Chapter 6

Japanese Industrial Policy: The Postwar Record and the Case of Supercomputers

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Japan is the world's most successful practitioner of industrial policy. Japan's industrial policies are largely, though not solely, responsible for its economic recovery from World War II and its increasing preeminence in high-technology industries. Other factors influencing these successes are intelligent corporate strategies, an emphasis on saving and investment rather than consumption, and social ethics that place premium value on hard work and good education.

The Japanese Government has used industrial policies throughout the postwar period-and indeed did so for decades before the war-to guide the economy in the direction of higher value added and greater knowledge intensity, and away from heavy reliance on unskilled labor and natural resources.[1] While there is no consensus on the impact of Japanese industrial policy on national income, research suggests that by reducing the costs and risks for domestic firms to invest in a given industry, and by helping firms to advance technologically, industrial policies and targeting have contributed to Japan's international competitiveness in many industries, including steel, motor vehicles, semiconductors, and computers. Considering the impact that competitive companies in these industries have on other industries both upstream and downstream, the effect is profound.

American analysts are divided in their assessments of Japanese industrial policy. All acknowledge that the Japanese bureaucracy has tried to create competitive advantages both in specific industries and for business in general. There is less agreement about the results. It is rare in economics or political science to encounter a bona fide control group; lacking one, it is difficult to know what would have happened in a particular nation if some historical circumstance had been different. We cannot be certain what Japan's economic development would have been without industrial policy; this leaves ample room for disagreement. At one end of the spectrum are analysts who view industrial policy as the major explanation of Japan's success. Analysts at the other end hold the view that Japan's industrial policies have had a marginal impact at best. OTA's conclusion is that industrial policy has been a key ingredient, along with several other attributes of Japanese society, policy, and business tradition.[2]

The debate over the effectiveness of Japan's industrial policies has been fierce for reasons other than the wide latitude for interpretation of historical events. Accepting that Japan's approach has been successful is close to admitting that perhaps our own policies and ideology might need rethinking, a difficult and painful process for any nation. But the admission of Japan's success does not mean a makeover of America in Japan's image. Other nations can learn from Japan's success, as Japan did from nations more advanced; most of the world's developed nations or regions are in the process of strengthening their commitments to industrial policies, in part because of Japan's economic performance. This does not mean that other nations or regions are blindly copying Japanese policies of the past or present.

As most Western writers on the subject have noted, Japan is changing, and has been throughout the postwar period. The speed and character of the changes in Japan are another part of the vigorous debate over Japanese policy. Some argue that Japan is becoming more like the West, in terms of both economic performance and government policy. In some ways, it is; yet the Japanese industrial policy tradition and bureaucracy are still powerful, and continue to operate in very different ways than the United States. Moreover, Japan's Government and economic system continue to support development of industries and products at the high-technology frontier, although the intervention is less heavy handed than it was a couple of decades ago.

ECONOMIC TRADITIONS AND INDUSTRIAL POLICY

From very early in its history, the Japanese Government took the initiative in industrialization and economic development. Threatened by foreign powers and lagging behind economically and technologically, the Meiji Government, together with the top merchant families, took the lead in the 1870s in establishing and promoting Japan's basic infrastructure and industries.[3] By the turn of the century, the policies devised by the Meiji Government to promote industrial development were paying off: iron and steel production doubled between 1875 and 1895, machinery production rose sevenfold, and textile production increased eightfold. Japan was developing military power as well, and was strong enough to renegotiate a few treaties that had rankled for some time.[4]

Successful experience with a strong bureaucracy and close relations between business and government gives modem Japan a view of competition and the appropriate role of the state that is quite different from the laissez-faire traditions of the United States or Great Britain. Active government intervention in the economy is considered natural and indispensible in the Japanese bureaucracies, and unfettered price and investment competition is viewed with reservation, at best. Many of the practices of business and government that are considered perfectly normal means of promoting industrial health and development in Japan are considered unfair in America. According to one analyst:

> The American criticism of Japan. . . stem[s] from the conviction that in many cases market outcomes are shaped by Japanese business practices considered unfair-predatory pricing, patent infringement, industrial espionage, and explicit or implicit protection of Japanese markets from import competition . . . the basis on which the problem must rest [is that] Japanese success in blocking imports into their own country or in penetrating U.S. markets comes, at least in part, from anticompetitive behavior rather than from competitive ability.[5]

Scholars differ not only on whether Japanese industrial policy has succeeded but also on the criteria they use to measure success. Some studies focus on the contribution of industrial policies (including targeting) to the development of the targeted industry,[6] others on consumer welfare or national return on investment,[7] and still others on how policies affect both specific industries and the nation's long-term technological trajectory.[8]

Analysts at one end of the spectrum believe that Japan's active state bureaucracy, close government-business relationships, the stable political rule of the Liberal Democratic Party, the weak Diet (legislature), and strong industrial policy are key ingredients of Japan's success. According to this school, Japan is a mercantilist country that focuses primarily on national economic goals and self-sufficiency. With the decline of U.S. hegemony, analysts of this stripe are particularly concerned about what they see as Japan's hesitation to take on a fair share of the economic and political burden of supporting the world economic order. They argue that Japan is benefiting tremendously from the open trading system, exploiting the openness of other nations. They acknowledge that fierce market competition has been another key ingredient of Japan's success, but suggest that market forces have been shaped by state industrial and trade policies and other institutional guidelines in ways that often benefit Japanese businesses at the expense of both foreign businesses and Japanese consumers. They identify institutions like MITI (the Ministry of International Trade and Industry), the *keiretsu, the* government's Japan Development Bank, and the quasi-governmental telecommunications giant, NIT, as hindering foreign access to the Japanese market. While they acknowledge that MITI's power has waned in recent years and that Japan's economy is more open now than it was a decade ago, they believe that MITI still plays an important role in nurturing industries and technologies, and that Japan's market is still more closed to imports than those of most other developed nations.

There are a variety of views within this school of thought. Some see the bureaucracy as having been the most important actor guiding development, some see big business as having the upper hand in the government-business relationship, and some believe that no one group in the ruling elite is really in charge.[9]

At the other end of the spectrum are those who see Japan's industrial policy as having had, at best, a marginal effect on Japan's success. These analysts argue that high rates of savings and investment operating in a free market, a good educational system, and willingness to quickly adopt foreign technologies are the key sources of Japan's success. This group sees Japan as being very similar to the United States and Western capitalist democracies in having policies that both support the free trade regime and focus on maximizing consumer welfare. Some argue that Japan has developed in spite of industrial policy, others that industrial policy has only compensated for Japan's underdeveloped stock and venture capital markets and small supply of scientists, and still others that industrial policy has helped at the margin in some industries.[10] Overall, they believe that the role of Japan's industrial policy has been greatly exaggerated and point out that some targeted industries, such as petrochemicals, have not been successful, while many competitive industries, such as consumer electronics, have not been actively targeted. Proponents of this view argued for a long time that the U.S. trade deficit with Japan had little to do with Japan's industrial and trade policies and was instead primarily the result of an overvalued dollar. The failure of the sharp plunge of the dollar since 1985 to correct the U.S.-Japan trade imbalance has led several of these analysts to change their views.[11]

In addition to the stubborn trade deficit with Japan, another development is reconciling some of the differences between the views described above. In the past decade or so, a group of economists often referred to as "the new international economists," using accepted economic methods, have given new life to an old idea: that there are industries that add more to national income and well-being than others, and that governments can raise national income by promoting such industries. These sectors are characterized by significant barriers to entry (in terms of both knowledge and resources), increasing returns to scale, a steep learning curve, high value added, and significant positive spillovers to other sectors of the economy. Some of these analysts suggest that the Japanese Government, by using strategic industrial and trade policies, has been able to increase national income in some cases by targeting such sectors.[12]

As new evidence becomes available, it seems increasingly clear that Japan's industrial policy has contributed significantly to the development of several specific industries, and has created a climate conducive to development in many more; its role has been particularly significant in high-risk, high-cost, and innovative industries.

OVERVIEW OF TOOLS AND TARGETED SECTORS

There have been four main periods of industrial policy since World War II. The earliest, 1945 to 1952, included the creation or rebuilding of many of the industrial-policy institutions to help Japan's economy get back on its feet. From the mid- 1950s to the mid-1960s, the government began to allocate scarce funds to specific industries, including steel, automobiles, and electronics. The following decade was the peak of Japan's so-called high-growth period, and represented to many Japan's last chance to gain a foothold in high-technology industries before the inevitable pressure to open up its markets began. Government still wielded powerful tools, though with less heavy handed policies than in the 1950s.

The current period began in the mid-1970s, following the first energy shock. Starting in the early 1970s, the state, besieged by the oil crisis and various pollution and quality-of-life problems, began to shift its support away from energy-intensive industries, such as steel, towards more knowledge-intensive, high value-added industries, such as computers, semiconductors, and biotechnology. In this period, and particularly in the 1980s, many Japanese companies became very strong, and thus less dependent on government for protection and subsidies. In response to increased trade friction, industrial and trade policies became less visible and formal, and tariffs and quotas were eliminated or substantially reduced. At the end of the decade, legal hindrances to foreign investment were removed as well. Despite this liberalization, Japan's market remains one of the most difficult to enter, especially among advanced capitalist countries; most of the current barriers are business practices and institutions, many of which evolved to serve other purposes as well as protection.

Institutions of Industrial Policy

The Japanese bureaucracy, fortified by new tools instituted during the Occupation, used industrial policy to try to change Japan's industrial structure from labor-intensive industries during and before the war to capital-intensive industries in the two decades following the war, and to knowledge-intensive industries beginning in the 1970s. In the first few years following the war, Japanese and Occupation leaders set up many of the institutions and laws that would provide a foundation for postwar industrial policy. MITI, the central and most powerful of those institutions, was created in 1949 (before that, it was the Ministry of Commerce and Industry, or MCI). In 1950, the Japan Export Bank (later called the Export-Import Bank) was established to promote exports by providing financing. The government's Japan Development Bank (JDB) was established in 1951 to help supply low interest loans to designated industries for investment in plant and equipment. JDB went on to be an important bellwether for commercial bank lending, as well as being a lender itself.[13]

Several laws, such as the Foreign Exchange Control Law of 1933, the Foreign Exchange and Foreign Trade Control Law of 1949, and the Foreign Investment Law of 1950, gave the Japanese Government control over the flow of foreign exchange, investment, and goods. Though necessary in the early years to deal with balance-of-payment problems, these laws also provided the government with an effective tool with which to protect Japanese industries from foreign competition. MITI's control over the foreign exchange budget "played a large role in protecting and fostering domestic industry," states Professor Nakamura Takafusa of Tokyo University.[14]

Numerous studies show how these laws prohibited or controlled the entry of foreign products and investment and promoted production-oriented rather than consumer products-oriented industries.[15] For example, the threat to fledgling Japanese producers from foreign firms that wished to sell cars or invest in automobile production in Japan was substantial in the early 1950s. The Japanese Government remembered that, in the 1930s, vehicles manufactured in Japan by General Motors and Ford came to dominate the market, inhibiting the development of Japanese auto companies. By 1934, vehicles made in Japan by American companies held almost 90 percent of the Japanese market, and the large volume of imported parts threatened to leave Japan with a chronic trade deficit.[16] So, when several European and one American automobile firm began to explore possibilities for building assembly plants in Japan in the early 1950s, MITI took several steps. One was to issue its "Basic Policy for the Introduction of Foreign Investment into Japan's Passenger Car Industry," supplementing the Foreign Exchange Law, which stated that repatriation of earnings from foreign investment in marketing facilities was not guaranteed, and earnings repatriation from production facilities would be guaranteed only if those facilities "contributed significantly to the development of domestic industry."[17] In effect, this gave MITI the authority to determine on a case-by-case basis whose earnings could be repatriated, and effectively barred marketing. Moreover, MITI stated that foreign firms would be allowed to enter the Japanese market only through technical tie-ups with domestic fins. It announced four provisions for inclusion in the contracts:

1. small European cars were more suitable than large American cars;
2. the use of foreign currency allocated for cars should be used for importing parts instead, and MITI could only allocate enough for production of 1,200 cars per company;
3. the Japanese company should try to obtain the right to sell the cars in Southeast Asia; and
4. domestically made parts should eventually substitute for imported parts.

