is also instructive to note that VHSIC had in place something that the photovoltaic solar energy program did not, a coordination mechanism in the form of a permanent DoD Staff experienced at working with industry on research and development."

Many would take issue with some of the details of Professor Ouchi's analysis. However, the major point of his remarks seems correct and certainly is applicable to super computers. What's more, the question of how much U.S. government involvement and what form it should take appear very basic to other considerations. Particularly, if past history is any guide.

In searching for the proper strategy for success in developing the super computers of the future, it is tempting to try to identify some key factors, if not guiding principles which might be helpful in thinking about the problem. The following seem to be some broad factors which are key.

1) The adequacy of National Security Consideration as the Primary U.S. Government axis for advancement in super computers must be assessed: It Is clear that the primary axis of Japanese government involvement in both the Super Speed and the Fifth Generation Projects is support for the needs of their industry. The goals are to support modernization in domestic industrial activities across a broad spectrum first and to compete effectively in the computer markets internationally. U.S. computer manufacturers have apparently received sufficient impetious from U.S. government concerned with national security matters to support their national and international commercial competition up until the present. However, it has been pointed out in Chapter Four that U.S. dominance was not really challenged until recently. What combination of government/private enterprise will be required to assure high probability of continued U.S. competitiveness?

2) Control of Advancing Computer Technology Will Represent a Difficult National Security Challenge: Competition in world markets already places a serious strain on U.S. government/industry relations where advanced computer technology, especially super computers are involved. The rate of advance over the next ten years may give some support to the proposition that even two or three year old technology represents no threat and controls on export should be relaxed in the interests of more international sales. Equally important will be our international agreements and mechanisms for controlling technology flow. Key to a successful technology control policy will be accurate definition of what constitutes critical technology and a clear set of rules and procedures which will satisfactorily control exposure of this technology.

3) Commercial marketability of Super Computer Will Be Critical: The extent to which super computer developments may be commercially adaptable will be important at least in the short run. That is not to say that military/government applications are not important, however, to the extent that they do not have commercial spin-off, government must bear the burden of making them profitable for industry. Strength and vitality within the industry both nationally and internationally will ultimately be dependent on ability to successfully compete in the commercial market place.

4) User Assistance and Advancement is Essential: There is little point to produce more powerful computers unless they are also more useful. Making these tools easier to use and educating a larger segment of the potential markets in how to use them is equally important. To this end, incremental advance in speeds of smaller computers and their gradual acceptance across a broader spectrum of industry will help the learning curve. The NSF university computer centers program will make super computers available to many future scientist and engineers. Nonetheless, computers in general and super computers especially must be made more useable to establish a broader commercial market. Software development is critical. In all but the most directly related defense industries, private enterprise must bear the burden.

5) The International Market in Super Computers Must be Balanced: In the oft used vernacular of the economists, we must find a means to "level the playing field". The commonly held view of the U.S./Japanese trade relations in past is characterized as follows: The U.S. develops the technology which the Japanese perfect commercially for sale in U.S. markets. In addition, U.S. products are constrained from competing fairly in the Japanese markets. On the other hand, the early struggles of the Japanese industry to regain Japanese computer markets from U.S. companies has surely developed a competitiveness and resolve that will not easily relinquish market shares anywhere; Japanese markets in particular. Then to what extent does Japanese government involvement tilt the field in favor of Japanese industry and what to do about it? In Chapter Two, the description of the present super computer market shows that the U.S. is the market with Europe a distant second. Are there areas for international cooperation between Japan and the U.S. that can mutually benefit our super computer industries? Japan invited foreign participation in its fifth generation project. Something beyond the U.S./Japanese company arrangements which amount to a marketing system for Japanese computers in the U.S. is required.

6) A Balanced Effort Across the U.S. Computer Industry Spectrum Must be Maintained: It is easy to understand why market forces by themselves can reduce the commercial R&D in super computers. It seems equally possible if uncertain futuristic goals are given too great a priority by government that the risks of producing little of near term commercial value can occur. Likewise, relegating important segments of the industry exclusively to foreign industry must be done only with careful judgement of the full consequencies. There is growing evidence for example, that our super computer development relies too heavily on the Japanese microelectronic industry. Vertical integration of R&D and commercial developments are key strengths of the Japanese effort.