Using these tough criteria, MITI rejected all but 4 of 11 proposed tie-ups.[18]

Access to foreign technology was preferred over both foreign direct investment and imports. Foreign technology was seen as an important source of profit, and access to it was tilted mostly towards basic industries.[19] The automobile case was perhaps the most notable exception; and even there, one of the primary reasons for promoting automobile production was to support the metalworking and machinery industries that auto production demanded. MITI (which was MCI before 1949, but which is referred to as MITI throughout this report, for convenience) emphasized that automobile production was closely connected with parts and machinery industries and established an automobile section in January 1946.[20] Later, in the 1950s, MITI used the same argument more strongly, again in support of its then uncompetitive automobile industry, promoting passenger car development as "the pinnacle of the modem machinery industry in our country where there is no aircraft industry."[21] Making cars would raise technology and quality in both machinery and steel industries, as well as create markets.

Though originally enacted to deal with immediate postwar problems, the laws controlling foreign investment and foreign exchange were retained far longer than the Occupation forces intended; in many cases, they were not revised until the late 1970s and 1980s, and many of the revisions were cosmetic. On the other hand, the antitrust law was weakened 1 year after the Occupation ended; this enabled the government to restrict competition and promote economies of scale, authorized anti-recession and rationalization cartels, sanctioned retail price maintenance, and relaxed restrictions on cooperative arrangements such as cross-shareholding, interlocking directorates, and mergers. In the late 1950s and 1960s, the Japanese Government exempted from the law certain sectors such as the machinery and electronics industries.[22]

The weakening of the antitrust laws was also a part of the government's strategy to encourage the rebuilding of the industrial groups after the Occupation. Industrial groups, or *keiretsu,* were also a prominent part of the Japanese economic scene before the war, but in somewhat different forms; the pre-war *zaibatsu* were family controlled enterprises, in many cases of quite grand proportions. While the Japanese authorities initially cooperated with the Occupation forces in dismantling the *zaibatsu* after the war, they had little commitment to a less concentrated economic structure overall.[23] The reemergence of these groups as looser, bank-centered alliances had two benefits: the government could more easily influence the behavior of firms through centralized control over funds and banking, and the close relations of buyers and suppliers (including cross-shareholding) within groups helped keep imports and foreign investment down. The cohesiveness of the industrial groups became even more important in the late 1950s and early 1960s, when foreign pressure to liberalize Japan's market stepped up. Japan also joined the Organization for Economic Cooperation and Development (OECD) and in 1964 agreed to accept the obligations of a developed country under Article 11 in the General Agreement on Tariffs and Trade (GATT), which meant working to eliminate quantitative restrictions on trade.[24]

Another institutional innovation that provided key financial support for industrial policies is the Fiscal Investment and Loan Program (FILP), a huge discretionary "second budget" separate from the general account budget.[25] First established in 1953 when the Ministry of Finance (MOF) pooled the postal savings accounts, national pensions, and various other accounts, this budget is made annually by MITI and MOF bureaucrats with little input from elected officials and other constituents. It is enormous; it has been from one-third to one-half the size of the General Account Budget and has ranged from a low of 3.3 percent of GNP in 1956 to a high of 6.3 percent in 1972.[26] In 1990, the FILP was in the neighborhood of 34.6 trillion yen, or about $250 billion (at an exchange rate of Y135 per dollar) .27 The postal savings system, which contributes nearly a quarter of the money in the total FILP budget, has deposits of over V134 trillion (about $1 trillion), making it the largest financial institution in the world.[28] The system was able to attract savings from citizens by allowing a lower tax rate on interest to depositors and allowing the post offices to offer higher interest rates than banks, although these "higher" rates are still low by American standards. In 1988, they increased to what was then a high of 1.68 percent, and recently went up to 3.48 percent.[29] By paying low interest rates to depositors, the FILP system has been able to subsidize producers with low interest loans.[30]

FILP money goes directly to finance government policies; it is still an important instrument of MITI influence.[31] In the 1950s especially, FILP was indispensable for implementing government policies; in the early part of that decade, it accounted for nearly 30 percent of the capital available to industry. In the 1980s, in contrast, FILP's contribution fell to less than 10 percent. Japan's companies now have many sources of capital and far less need for publicly funded capital investments or indicative loans to encourage private sector lending.[32]

Targeting was also supported indirectly by a broader financial system that favors producers over consumers. Indeed, by not allowing instruments of consumer credit to develop until recently, Japan has made it imperative that its citizens save a large part of their income for any major expenditures. The lack of adequate provisions for retirement also made saving for old age a must. By limiting the development of viable alternatives to savings deposits and limiting interest rates on those deposits, the government gave citizens little choice but to put their savings in bank or post office accounts at very low interest rates, while Japanese financial institutions were able to invest those savings abroad at interest rates often exceeding 10 percent.

MITI thus controlled a large source of money that was unaffected by political maneuvering or lobbying, foreign exchange and investment, and trade. Also in the toolkit of policies to promote industrial development were policies to gain cheap access to foreign technology, tax measures to encourage specific types of investment, the ability to organize cartels, and a limited ability to affect industrial concentration (the number and size of firms in an industry). Through a process of constant consensus building with industry representatives, MITI bureaucrats could bring many specific measures into play as needed for the industries it wished to promote, as illustrated by the case studies below.

Industrial Policy and Steel Industry Development

The steel industry is a key example of Japan building up a competitive industry in an area in which it clearly had no comparative advantage. The steel industry was badly damaged during the war, leaving only about 25 to 30 percent of plant capacity functional as late as 1949.[33] Japanese producers also had tremendous cost disadvantages, largely due to the high price of imported raw materials and poor labor productivity resulting from inefficient equipment.[34] To help the industry become competitive, the government protected it from foreign competition, gave it financial aid for investment in new technologies and improved plants, created various mechanisms to manage domestic price and investment competition, and encouraged mergers to help the firms gain greater economies of scale.

Initially the steel industry was protected by high tariffs. Japan imported very little steel during the 1950s, even though domestic steel cost more than U.S. steel. Except during the 1957 recession, steel imports never exceeded 2.7 percent of internal demand.[35] Imports of raw materials and equipment necessary to produce steel were generally exempt from import duties.

Financial assistance in the form of grants, low interest loans, and tax breaks were given to the industry, especially in the 1950s and early 1960s. Much of the aid came from Japanese coffers, but in the 1957 to 1958 recession, MITI arranged for the World Bank to funnel loans to the steel industry through the Japan Development Bank. The JDB guaranteed the loans and also got the World Bank to loosen its regulations on the percent of equity and liquidity required for a firm receiving World Bank loans.[36] As in other industries, financial aid had strings attached: it went only to the firms MITI felt were strongest and most capable of using the money effectively, and it was given for investment in specific types of equipment, especially to larger, modern factories using efficient technologies.

MITI's control over access to foreign exchange enabled it to play a key role in the introduction and diffusion of basic oxygen furnace (BOF) technolofg.[37] In 1955, two Japanese steel makers asked to license BOF technology from an Austrian firm. Mill, concerned that competition between the two for technology would result in a higher price, selected one to be the general licensee and required that it give the other steel makers equal access to the technology as sublicensees.[38] This kept the Austrian patent holder from playing the Japanese companies off against each other to get a higher license fee, a strategy MITI would use again in gaining access to foreign technology, notably in semiconductors and computers. A complex agreement was worked out by which all firms using the BOF technology contributed to the $1.2 million license fee. As a result, the technology was cheap: during the 14-year period of the license, it cost Japanese steel makers 0.36 cents per ton, compared with the 15 to 25 cents per ton that North American firms paid in royalties.[39] In addition, MITI's action helped diffuse the technology quickly.[40] The competition, then, quickly shifted from who could gain access to the technology to who could apply it rapidly and efficiently. MITI did not pick BOF technology as a winner; the two firms discovered it themselves. But by making it available at a reasonable rate and on terms that promoted rapid diffusion, MITI helped upgrade Japan's steel industry faster and more cheaply than market forces would likely have done.

MITI also helped stabilize prices, production, and investment through cartels. A major problem in capital-intensive, high-freed-cost industries like steel, which make relatively undifferentiated producer goods, is that their boom-bust cycle can often lead to severe investment and price competition. During boom times, the firms expand capacity to cut costs through economies of scale; during recessions they cut prices to minimize losses inherent in businesses that have high freed costs.[41] Many studies have concluded that these investment and price cartels helped provide the industry with stability of supply and prices, especially during recessions.[42] Japan's companies were particularly vulnerable to economic downturns because of lifetime employment, high debt-to-equity ratios, and especially intense domestic competition. Because of these, it was much harder for Japan's companies than for their foreign competitors to lay off workers, cut back on production and investment, and operate at low capacity utilization. While these rigidities are partially offset by other institutions such as widespread use of temporary workers, subcontracting, close relationships with banks, deep pockets and ready availability of capital, recessions still pose a special problem.[43] Of course, this also means that part of the problem of over-investment and excessive price competition is a result of government industrial policy; some studies argue that MITI's cartels, by sharply reducing risks, encouraged firms to overinvest in plant and equipment, which in turn exacerbated the problems of recession vulnerability.[44] While Japan's steel makers have had excess capacity problems, particularly right after the first oil shock in 1974, their capacity utilization has almost always been higher than that of their U.S. and European counterparts,[45] perhaps enabled by the very fast growth of the Japanese economy, the emphasis on exports, or both. And Japan's big integrated mills did contribute to Japan's becoming the world's lowest cost producer of steel.

MITI's original plan for the steel industry encouraged cooperation in order to stabilize investment, prices, and output. Later, it encouraged mergers to increase the size of firms, hoping to strengthen the steel companies to compete with foreign firms.[46] In the 1960s, as Japan was beginning to liberalize its markets to conform with GATT and OECD requirements, MITI pushed for mergers in many industries to strengthen them and thus prevent U.S. firms from dominating Japanese producers.[47] Yawata and Fuji Steel, Japan's two largest steel fins, were one firm--a nationalized steel company-until it was broken up and privatized by the U.S. Occupation. With MITI pressure and financial assistance, the two companies merged to form New Japan Steel in March 1970, creating the world's largest steel maker. MITI's goals were to create a dominant firm that could provide stable leadership in price, technology, and production volume, and to decrease costs.[48] The merger attained these goals, and the higher steel prices that Japanese scholars feared would result never materialized. Imai Kenichi, a scholar who was particularly concerned that the new company's size and domination of the market would have a negative impact on market performance, admits that:

> within only 2 years after the merger, the Nippon (Japan) Steel Corp. developed its international competitiveness beyond a necessary level to the point where Japanese-U.S. relations maybe brought to another crisis similar to that which developed over textiles. ..49

In short, the merger was so successful it caused trade friction.

Other policies promoted development of the steel industry. Special depreciation allowances promote investment in rationalization (a term that covers many things having to do with achieving the proper size of industry and enterprises, including downsizing to eliminate excess capacity, advancement of technology, improvement of quality, reduction of costs, and improvement of efficiency), acquisition of experimental equipment, and exports. During the 1950s, the steel and automobile industries received exceptionally large benefits from special depreciation schemes, and between 1962 and 1973, the steel industry ratio of special depreciation allowances to total depreciation was, at 15 percent, almost twice the industry average of 8 Percent.[50] By another estimate, a revision of the depreciation schedule in 1961 reduced the statutory life (depreciation period) of industrial equipment by 20 percent; another revision 3 years later reduced it an additional 15 Percent.[51]

Early in the 1950s, the steel industry was also an object of special attention from the Japan Development Bank. JDB provided up to 15 percent of the funds to implement MITI's first rationalization plan for the industry from1951 to 1953.[52] Until the late 1960s, the iron and steel industries were protected from imports by measures equivalent to a 30-percent tariff. By 1973, the effective rate of protection had fallen to 17 percent, but it shot backup to over 50 percent in 1975 (Japan's severe post-oil-shock recession), and fell again to below 20 percent by 1978.[53] The steel industry got approval to import needed industrial equipment without paying the tariff on it. Finally, the industry was encouraged to export through the use of a tax deduction in the early years; this provision disappeared in 1963.

Without industrial policy it is extremely unlikely that such a competitive industry would have emerged so rapidly after the devastation of the war. While Japan's steel industry has had some problems—especially excess capacity after the oil shock in the mid-1970s--it has been able to scale back its operations and shift into specialty steel. Some scholars nonetheless argue that steel may be "the success that never was" because it had a relatively low return on investment compared with other industries in Japan;[54] they assert that the resources poured into the steel industry could have been allocated more efficiently in other industries to gain a higher return. Targeting steel, they maintain, "probably reduced Japanese national income."[55]

Japan's steel industry did have a relatively low return on investment. But this was not the concern of the Japanese Government, nor the firms or their shareholders. Their goal was to gain greater world market share and to provide the foundation for industries that use steel, such as automobiles, machine tools, and shipbuilding. Low return on investment in an industry that provides key inputs into other industries does not necessarily lead to a net loss for the economy.

Indeed, evaluating the effectiveness of industrial policy on the basis of return on investment often leads to the conclusion that Japan is largely a failure. Many of Japan's top firms today have returns on investment that are unacceptable by U.S. standards, made possible by, for example, cross-shareholding and stable shareholding, low capital costs, and a general preference for increasing market share over increasing share prices.[56] But while many Japanese firms and industries may be *inefficient* by U.S. financial standards, they are *effective in* consistently winning market share in many key industries. Also, the low returns on steel may well have been compensated by higher returns in industries that use steel, including automobiles and machinery. Steel had other benefits for Japan; by 1960 it was the country's largest earner of precious foreign exchange.[57] More generally, it provided the industrial infrastructure necessary for an advanced, industrialized nation, including a large pool of skilled workers with high-paying jobs.

Industrial Policy and Motor Vehicle Industry Development

Policies towards nurturing an internationally competitive automobile industry followed a pattern similar to those of the steel industry: heavy protection and subsidization, incentives for investment in technology, and increased concentration in the industry.

Efforts to support Japan's fledgling auto industry began before the war.[58] Early car producers were true entrepreneurs, but without support they might well have withered on the vine. The Japanese military became interested in motor vehicles as early as 1906; by 1918 the government had passed the Military Vehicle Subsidy Law to provide manufacturing, maintenance, and purchasing subsidies to producers and buyers of qualifiedd vehicles (buses and trucks). To qualied for the subsidies, a producer had to show that over half the capital and voting rights of the company were held by Japanese nationals, and most parts had to be made in Japan. This was an important stimulus to the domestic industry, but not enough to protect it. Ford and General Motors, watching their sales take off after the Great Kanto Earthquake of 1923 damaged all of Japan's domestic auto producers, rushed to set up their own offices in 1924 and 1925, and quickly came to dominate the market. It became apparent to the government that imports and foreign direct investment could cripple the technologically backward domestic industry, which could in turn contribute a chronic deficit to the trade accounts and be a drain on Japan's scarce foreign exchange. The Automobile Manufacturing Enterprise Law of 1936, through various regulations, forced Ford and GM to terminate their successful operations in Japan and enabled Toyota and Nissan to use the U.S. companies' dealer networks to build their own distribution systems. This law also gave the army control over policies affecting the automobile industry, and turned domestic producers' attention almost exclusively to making trucks and buses.

After a few chaotic postwar years during which Japanese automobile producers had trouble getting permission from the Occupation forces to produce cars or obtain the raw materials and parts needed to do so, responsibility for promoting the auto industry was transferred to MITI. The Ministry pushed automobile industry targeting because, it argued, the auto industry would provide the source of demand needed for Japan to modernize related industries, including machinery.[59] This decision was controversial—the governor of the Bank of Japan, for example, initially argued that:

> . . . since Japan should develop its foreign trade on the basis of the international division of labor, efforts to develop the auto industry will be futile. . . As we can get inexpensive motor vehicles of excellent quality from the United States, why don't we rely upon them?[60]

MITI prevailed.

The first 5-year plan for promotion of the auto industry came from MITI in 1948, and it featured the use of imported technology and financial assistance provided by the Reconstruction Finance Bank to help obtain capital, raw materials, electricity, and labor. The Asian market was the main export target, and controls on prices and distribution were put in place for an interim period, to be lifted when appropriate.[61] Recession caused by economic policies known as the Dodge Line (after Joseph Dodge, the Detroit banker who drafted and implemented Japan's deflationary program) forced abandonment of the plan and threw the automobile companies into chaos. Nissan laid off over 1,800 employees in October 1949 and cut wages 10 percent, Diesel Motors abolished its agreement with its union and laid off nearly a quarter of its workers, and Toyota almost collapsed (although its founder refused to lay off anyone and was eventually forced out of the company as layoffs were implemented). Rescue came in the form of the Korean War. Japan, as the best source of emergency supplies, received many orders for special procurements by the U.S.-led U.N. forces, enough to end the recession and save the struggling automobile industry.[62]

The hiatus in government promotion of the automobile industry brought by the Dodge Line was brief. After the recovery, many new policies were implemented to support the industry. They included an ambitious road construction program; protection from imports and direct investment; imports of foreign technology under favorable terms; and direct financial assistance.[63] Protection consisted of high tariffs (35 to 40 percent on cars until 1969, falling to zero by 1978), commodity taxes that favored domestic automobiles, foreign exchange allocation that restricted imports, and foreign exchange controls on direct investment. Excise taxes that favored small cars over large, luxury vehicles effectively kept out American cars, but after a surge in imported small cars from Europe, additional measures were implemented. Among them were allocation of foreign exchange to buy European cars only for taxi companies and the media, and prohibition of resale for 3 years.[64]

Other measures were similar to those used in steel: low interest government loans, subsidies, special depreciation allowances, exemption of necessary equipment from import duties, and approval of foreign exchange essential for foreign technology imports.[65] In 1956, the Law on Temporary Measures for Promoting the Machinery Industries added auto parts and automobiles, and research suggests that this promotion was particularly effective.[66] For example, financial aid along with efforts to encourage standardization and increase concentration of the auto parts industry contributed to a 56-percent cut in the cost of producing a passenger car between 1961 and 1965.[67]

Even with all these supports and the outstanding performance of the Japanese motor vehicle producers, the auto industry is frequently pointed to as a failure of Japan's industrial policy because of MITI's repeated failures to consolidate the industry into one or two firms or groups. In 1955, for example, MITI tried to promote production of an exportable subcompact by a single company, an idea the firms rejected strongly. In 1961, MITI tried to consolidate the industry into three groups to develop three types of cars. This plan was rejected, too. Had it been adopted, it would by widespread agreement have damaged the industry's long-term competitiveness. It is important to realize, however, that what would clearly have been a mistake did not, in fact, occur. Indeed, there have been very few large blunders of industrial policy, such as would have occurred if MITI had succeeded in merging the auto companies, because there is a system of checks and balances among the firms and government officials; policies are made through a process of negotiation and compromise, and in cases where the firms believe that a government policy goes sharply. . against their long-term interest, they reject it. The auto case is not the sole example of MITI unsuccessfully attempting to merge firms; in the late 1960s and early 1970s the ministry also tried to get the six major computer firms to merge into two or three companies, and the firms refused. A compromise was reached whereby the six firms formed three different groups for cooperative research and development. Despite this failed MITI attempt to consolidate the computer industry, even the most skeptical analysts acknowledge that industrial policy contributed to the development of the computer industry.[68]

Protection from imports and foreign investment, along with financial assistance, help in importing needed inputs, and special access to foreign technology were necessary though not sufficient conditions for Japan to develop comparative and competitive advantage in the automobile industry. The government did not create the automobile industry in Japan, nor did it create other successful industries such as electronics. Clearly, the companies' willingness to invest in new technologies, their persistence in finding new and better ways to use technologies, their continual improvement, and intelligent strategies for penetrating foreign markets played a vital role, as did Japan's well-educated and disciplined workers and overall financial policies that encouraged savings and discouraged consumption.

Color Televisions

Many proponents of the market explanation of Japan's economic development point to consumer electronics as an industry that succeeded without government promotion. In fact, they argue that the industry boomed in spite of a blunder by MITI: that of delaying Sony's acquisition of transistor technology by restricting Sony's use of foreign exchange.[69] In 1953, MITI refused Sony permission to acquire transistor technology from the United States because MITI did not want to use scarce foreign exchange for the technology; it also felt that a small, recent start-up such as Sony would not be able to use a brand new technology successfully .70 While the frequently cited American account of this refusa1[71] says that MITI delayed Sony's access for 3 years, Akio Morita of Sony says it took 6 months to persuade MITI to give them the needed foreign exchange.[72] Nonetheless, this mistake stands out as one of MITI's more serious errors.

The argument that the industry succeeded without government help is less powerful when the evidence is analyzed. The producers of televisions did not enjoy the number of tailor-made policies and degree of support given to targeted industries like automobiles, steel, semiconductors, and computers. But the television industry, like many others in Japan, benefited from government policies that lowered capital costs, protected against imports and foreign investment, promoted exports, and tolerated behavior that, in the United States, would have run afoul of antitrust laws.[73] MITI's policies made it possible for the color television industry to keep prices high at home and low abroad—in fact, Japanese producers were found guilty of dumping in the U.S. and European markets. For over a decade, Japanese makers sold televisions in the United States for about one-third to one-half the price of the same sets in Japan; this export price was also below cost.[74] High prices at home could only work under certain conditions: that is, if all major manufacturers agreed not to undercut one another's prices (collusive behavior, by U.S. standards), and if the market were effectively closed to imports. Both occurred. To fix export and domestic prices, the managers of the major manufacturers met regularly in groups such as the Okura Group and the Palace Group, named after the hotels in which the meetings took place.[75] And in the first half of the 1960s, the tariff on television imports was 40 percent.[76]

While Japanese firms needed to charge low prices to win U.S. market share, they avoided undue price competition with each other. Domestic firms set minimum export prices,[77] which MITI monitored. Another safeguard was the so-called "five company rule,' which required that each Japanese exporter specify five U.S. dealers as its only and exclusive customers. This kept large U.S. retailers such as Sears from playing the Japanese suppliers against each other to lower prices. An export association managed the formal registration of these buyer-supplier relationships; firms reported to that association each specific shipment of color televisions to the United -States, stating the buyers and suppliers involved, and the type, quantity, and price of the televisions.[78]

When the United States started to complain about this dumping in the late 1960s, Japanese consumers became aware of the discrepancy and boycotted Japanese televisions. MITI immediately gave guidance to the industry to reduce domestic prices, and the firm complied, though export prices were still much lower.[79] The secret meetings among the firms and control of distributors were allowed to continue.[80]

Japanese firms raised prices in the United States in 1974 in response to growing allegations of dumping and antitrust violations. This price change reduced but did not eliminate the gap between high domestic and lower export prices. Moreover, Japanese television manufacturers reportedly began to give kickbacks to U.S. retailers, making the actual prices much lower than those reported in accounting records, customs forms, and invoices.[81]

Collusion and dumping were not the only reasons for the success of the Japanese television makers. Japanese manufacturers worked hard to reduce their costs by introducing new technologies; in particular, they converted their TV production to solid-state integrated circuits early on. Japanese televisions gained a reputation for reliability in America, and made it possible for televisions to be repaired by large retail establishments rather than repair shops. As in every other successful Japanese industry, success came from a combination of intelligent company strategy and diligence, good workers, and government policies. None of these factors alone would have resulted in the same record of success.