CHAPTER EIGHT

CONCLUSIONS

A U.S. competitiveness, if not outright dominance in the super computer and related fifth generation computer technologies, must be maintained. This is a central matter of national security first and international commerce in high technologies as a close second.

The consequences of foreign technological superiority are clearly unacceptable. Assuming that domestic consumption will take the first two years of leading technology, an unacceptable time lag in U.S. access is developed. In the worst case, total denial of the technology would cause further delays while U.S. R&D develops the technology. Finally, the commercial spin offs for use in other computers would be lost.

The key is how to maintain a sufficient R&D effort across the spectrum of related technology and improved transfer of this technology from federal R&D to the commercial sector to assure that the rate of technology advance is at least equal to others and in particular the Japanese. It would appear that the chief strength of the Japanese is their planning and vertical integration of R&D. Much of the reaction to their plans appears a little like Babe Ruth pointing at the centerfield fence. It's only significant because he subsequently hit the ball over the fence. The stakes are sufficiently high that the U.S. must assure the U.S. position.

As Malcolm Peltu suggests in his article on "The dangers of the fifth-generation ballyhoo", there is real danger that in the zeal to keep up, or capitalize on the challenge as a means to secure funds, other promising avenues of research may be ignored. It does seem important to maintain flexibility in research programs to guard against this pitfall.

The actual degree of government involvement is also a dilemma. The U.S. government is already doing a lot through NSF, DARPA, DOE and NASA. Possibly there is more that must be done. Most recently a Software Engineering Institute has been started at Carnegie-Mellon and a Super Computer Research Center has been established in the Maryland suburbs. At least three major studies have been commissioned and associated advisory panels have been formed to assess the status of U.S. computer R&D. (But, there is such comfort in having a <u>national</u> plan.)

The panel organized by DoD, DOE, NASA and NSF and chaired by Peter D. Lax of NYU recommended a long term government - directed super computer production plan. M. Douglas Pewitt, assistant director of the Office of Science and Technology Policy (OSTP) commented on the proposal as follows: "We have a real problem. It's a problem that is not immediately amenable to a federal solution. The government could upset the development of faster super computers by barging onto the scene." Mr. Pewitt went on to say that accelerated federal spending in this area was possible.

The British experience of 1959-1962, whatever it's weaknesses did in fact have exactly the negative effect on British industry that Mr. Pewitt suggests might occur if overzealous government efforts were unleashed. A large centrally directed effort is generally thought to limit flexibility of small team research and thereby stifle potentially productive efforts in highly developmental work. Clearly there are at least two opposing views of how best to assure continued dominance in the super computer field.

There are at least three other areas in which U.S. government effort can be productive. First, legislative action to permit limited cooperative R&D without automatic anti-trust challenge is being proposed. It would seem that this is an important step toward better industry R&D. Other R&D incentives such as tax incentives might also be considered. Second, a major effort must be made to free up the international market with the Japanese. The future stakes for both countries are extremely high. The possibilities of closing U.S. markets to Japanese industry would seem to make a compelling argument for cooperation. This is of course, only a subset of the much larger imbalance in U.S./Japanese trade needing a remedy. The U.S. government should be prepared to collaborate on technology if this can be done to mutual advantage. Third, a thorough review of the rules, regulations, procedures etc., concerning technology transfer must be undertaken. The subject is of gravest concern for national security. At the same time, some degree of realism must be brought to bear. Control of technology in some of these areas is very difficult and due consideration must be given to the ability of U.S. companies to compete in the international market. Clearly, if this matter is not resolved, then the foreign portion of the market may go to the Japanese by default.

Finally, this very sketchy overview of the leading edge of computer technology brings home just how far we have advanced into the computer revolution in thirty years. The next ten years have been called the beginning of the second computer revolution or possibly the important computer revolution. The vitality of the industry, the creativity of the people, makes the descriptions of fifth generation computers seem possible, even likely by the 1990's. Hopefully, the right strategies will be followed and the U.S. will not have relinquished a major portion of computer technology to others.