Semiconductors

While there is a range of views about how important industrial and trade policies have been to some industries (consumer electronics particularly), there is much less skepticism when it comes to the semiconductor industry, and still less for the computer industry. There is no question that in a free market, U.S. companies would have dominated the Japanese semiconductor industry. Texas Instruments (TI) applied for 14 patents in Japan in 1960 and for permission to establish a wholly owned subsidiary there in 1964. These applications threatened to disrupt the development of a domestic semiconductor industry, an area that business and government leaders had decided was strategic to Japan's long-term economic growth. By refusing to act on either application, the bureaucracy allowed the Japanese companies to copy TI's technology for years without paying for it.[82] TI did finally win approval of some of its patents in 1977, and combined the others into one application, pursuing them until it was granted its final patent in October 1989.[83] This was an exceptional case, even by Japanese standards, where it commonly takes 6 to 7 years to process a patent application (compared with 18 months in the United States).

TI threatened that any Japanese exports using its technology would be met with an immediate lawsuit based on TI's patents in the destination country, and this began to pose a problem for Japanese consumer electronics makers in the late 1960s.[84] Something needed to be done to appease TI. MITI had to agree with TI's request for a wholly owned subsidiary because it needed [a license under] TI's patents [to export]," explained a former MITI official closely involved in the negotiations.[85] But granting TI permission to operate a wholly owned subsidiary in Japan also posed serious problems.

Fairchild and Motorola both had wholly owned subsidiaries in Okinawa. The Japanese Government was then negotiating with the U.S. Government for the return of Okinawa. Had TI been allowed to open a subsidiary in Japan proper, it would have been difficult to keep Motorola and Fairchild from retaining theirs in Okinawa when that island came back into the Japanese fold. To avoid the precedent, MITI pressured TI to make a nominal joint venture with Sony "on paper, ' one that would last only 3 years, after which Sony would sell its shares to TI.[86]

MITI's strategy worked. When the United States returned Okinawa to Japan, the Okinawan subsidiaries of Fairchild and Motorola were forced to enter 50-50 joint ventures with Japanese partners.[87] In addition, it was difficult for these American companies to form ventures with any of Japan's major electronics companies, because MITI favored pure blooded *(junketsu)* Japanese firms over mixed breed *(konketsu)* joint ventures.[88] MITI ultimately found them relatively small, inexperienced partners.[89]

Japanese firms only began to produce sophisticated chips in the 1960s; in 1966, a couple of years after beginning production, Japanese firms were selling one type of IC (integrated circuit) for over Y1,000, some three times the price of a similar one sold in the United States. The higher Japanese costs reflected lower yields, which were about 10 percent in the mid-1960s, compared with 25 percent in the United States on average.[90] As late as 1972, the semiconductor divisions of all the major Japanese producers were in the red;[91] in 1971, Japanese makers had to sell at more than 20 percent below cost to compete with U.S. manufacturers.[92]

Protection is only part of the story. Government financial assistance, such as low interest loans, accelerated depreciation, and other measures that lowered capital costs, enabled Japanese companies to continue investing heavily despite years of large losses. Another major theme of the Japanese approach to a home grown semiconductor industry was technology development and acquisition. U.S. firms that wanted to make joint ventures in Japan were obliged to transfer technologies as part of the deal.[93] The government also sponsored several cooperative R&D projects that helped domestic firms gain the technological expertise necessary to compete with U.S. companies over the long term. To help the six major companies get an early jump on integrated circuit R&D, MITI organized a 2-year cooperative R&D project from 1964 to 1966. Tarui Yasuo, a member of MITI's Electrotechnical Lab who participated in this project and later led MITI's well-known VLSI project (1976-1979), said that a major goal of the government was to "reduce duplication of effort" by dividing up the labor; another purpose was "frankly to avoid patents that cover procedures developed in the U. S.A.' '[94] Government-sponsored programs continue through the present.

Some of the most famous projects were the VLSI project, which accelerated the rate at which Japanese

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producers caught up with American memory technology; a software and peripheral development program from 1979 to 1983; the optoelectronic IC (OEIC) project lasting from 1981 to 1986; and a project in the mid-1980s to develop super-high-speed device technologies.[95] By the mid- 1980s, the Japanese companies had come to dominate several semiconductor markets, had made inroads into all of them, and were poised to advance in almost every area of computer technology.

SUCCESSES AND FAILURES OF INDUSTRIAL POLICY

So far, this chapter has focused on successes of Japanese industrial policy. It probably bears repeating at this point that a number of the cases that some observers regard as failures-such as MITI's failure to reduce the number of firms in the automobile industry-ended up as very successful industries. There is a big difference between mistakes, or unsuitable proposals, and failures of industrial policy. Not every proposal MITI advances is a winner, but even so, its interventions have helped targeted industries and Japanese industry on the whole become more competitive. MITI and other ministries reduce the likelihood of mistakes by extensive consultation with the private sector.

A few targeted industries have not improved their competitiveness. Industrial policies towards petrochemicals, oil, and coal are often pointed to as failures.[96] For example, the petrochemical industry, completely dependent on imported oil, was left with huge excess capacity when the oil shock hit Japan in the early 1970s. It had to be scaled back dramatically in a process that was costly to the government and the firms. The huge subsidies that have supported Japan's uncompetitive agricultural sector are also sometimes identified as industrial-policy failures. Overall, the fact that the Japanese Government spends more on declining industries than on ascending ones is also cited as proof that industrial policy is a waste of government resources.

It is important, however, to evaluate the success of policies based on their goals. Japan has never entertained the idea of developing an internationally competitive energy sector, which would obviously be impossible given the nation's lack of energy resources; policies toward oil and coal have been aimed at providing Japan with a stable and predictable energy supply and at keeping as much domestic control over energy as possible. Such a policy makes sense considering Japan's vulnerability to disruptions in energy supply and price; it took fully 5 years for Japanese manufacturing production to exceed 1973 levels after the oil-shock-induced recession of 1974-75.[97] Similarly, Japan has never aspired to having an internationally competitive agricultural sector; rather, the industry has been protected and subsidized for political and social reasons—primarily to assure farming communities' strong support for the pro-business Liberal Democratic Party.

To a skeptic, the heavy support for Japanese agriculture is proof of the proposition that government intervention in the economy is prone to become the servant of political power and special interests. Yet most nations do not wish to depend on imports for food, particularly for dietary staples. As a result, all developed nations support their agricultural sectors (some more than others). In Japan, it is not easy to find other industries as heavily subsidized as agriculture with as little economic payoff; for the most part, the separation between Japan's legislature (Diet) and bureaucracy hinders special interests from getting MITI support unless there is good economic sense behind their appeals.

For MITI to spend more on declining than on sunrise industries is not unreasonable. Supporting so-called 'structurally depressed' industries, which are not expected to recover from recessions or exceed past output records, is an inherently expensive activity. Industrial adjustment-contracting the size of an industry and shifting workers, managers, and capital from one industry to another-is difficult, time-consuming, and expensive in any Country. Countries differ in the extent to which those costs are borne by workers and owners of enterprises, as opposed to the public sector. Japan's government takes more responsibility for adjustment, and bears more of the cost, than do most developed nations. One reason is the value Japan places on employment security. Culturally and economically, Japan depends on steady employment; the option of laying off workers without making some provision for their future employment is abhorrent to the Japanese Government and employers alike. While not all Japanese employees are covered by so-called lifetime employment, most Japanese employers are reluctant to lay people off. It is even more important in Japan than in the United States that downsizing be orderly. As a result, the government has frequently organized cartels among producers to promote steady contraction and paid for some of the worker adjustment costs. While the money the government spends on declining industries does not contribute to increasing the competitiveness of a sunrise sector (a goal that some American analysts think is the only supportable objective of government targeting), it is not wasted. It contributes to a stable business environment, prevents cutthroat competition and large-scale, chaotic layoffs, and helps keep Japan's unemployment rate extraordinarily low.

A few efforts have disappointed MITI's expectations. Promotion of software development in the 1970s and 1980s has not been very effective; projects were scattered and inadequately funded and money was generally given to software houses to develop products approved by the Information Promotion Agency (IPA), a MITI-related association, rather than responding to the software needs of the users. By neglecting to tie its aid to the market, the government ended up with mostly unused software.

An even clearer example of disappointed expectations is the aircraft industry. Commercial aircraft was targeted in MITI's visions for the 1970s and 1980s, yet Japanese industry has never become a successful assembler of large commercial aircraft, as MITI hoped. But even here, calling MITI's policies a failure is inaccurate. With MITI support, Japan's aircraft industry has become a major supplier of parts, generating $1.2 billion worth of commercial aircraft products in 1989; over half were exported. Japanese companies had a 15-percent share in developing Boeing's 767, making most of the fuselage and underwing fairing; they have taken a 20-percent workshare as a risk-sharing partner in the development of the new 777 (see ch. 8, or volume 2). Moreover, Japan's aircraft industry faced unusually formidable obstacles to development; for example, after World War II the country was barred from aviation-related activities while the rest of the world moved into the jet age.

While there have been failures as well as successes in Japan's efforts to promote certain industries, Japan has a good batting average in targeting industries for international competitiveness. Several factors distinguish the Japanese experience from those of less successful nations. Most critical perhaps is that on the whole, policies have been structured to preserve the forces of competition. While that may sound strange to say about a nation that protected its developing industries as assiduously as Japan did, still the government almost always promoted several firms in an industry. R&D projects usually had two or more companies work together on a topic, each of which could bring the new technology to the market. Moreover, firms were strongly encouraged to export-often to America, where they had to compete with then-dominant fins. In a few instances, MITI has given a company a monopoly position in an industry or an R&D project; generally these have been failures.[98] In Europe, attempts to nurture domestic computer industries by promoting national champions also failed, in part due to their lack of domestic competition (see ch. 5). The lesson from Japan is that if a state protects the domestic market from foreign competition, it is imperative to at least keep domestic competition intact. Another lesson is that firms must compete somewhere (in Japan's case, in export markets) with the best producers.

Business input into the policymaking process has contributed to the success of Japan's industrial policies. Government officials consult closely and extensively with industry. This consultation is necessary because industry representatives know more about their products, technologies, and business environment than bureaucrats do, and often can tell better what will or will not work. Business functions as a check on government policies, and, in turn, the state counterbalances business demands. For example, the automobile industry resisted MITI's plans to merge the firms, which likely would have hurt the industry; but MITI did increase specialization in the industry. The private sector's role in policymaking increases business' commitment to make the policies succeed.

Another' attribute of Japan's industrial policy structure is stability. A stable institution, partially insulated from day-to-day interest group demands, is essential for consistent, long-term guidance. Even when an administration changes, Japanese companies can be assured that MITI's basic policies will not, and that there will not be a sudden turnover of ministry officials. The relative impartiality and lack of corruption of MITI officials is also critical: industrial policy can only work in an environment of trust in which high-quality career bureaucrats work in the national interest.

Tying government aid to performance and requiring firms to Commit' some of their own funds to R&D projects have helped to increase the success of Japanese policies. Japan's market is another factor; the domestic market is relatively large, enabling domestic firm to gain economies of scale at home before entering foreign markets. Of course, having access to the world's biggest market-the United States-was also key.

The importance of the comprehensive approach to nurturing an industry cannot be overstated. MITI has promoted not just products, but the entire industries, including the needed parts and infrastructure. For example, Japanese policy frost encouraged development of semiconductors and computer parts, then the hardware of small computers, large computers, and finally software and supercomputers.

As stated before, all of Japan's targeting policies were boosted to a large degree by economy-wide policies and cultural factors. Without government's provision for a large pool of savings-and many other measures designed to transfer capital from consumers to producers—Japan would not have been able to finance its targeting policies. Japan's industrial policies and targeting have cost consumers a great deal in terms of current consumption (while the resulting increases in productivity allow them to improve their living standards in the long run), and the contribution of this deferred gratification on the part of millions of ordinary Japanese citizens should not be underestimated. A first-rate education system, and a culture that reinforces even for small children the importance of educational performance, is another factor. A long history of adopting and modifying for Japanese use successful policies and practices (including technology) from other countries was helpful, as was sheer diligence. It is worth remembering that in most cases where an infant, technologically backward industry was protected in Japan, that industry was working toward world leadership in technology application and development. Most of them got there.

INDUSTRIAL POLICY FOR THE 1990s

Japan's star is on the rise. Its people are growing richer faster than any others among the developed countries; its fins-at least, its international firms—are cash-rich and outstripping their American and European competitors in advancing and applying technology. In foreign policy, Japan is, with caution, taking a more independent path. In business, Japanese firms are increasingly independent of their government and their banks. Some have suggested that MITI's power and Japan's industrial policy are artifacts of the past.

But a look at MITI policy today indicates that while targeting policies are less important than they once were, the role of MITI and its sister ministries is far from marginal. Indeed, while Japanese companies have money, they may still need encouragement to invest much in technologies that are unlikely to bring about a profit for a decade or more; competing firms also need more encouragement to cooperate with one another than in the past, when cooperation was considered necessary for survival. In many industries, a Japanese fro's fiercest competition comes from other Japanese firms. Finally, Japan's era of cheap capital may be over; in the past year, Japanese interest rates and capital costs have increased rapidly as the bubble burst in the Nikkei stock market.[99] For these reasons, MITI's role in providing seed money and in coordinating cooperative R&D remains important.

MITI is funding more R&D directly, in absolute amounts, than previously. This may seem ironic considering the wealth of many Japanese firms, but they have also moved from being technological followers to positions of leadership, which means the payoffs of R&D are less certain. For example, one new large-scale MITI project focuses on developing micromachines that combine sensing devices with microprocessors and motors (a technology that originated in the United States) for uses such as surgery without incisions and inspection of cooling pipes in nuclear plants (see app. 6-A).[100] MITI will plow some $200 million into this 10-year project beginnin g in autumn of 1991. Another project focuses on electronic lasers. Eight companies—Mitsubishi Electric, Toshiba, Hitachi, NEC, Sumitomo Denki Kogyo, Kobe Steel, Kansai Electric Power, and Nisshin Electric-have created a cooperative R&D association for the project. Each firm will put in 4 percent of the Y10 billion ($78 million) project, and government will provide the remaining 68 Percent.[101] The aim is to catchup with the United States in an area that Japan sees as important for applications such as medical equipment, space communications, energy transmission, semiconductors, uranium enrichment, and nuclear fusion.[102]

As the content of these two projects suggests, MITI is increasingly supporting basic technologies that, while not close to the market, will have a broad impact on many areas. This strategy makes it easier for competing firms to cooperate and minimizes foreign criticism. Other targeted technologies include new materials, biotechnology, superconductivity, hypersonic flight, high-definition television, biocomputers, parallel processing, and optoelectronics.

Japan's long history of outright trade protection and the fact that her market is still especially difficult to penetrate, in combination with the spectacular successes of many Japanese industries in international competition, have led to increasingly sharp trade conflicts with major trading partners. If the conflicts were only with the United States, it might be possible to attribute them to jealousy. But trade friction is growing rougher with Europe, too, and there are reports of growing wariness toward Japanese investment and imports in Australia. MITI has assumed much of the responsibility for oiling these troubled waters, helping to ease trade fiction through negotiations and encouragement of Japanese firms to use foreign products.[103] For example, MITI loans companies roughly $1 billion to promote aircraft imports. To escape being even larger targets for those who urge retaliatory protection or reciprocity, Japanese firms might need some powerful agency to mediate, intervene, and palliate.

A nation with little or no formal trade protection and a huge market should not need such an agency; Japan's market should be a magnet for foreign goods and companies, as is America's. But MITI's role as ombudsman for the interests of foreign governments and enterprises arises from the Japanese Government's still-powerful ability to govern the activities of foreign firms (be they investors or traders) in Japan. Government procurement practices, customs clearances, inspection standards, approvals on foreign investment, antimonopoly law enforcement, and administrative guidance on issues such as price and production cartels are done largely at government's direction, rather than according to strict legal criteria. There are few clear rules for foreign firms to follow and there are few open, transparent systems for dispute resolution. This discretionary system enables the Japanese Government to use relatively subtle, informal tactics that, according to the weight of anecdotes of those who do business there, still can impede (or assist) the efforts of foreign firms in the Japanese market.

SUPERCOMPUTER INDUSTRY DEVELOPMENT

A supercomputer is a general purpose computer that is faster than commercial competitors and that has sufficient central memory to compute problem sets of general scientific interest.[104] A supercomputer can do in 1 minute what it takes a mainframe computer 3 hours to do, a workstation 15 hours and a personal computer 96 hours.[105] These very fast machines enable researchers to analyze a wide range of physical phenomena. They are used, for example, to predict and analyze weather, to design airplanes and automobiles to reduce air turbulence, to discover pharmaceutical compounds with desired effects, and to design semiconductor chips.

A healthy supercomputer industry is considered important because it is a technology driver. "Supercomputers are the testing ground for Japanese logic and memory chips and new types of technology [which can then also be used in mainframes and other products]," explains Raul Mendez, a U.S. supercomputer expert, who after working at the U.S. Office of Naval Research in Tokyo is now the Director of the Institute of Supercomputing Research in that city.[106] Sekimoto Tadahiro, President of NEC, one of Japan's major supercomputer companies, agrees: "Japanese supercomputer makers can use their technological improvements [related to supercomputers] in their mainframe computers; in that sense we are in a more advantageous position than the U.S. firms that specialize in supercomputers."[107] Uenohara Michiyuki, executive adviser to NEC and formerly the VP in charge of NEC's research division, explains: "The reason Japanese companies are going into the supercomputer business is for the same reason that auto companies get into race cars; even though it's a small market, it drives the technology."[108] IBM, which had not been a supercomputer producer since 1970, reentered the field in 1985 with a vector version of the IBM 3090 that performed in the supercomputer class at the low end;[109] moreover, IBM is providing financial support to Supercomputing Systems, Inc. (SSI), a new company that expects to produce a new supercomputer in the early 1990s. This suggests that IBM came to the same conclusions about the importance of supercomputer technology as the Japanese companies.

Supercomputers are important tools for other industries. Increasingly, designs of automobiles and aircraft, pharmaceutical products, and new materials all rely on supercomputers. For example, supercomputers allow simulation of automobile crashes, which in turn can reduce time and expense involved in developing new products. Proposed designs can be tested by computer, without the need to build a model. The computer simulation gives much more precise results than some actual experiments, such as slow-motion blow-up movies of critical parts. Real test crashes can be reduced in number and designed precisely to confirm that a design will work. Similarly, NASA uses a supercomputer to simulate airflow inside aircraft engines, allowing designers to observe things that could not be seen directly in a wind tunnel. To have the benefits of supercomputers in applications, however, it may not be necessary to have a domestic industry.

There are two major types of supercomputers: traditional supercomputers and massively parallel processing supercomputers. Traditional supercomputers—with one or a small number of processors (currently up to eight)--are the major focus of this study. (A processor, sometimes called a central processing unit or CPU, is the heart of a computer. A processor manipulates data. Other parts of a computer are memory, which stores data, and input-output devices, which transfer data between the computer and the outside world.) Massively parallel processing machines, which have from about 64 to thousands of processors, may be the trend for supercomputing in the next century; their prospects will be discussed as well.[110]

Supercomputer Companies

There are four major companies in the world supercomputer industry today: Cray Research of the United States, and Fujitsu, Hitachi, and NEC of Japan. Two other companies are also working to bring out their first supercomputers, Cray Computer and SSI (Supercomputer Systems, Inc.). Cray Computer, Seymour Cray's firm that broke off from Cray Research in 1989, has just sold and (as of mid-1991) plans to deliver the first unit of its new supercomputer, the Cray-3, to the Lawrence Livermore National Laboratory before the end of 1991. SSI, a firm started by Stephen Chen after he left Cray Research in 1987, is backed by IBM. Chen's new supercomputer, a 48 to 64 processor machine, is not expected until 1992 or 1993. ETA, a subsidiary of

Table 6-l-Comparison of Cray Research, Fujitsu, Hitachi, and NEC Revenues, R&D Expenditures, and Profits, 1981,1982, 1988, 1989

	Revenue ($ millions)	R&D expenditures ($ millions)	R&D as percent of revenue	Profit as percent of revenue
1981				
Cray	101.6	17.0	16.8	17.9
Fujitsu	2,529	141	5.6	3.4
Hitachi	8,465	NA	NA	3.5
NEC	3,882	214.4	5.5	2.4
1982				
Cray	141.2	*29.5*	*20.9*	13.5
Fujitsu	2,918	*185*	*6.3*	3.8
Hitachi	9,308	NA	NA	3.7
NEC	4,583	221	4.8	2.5
1988				
Cray	*756.3*	117.8	*15.6*	20.7
Fujitsu	*15,420*	1,826	11.8	2.7
Hitachi	*24,862*	1,542	6.2	3.6
NEC	*19,554*	1,561	8.0	2.4
1989				
Cray	784.7	143.4	18.3	11.3
Fujitsu	16,351	2,102	12.9	*3.4*
Hitachi	27,117	1,838	6.8	*3.7*
NEC	21,235	1,780	8.4	3.0

NA-not available.

NOTE: Japanese yen converted at 230/$ in 1981 and 1982, 130/$ in 1988 and 1989. The Japanese year ends on Mar. 31. Thus Japanese data are for years ending Mar. 31, 1982, 1983, 1989, 1980.

SOURCE: Company financial reports.

Table 6-2-Cray Research's Revenues, R&D Expenditures, and Profits

Year	Revenues ($ millions)	R&D expenditures ($ millions)	R&D as percent of revenues	Profit as percent of revenues
1977	11.39	1.90	16.7	17.8
1978	17.18	2.53	14.7	20.4
1979	42.72	6.42	15.0	18.3
1980	60.75	9.55	15.7	17.9
1981	101.64	17.04	16.8	17.9
1982	141.15	29.51	20.9	13.5
1983	169.69	25.54	15.1	15.4
1984	228.75	37.54	16.4	19.8
1985	380.16	49.17	12.9	19.9
1986	596.69	87.68	14.7	20.9
1987	687.34	108.83	15.8	21.4
1988	756.31	117.76	15.6	20.7
1989	784.70	143.35	18.3	11.3

SOURCE: Cray Research annual financial reports.

Table 6-3-Divisions of U.S. and Japanese Supercomputers Firms, 1989
(by percent of sales)

	Computers	Telecom-munications	Electronic devices	Consumer electronics	Heavy electric equipment	Other
Cray Research	100	—	—	—	—	—
Fujitsu	70.5	16.3	13.2	—	—	—
NEC	47.0	29.4	20.1	3.5	—	—
Hitachi[a]	30.0	5.0	10.2	13.7	21.4	19.7

[a]Hitachi data give totals for computers, telecommunications, and electronic"~ devices only. The percent are estimated based on other sales data.

SOURCES: Company financial reports. Japanese figures are as of Mar.31,1990.

Control Data Corp. (CDC), was a major player until it withdrew from the market in 1989.

The sales, R&D, and profit data of the four major firms are given in tables 6-1 and 6-2. It is hard to make direct comparisons between Cray Research and the Japanese firms because Cray makes one product line-super-computers-whereas the Japanese firms are both vertically integrated and diversified into various related electronics industries (table 6-3). What is clear from the numbers is that Cray Research is very small compared with its chief competitors: in 1989 its sales were 4.8 percent those of Fujitsu, 2.9 percent those of Hitachi, and 3.7 percent those of NEC. Cray spends a much higher percentage of revenues on R&D than its Japanese counterparts, 18 percent in 1989 compared to 7 to 13 percent for the Japanese makers.[111] The data also show that healthy Japanese companies have profit rates (profits as a percentage of revenues) of only some 2 to 4 percent per year, a level that would put a U.S. firm in serious trouble; Cray's profit as a percent of revenues has ranged from a high of 20.7 percent in 1988 to 11.3 percent in 1989 (table 6-2).

Potential Market

The world supercomputer market is over $1.1 billion today. Its annual growth rates in the 1980s ranged from a high of 84.3 percent in 1981 to a low of 4.5 percent in 1989, with an average of 30 percent (table 6-4). The Japanese market has been growing much faster although it has slowed suddenly in the past year: the growth in the number of supercomputers sold has ranged from a high of 145.5 percent in 1986 to a negative growth rate in 1990 of about -47 percent (table 6-5). One reason for the sharp decline in 1990 is that higher prices charged to the Japanese Government (resulting from the 1990 U.S.-Japan supercomputer agreement, which limits Japanese companies' discounts) have not been matched by equally high government budgets, inevitably leading to fewer procurements. Public and private sector purchases of upgraded models have also declined because users are waiting for new, more sophisticated models expected out in 1991.

The drive for ever faster computers pushes the technology in two directions: making faster proces-

Table 6-4-Value of Worldwide Supercomputer Shipments

Year	Shipments ($ millions)	Annual growth rate (in percent)
1980	89	NA
1981	164	84.3%
1982	211	28.7
1983	245	16.1
1984	308	25.7
1985	479	55.5
1986	651	35.9
1987	880	35.2
1988	1,034	17.5
1989	1,081	4.5
1990	1,164	7.7

SOURCE: Gartner Group, Inc., *High Performance Computing and Communications: Investment in American Competitiveness,* Mar. .15, 1991, p. 73.

sors (a processor is the part of the computer that does arithmetic calculations), and using many processors at once. The latter is becoming more important. Traditional supercomputers rely heavily on having fast processors, but manufacturers have been increasing the number of processors to gain extra speed. Cray Research's top-of-the-line machine today has 8 processors; both Cray Research and Cray Computer have announced that they are developing 16-processor machines that they expect to debut in the next few years. Cray Research, along with other companies, is working on machines with 64 processors. The world market for traditional supercomputers is expected to continue healthy growth for the rest of the 1990s, but some analysts expect massively parallel machines to begin taking some of the market from traditional supercomputers.

In the future, the greatest speeds will be achieved by having a large number of processors, even if each processor is only moderately fast. The market for massively parallel supercomputers, which have from 64 processors to many thousand, could prove to be much greater than for traditional supercomputers in the future. To use so many processors to advantage, it is necessary to divide the problem into many independent parts that individual central processing units (CPUs) can work on in parallel. It is difficult to write software to break down problems in this way and even harder to write the software so that all of the CPUs are able to communicate with one another. "There are daunting software problems in massively parallel processing machines, " explained an expert at Lawrence Livermore National Laboratory.[112] Even if writing software were simpler, there is still a much larger existing stock of software for traditional supercomputers; it will take some time before a comparable library is available for massively parallel machines. The software that has been written was designed to handle special problems, such as pattern recognition. Writing software to make a massively parallel machine into a general purpose machine is much harder.

Scientists and supercomputer users give varying predictions of the future market for massively parallel processing computers, ranging from pessimistic predictions that such machines will never be general purpose machines to optimistic views that they will became more important than traditional supercomputers within the next 5 to 10 years.[113] Several companies-including Thinking Machines, Alliant, Intel, BBN, Ncube, MasPar, and Cray—are betting on the latter. Most supercomputer experts and supercomputer users agree that the software problem may take a decade to solve, and some analysts see the massively parallel machines as remaining niche machines for the foreseeable future.[114]

Comparisons of U.S. and Japanese Supercomputers

Japanese manufacturers have faster components, which, all other things equal, would mean faster machines. However, Cray appears to have three compensating advantages. First, Cray excels in packaging and connectors, which also affect machine speed. Second, Cray's processors appear to have a "more balanced" design, meaning that its different elements work together more smoothly, with fewer bottlenecks.[115] (A bottleneck could occur, for example, if the processor's arithmetic unit-that part of the processor that actually adds, multiplies, etc.—has to stand idle waiting for data to be fetched from memory.) Third, some of Cray's supercomputers gain speed by using more than one processor; no Japanese machines with more than one processor have yet been sold. While using more than one processor is an advantage, it is often tricky to keep all processors busy at once, just as it is tricky to keep different parts of one processor busy at once. Cray's multiprocessor machines tend to work best when doing many problems at once, so that each processor can be assigned its own problem to work on by itself; this reduces the need for inter-processor coordination. Thus, these machines perform better in timesharing systems, running many applications at

Table 6-5--Number of New Installations in Japanese Supercomputer Market

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total (number of supercomputers)	2	0	0	4	6	11	27	36	37	32	17
Annual growth rate	—	•	—	400%	50%	83.3'%.	145.5%	33.3%	2.8%	13.5%	46.9%
Sales to public sector:											
Total	0	—	—	2	4	4	12	11	8	4	6
By foreign firms	—	—	—	0	1	0	0	0	2	1	1
By Japanese firms	—	—	—	2	3	4 '	12	11	6	3	5
Percent of public procurement of foreign machines	—		—	0%	25%	0%	0%	0%	25%	25%	16.7%
Sales to private sector: Total	2	—	—	2	2	7	15	25	29	28	11
By foreign firms	2	—	—	0	0	1	2	2	6	8	2
By Japanese firms	0	—	—	2	2	6	13	23	23	20	9
Percent of private sector procurement of foreign machines	100%		—	0%	0%	14.3%	13.3%	8.0%	20.7%	28.6%	18.2%
Foreign share of all new procurements	100%	—	—	0%	16.7%	9.1%	7.4%	5.6%	21.670	28.1%	17.6%
Japanese share of all new procurements	0%		—	100%	83.3%	90.9%	92.6%	94.4540	78.4%	71.9%	82.4%

NA=Not applicable.

SOURCE: NIkkel *Uotcha, IBM-Ban,* Apr. 30, 1990, pp. 21-24.

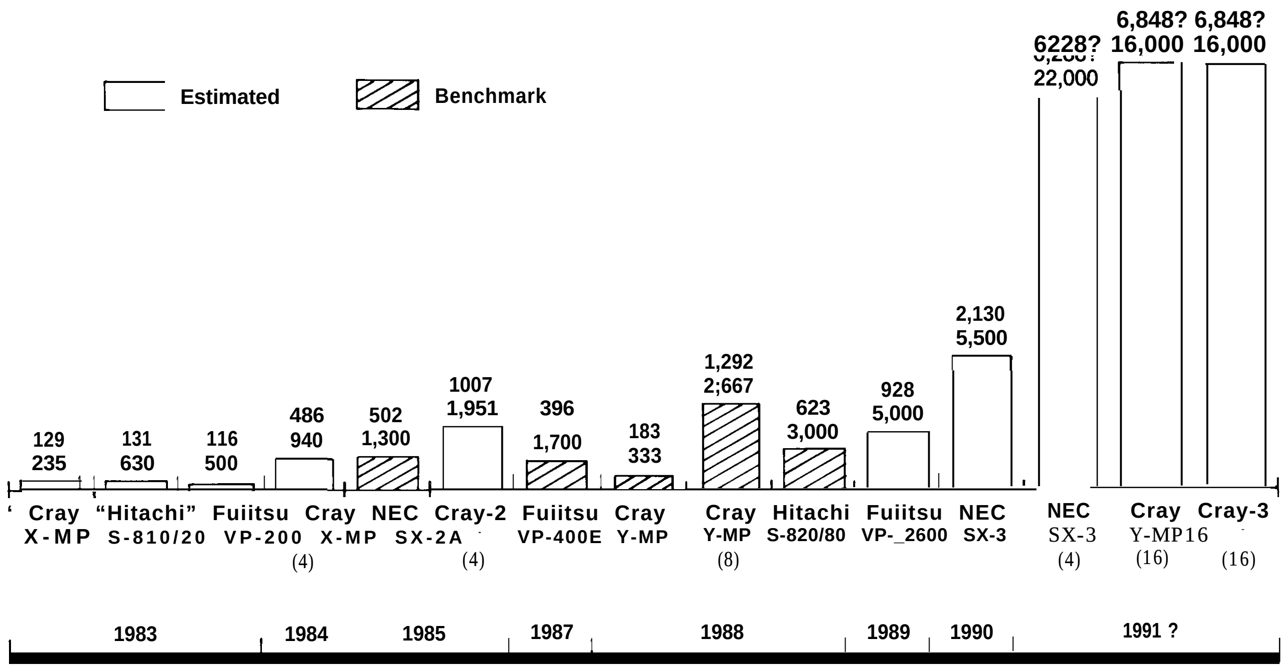
once, than when dedicated to solve one very large problem.

As these last two factors suggest, measuring a supercomputer's speed is not a cut-and-dried affair. Each machine has what is called a theoretical or peak speed-the speed at which the hardware in principle can do raw calculations. However, on real problems the speed is usually much less—typically between one-half and one-tenth of the peak speed. How much less depends on the hardware design (issues of balance within a processor and coordination among processors), the software (which might be more or less clever at breaking up the problem to keep the whole machine busy at once), and the particular problem (which may, for example, require a great deal of multiplication and division but relatively little fetching and storing of data to and from memory, or vice versa).

One way of comparing the performance of different supercomputers is by benchmarking-running certain problems on each, and comparing the speeds. While benchmarking results depend on which problems are chosen and what software is used, all comparative analyses of supercomputers use benchmark tests as at least one important indicator of performance. Benchmark tests have been done on U.S. and Japanese supercomputers by various universities and labs. Cray Research reported as of May, 1990, that its machines always came out on top (figure 6-1).[116]

In the next generation, however, the gap will narrow; if current rates of progress do not change, Japanese makers will exceed Cray in the peak speeds of multiprocessor machines and likely the actual performance of hardware in the next decade. Japanese supercomputers are rapidly catching up in speed. In recent tests run by Jack J. Dongarra, a computer scientist at the Oak Ridge National Laboratory and a specialist on supercomputer speeds, the one processor SX-3 ran nearly three times as fast as a single processor Cray Y-MP, though not quite as fast as the eight processor Y-MP.[117] Hideo Yoshihara, a former Boeing specialist in the use of supercomputers for computational fluid dynamics, estimates that the four processor NEC SX-3, which is expected out in late 1991, will have an actual speed of some 7 gigaflops, higher than current Cray machines (1.5 gigaflops), and that the Cray Research C-90 (which will be released as the Y-MP16), also expected in late 1991, will have a similar speed-7 to 8 gigaflops. Cray disputes this, predicting that its C-90 will be considerably faster than NEC's four-processor SX-3. Yoshihara estimates that Cray Computer's Cray-3 will have an actual speed of 7 to 8 gigflops,[118] and another estimate agrees[119] that all three new machines will have similar speeds.[120] Fujitsu is said to be working on an eight CPU

Figure 6-l—Actual v. Peak Supercomputer Performance (megaflops)



NOTES: Bars show actual or estimated performance on Navier/Stokes benchmark. Numbers show actual or estimated benchmark performance (top) and peak performance (bottom). All systems have only one processor, except where a different number is indicated in parentheses.

SOURCE: Gartner Group, Inc., *High Performance Computing and Communications: Investment in American* Competitiveness, report prepared for U.S. Department of Energy and Los Alarms National Laboratory, Mar. 15, 1991, p. 205.

machine,[121] and to have a four CPU machine likely to be introduced in 1992, but no estimates have been made of their speeds.

In short, while Japanese supercomputers currently in use are slower than their U.S. counterparts, and their actual speeds have been substantially slower than their advertised peak speeds, they are still fast and closing the gap. In price/performance ratio, Japanese supercomputers are less competitive than Crays even when the Japanese machines are discounted by 50 percent, according to data from Cray (figure 6-2). According to a different source (and using peak rather than actual performance data) Japanese machines do better in price/performance, and will maintain this edge over traditional U.S. supercomputers, though the United States could beat Japan with massively parallel supercomputers.[122] In reliability, Japanese machines excel; Japanese machines have been running at more than 5,000 hours mean time between failures (MTBF), compared with Cray's record of less than 1,000 for the Cray X-MP series. While the Y-MP machines are much better in MTBF than the X-MPs, they are not as good as the Japanese machines.[123]

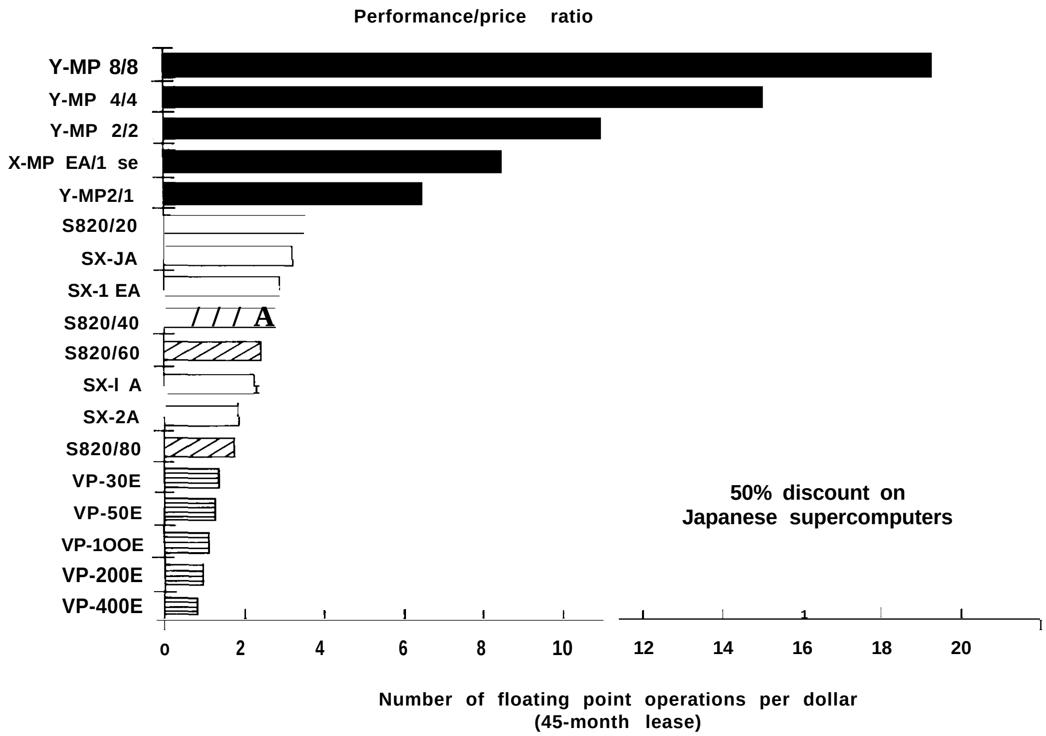
While Japanese manufacturers are closing the gap with Cray in speed and are ahead in reliability, they still suffer from a relative lack of applications software. When NEC announced the SX-3, in April 1989, with the claim that it was the world's fastest supercomputer:

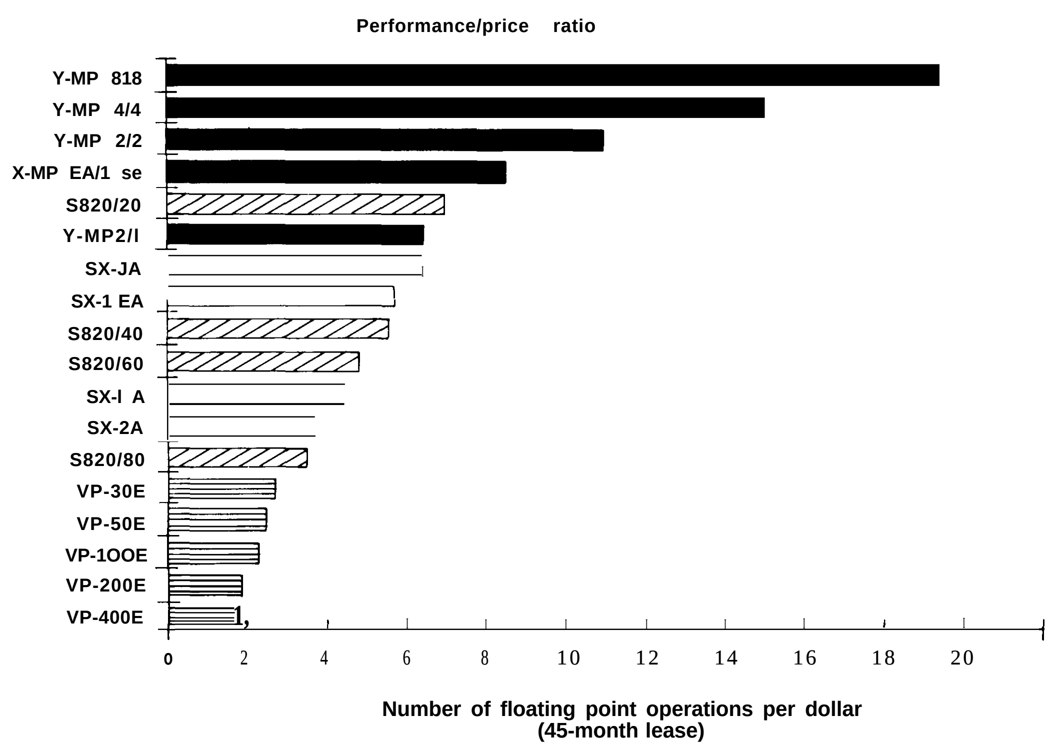
> . . . people in America were amazed, but Japanese users were not nearly as impressed; they understand that even if it is potentially very fast, it is worthless unless NEC provides [applications] software to use that Speed.[124]

Indeed, NEC has only sold seven supercomputers in Japan to firms outside of the government and its own industrial group (table 6-6).

In massively parallel machines, the United States holds the clear lead. There are no commercialized massively parallel processing machines in Japan. Matsushita, together with Kyoto University, has been developing a parallel processing minisupercomputer, the Adena 256. This machine has 256 processors and a speed of 1.6 gigaflops, and will sell for about Y150 million ($1.15 million). They are also working on a 25-gigaflop machine that they

Figure 6-2—Performance/Price Data





NOTE: Performance/Price ratio is calculated from published list prices on all supercomputers shown as of Sept. 30, 1989. A 45-month lease is assumed. It is also assumed that the code run on the computer is 70 to 80 percent vectorized.

SOURCE: Cray Research, Inc.

Table 6-6-Japanese Procurement of Supercomputers, 1980-90

	Number of machines						
Company	Total procurement	Procurement for internal use	Purchase by own group company	Purchase by a firm in another supercomputer maker's group	Purchases by the government	Purchases by private universities	Purchases by private companies unaffiliated with the three groups
Fujitsu	85	9	10	5	26	14	21
Hitachi	35	12	3	0	11	1	8
NEC	24	3	5	1	9	3	3
Cray Research	26	—	—	8	4	1	13
CDC	2	—	—	—	1	1	—

SOURCES: *Nikkei Uotcha, IBM-Ban,* Apr. 30, 1990, pp. 21-24; *Kigyo Keiretsu Soran, 1991.*

hope to finish by 1992 and a 100-gigaflop machine by 1995-96.[125] U.S. and Japanese scientists do not see these efforts as a real threat to U.S. dominance in this area in the near future, but the Japanese are beginning to invest heavily in this technology.[126]

HISTORICAL BACKGROUND: THE EFFECT OF PAST TARGETING OF THE MAINFRAME COMPUTER AND SEMICONDUCTOR INDUSTRIES

Japan's three supercomputer firms-Fujitsu, Hitachi, and NEC--are also its major producers of mainframe computers, and three of its major producers of semiconductor devices. These firms' experience with computers and semiconductors was crucial in preparing them to make supercomputers. Their rise in the supercomputer industry today depended on previous Japanese Government policies that helped these companies acquire the necessary technological knowledge and skills.

In the late 1950s, Japanese Government officials and businessmen decided to nurture a domestic computer industry. Their main concern at the time was not whether computers alone would become a profitable business, although they hoped it would be. Instead, the primary interest was in the positive contributions of computers to other industries, such as telecommunications, automation, and aerospace, and to the economy's overall productivity. "It was clear to both the government and the telecommunications and heavy electric equipment makers that to survive they had to go into computers," explained Yoshioka Tadashi, who was a MITI official closely involved in nurturing computers in the 1950s and 1960s and more recently the Director and adviser of the Japan Electronics Industry Development Association (JEIDA).[127] The first step, in 1957, was to pass the Extraordinary Measures Law for Promotion of the Electronics Industry, targeting electronics in general and computers in particular. This law and its later extensions provided various subsidies and tax benefits for the industry; it also exempted the industry from antitrust law and encouraged firms to cooperate on price, production, investment, and R&D to gain the economies of scale necessary to compete with IBM. Japan did not want to depend on foreign firms for something as critical as computers.[128]

There were four key types of policies that the Japanese Government used to nurture a competitive computer industry: protection, a computer rental company, substantial financial aid, and government-sponsored R&D projects. In the 1960s and early 1970s protection was heavy against both imports and foreign investment. While IBM had a sales office in Japan since 1925, MITI repeatedly rejected IBM's efforts to transfer the technology and capital necessary to produce in Japan.[129] In the late 1950s, according to a former MITI official, IBM started warning the Japanese electronics firms and the government about their infringement of IBM's patents.[130] MITI realized that the industry would not be able to get off the ground without licenses under IBM's basic patents[131] and thus negotiated with IBM. IBM agreed to license its basic patents in exchange for permission to set up a wholly owned subsidiary to produce computers in Japan.[132] By negotiating with IBM on the behalf of the firms, MITI was able to get licenses at lower rates than if IBM had been permitted to negotiate with each firm alone. MITI also controlled which models IBM could produce and sell in Japan, quantities of each model, and how much and which specific parts IBM could import for its production.[133] It also decided how much IBM had to export[134] (indeed, IBM was one of Japan's largest earners of foreign exchange at the time) and limited the profit IBM's Japanese subsidiary could repatriate to its parent company.[135] Finally, it delayed the start of IBM's production by 2 years after the agreement had been made.[136]

Even with all MITI's controls, IBM was lucky. By reestablishing itself in Japan in 1949 (after receiving back its assets that had been confiscated during the war), IBM Japan avoided being forced by the Foreign Investment Law of 1950 to make a joint venture with a Japanese firm.[137] When Sperry Rand (UNIVAC computers) wanted to sell computers in Japan in the late 1950s, MITI used this law to require it to make a joint venture with Japanese companies and to give the Japanese partners a majority of the shares; MITI felt it could more easily control a firm with majority Japanese ownership.[138] When Sperry Rand decided in the early 1960s that it wanted to produce computers in Japan, MITI insisted that it make another joint venture, this time with Oki Electric, to create Oki UNIVAC; Oki was required to hold 51 percent of the shares. Similarly, MITI allowed Hewlett Packard into Japan only on the condition that it make a joint venture with Yokogawa Electric, with the latter holding 51 percent of the shares.[139]

In addition to controlling the actions of U.S. manufacturers, the state also had a "Buy Japan' policy. In the 1960s and early 1970s the government procured some 25 percent of all Japanese computers; in the last half of the 1970s and early 1980s, this increased by up to 5 percentage points.[140] In both 1984 and 1989,90 percent of the computers used by the government were Japanese machines while only 59 percent of the machines used by the private sector were domestic.[141] "Protectionism was one of the most important policies [to promote the computer industry]. The government created the computer market, first by making government labs buy domestic machines, then having national universities purchase them,' explained Takeuchi Hiroshi, Managing Director of the Long Term Credit Bank of Japan.[142]

While not a formal government policy, the tendency of Japanese firms to purchase computers made by their group *(keiretsu)* computer company also serves to protect the market; in 1968, for example, about half the computers being used by firms in the major industrial groups were machines made by their own group's computer firm.[143] As of the late 1980s, 45.7 percent of the Sumitomo group machines were of NEC origin and 54.3 percent of foreign origin (the Sumitomo group did not use machines of other Japanese computer makers); 70.6 percent of machines being used by Daiichi-Kangyo group companies were of their group members Fujitsu and Hitachi, 28 percent were of foreign origin, and a mere 1.4 percent were machines of other Japanese makers.[144] This pattern, with Japanese firms in each group buying computers either from their own group or from foreign fins, suggests that the fins' in-group purchases are made at least partly because of group loyalty rather than the machines' worth. This loyalty handicaps foreign firms operating in Japan. The foreign share of the Japanese installed computer base plunged from 93 percent in 1958 to 48 percent by 1965 and 42.5 percent by 1969.[145] In 1989, the foreign share stood at about 37 Percent.[146]

While early protection gave the computer firms a safe harbor within which to develop, it was clear that the government would ultimately have to open up its markets; the firms had to become competitive in order to survive over the long term. A major problem they faced was that of renting their machines. Most Japanese computer users did not have the huge amounts of money needed to purchase computers; rapid technological advances deterred those that did from purchasing machines that would inevitably become obsolete within a year or two. IBM was renting its machines, so domestic companies needed to be able to rent to compete. But domestic firms did not have the funds necessary to finance a rental system, nor were banks willing to lend them the money.[147] To enable the firms to offer rentals, MITI helped them establish the Japan Electronic Computer Co. (JECC), a joint venture among the major computer makers, in 1961. JECC's role was to finance the rental of mainframe computers; by the 1980s it would also become the major renter of supercomputers. Between 1961 and 1989, the government channeled over $6 billion in loans into JECC to help the company buy computers from member firms and rent them to users for low monthly fees.[148]

When a user wanted to rent a computer, it notified JECC, and JECC purchased it from the maker and rented it to the user. The effect of purchasing the machines was to give the makers their return on investment up front-similar in effect to an interest free loan.[149] Since the firms themselves put capital into JECC,[150] to some extent the firms were lending money to themselves. However, between 1961 and

1989 JECC also received low interest loans from the Japan Development Bank with an implicit subsidy value of $461 million.[151] "JECC had a very big effect in reducing our need for capital; if there had not been a JECC in the 1960s and 1970s, we [Fujitsu] could not have expanded our scale of production; in that sense JECC played a very big role,' explained Tajiri Yasushi, a manager at Fujitsu.[152]

By enabling Japanese computer companies to rent their machines at low monthly fees, JECC stimulated both the supply and demand for *domestic* computers.[153] JECC also managed a price cartel for the industry and did not allow any discounting. By limiting price competition, JECC assured firms that profits would not evaporate in cutthroat price wars and shifted the competition to cost, technology, and quality.

JECC and domestic protection severely limited foreign computer fins' market share in the Japanese market, but they were not enough to improve Japanese electronics companies' competitiveness to match that of IBM or Cray Research. In the early 1970s, the Japanese computer makers' scale of production was, on any given model, 1 to 2 percent that of IBM[154] and the technology was far inferior. They needed financial help. One estimate is that government financial assistance-subsidies, loans, and tax benefits—to the industry amounted to some $14.3 billion from 1961 to 1989.[155] According to this estimate, in the 1960s, government aid was some 188 percent of what the firms themselves were investing in R&D and plant and equipment; from 1970 to 1975, it was 168 percent; from 1975 to 1981, 92 percent, and from 1982 to 1989,26 percent. As a percent of sales, government aid was 53 percent from 1961 to 1969; 40 percent from 1970 to 1975; 14 percent from 1976 to 1981 and 5 percent from 1982 to 1989.[156] OTA has reestimated the total government financial assistance as $12.6 billion (see app. 6-A). Under OTA's reestimated, government aid as a percentage of investment in these four time periods, from earliest to latest, was 87, 148, 84, and 23 percent; as a fraction of sales it was 24, 35, 13, and 4 percent respectively.

This does not include the tremendous benefit the firms received from the Japan Telegraph and Telephone Co. (NIT'), which was a government-owned company until April 1, 1985, when the Ministry of Finance started to sell some of its shares to the public (the government intends to keep one-third of NTT's shares permanently, and the company remains under the supervision of the Ministry of Post and Telecommunications). NTT has long been referred to as the *doru bako* (dollar box) helping the computer companies by purchasing their products (according to some, at artificially high prices).[157] Tajiri Yasushi, a manager in Fujitsu's marketing department, stated in 1987 that:

> NIT has probably been the greatest help to Fujitsu's business. Because of the profitability of doing business with NIT, it was more important [than MITI] for private industry. Our business with NTT has always been based on NTT purchasing the product, and we have always made a profit on business with NTT.[158]

Indeed, Fujitsu, NEC, and Hitachi got the bulk of NTT's computer procurement, which totaled some $13.3 billion from 1965 to 1975[159] and $13.6 billion from 1980 to 1986.[160]

The government also used cooperative R&D projects to nurture a competitive computer industry. These were aimed at helping the firms reduce their technological gap with U.S. computer companies by reducing duplicative research and accelerating technological advances. Numerous projects were undertaken from the early 1960s through the 1980s and early 1990s (table 6-7). Several have been particularly important in enabling Japanese firma to develop the technologies and skills necessary to produce supercomputers in the 1980s. Early projects, such as the 1966 Super High-Performance Computer Project, helped the firms gain a foothold in the supercomputer industry both in design and in integrated circuits.

The "New Series" Project, from 1972 to 1976, was critical in getting Fujitsu and Hitachi to standardize their architectures and go the IBM compatible route.[161] Standardizing their architectures meant that with minor modifications, software created for a Fujitsu machine could also run on a Hitachi and vice versa, and that the two machines could be used with each other. This assured potential users that if one of the two companies withdrew from the computer business, machines and software purchased from the defunct supplier could be kept and used with machines and software from the remaining firm.[162] Possibly, these decisions also helped Japanese companies to compensate for weakness in software development and small libraries of

Table 6-7-Government Subsidies for Computer-Related Government-Sponsored R&D Projects

Project	Year	Yen in billions	Dollars in millions
FONTAC	1962-65	Y 0.35	$ 0.972
Very High-Performance Computer Systems	1966-71	12.0	33.33
DIPS-I	1968-71	30.0	83.33
Pattern Information Processing Systems (PIPS)	1971-80	22.0	66.67
New Series Project	1972-76	70.3	235.50
Software Module Project	1973-75	3.0	9.09
DIPS-II	1973-75	5.0	15.15
NTTs VLSI Project	1975-77	20.0	100.00
MITI's VLSI Project	1976-79	30.0	150.00
Software Production Technology Development	1976-81	6.5	32.5
Basic Technology for Next Generation Computer Systems (Fourth Generation Computer Systems)	1979-83	21.15	105.75
Optical Measurement and Control Systems (Optoelectronics Application Systems)	1979-85	18.0	90.00
Basic Industrial Technology for the Next Generation	1981-90	50.0	333.33
Very High-Speed Scientific Computing Systems (Supercomputers)	1981-89	18.2	121.33
Fifth Generation Computer Systems (FGCS)	1982-91	50.0	333.33
Software Industrialized Generator and Aids (SIGMA)	1985-89	12.5	96.2
Interoperable Database Systems	1985-92	20.0	153.8

NOTE: There have been sharp exchange rate changes since the late 1970s. Thus, exchange rates used vary sharply depending on the project's date.

SOURCE: Marie Anchorodoguy, *Computers Inc.: Japan's Challenge to IBM*, pp. 225-244; *JECC Kompyuta Noto*, various issues.

software (an area of strength for IBM). At any rate, Fujitsu and Hitachi cooperated just long enough to "unravel the secrets" of the architecture of IBM computers.[163] In explaining to his employees Fujitsu's decision to cooperate with Hitachi in this project, Kiyomiya Hire, Fujitsu's Vice President, said:

> Frankly speaking, if we do not do this, we cannot confront our American competitors. If Japanese makers in the domestic market did not cooperate and only competed, before we knew it, we would be taken over by the American firms; there is a danger that every maker would be dealt a fatal blow. On the other hand, if we only cooperate and do not compete at all, we will all slide into stagnant waters, which also would be bad. The British and French computer industries are examples of this. Thus, using cooperative relations during the early stages of development as a base, we will then compete on commercializing the product; as a whole, we must oppose the threat posed by foreign capital. Thus we will cooperate on R&D, but in sales and production we will compete fiercely as we have in the past. . . . Finally, I would like to add that in the background of this move is the earnest guidance of MITI and the deep understanding of NTT. In regards to the big problems created by the decision to liberalize the computer industry in three years, both NTT and MITI have been serious and forward-looking in considering what form our computer industry should take in order to oppose the giant power of American capital.[164]

The architecture of the M-series computers Fujitsu and Hitachi developed during this project is the basis of their mainframe and supercomputer architecture today; Fujitsu's M-380 mainframe and Hitachi's M-280H mainframe were used as the starting point for the development of their Fujitsu VP series of supercomputers and Hitachi S-81O supercomputers respectively.[165] When Fujitsu Chairman, Kobayashi Taiyu, was asked how the Japanese were able to survive during this volatile period in the early 1970s even though RCA and GE withdrew from the computer industry at this time, he replied: "[B]ecause MITI started providing research grants and made different companies get together for cooperative development of new machines; for the first time, Japanese makers were ready for battle."[166]

NIT's and MITI's VLSI (very large scale integrated circuit) projects, from 1975 to 1977 and 1976 to 1980 respectively, were also key in helping the Japanese companies catch up in device technology. This was a necessary step to their becoming competitive in supercomputers today. NTT provided Y20 billion ($100 million) to work with Fujitsu, Hitachi, and NEC on 64K RAMs (random access memories with 64 kilobits, or 64 thousand bits, of memory), something immediately commercializable.[167] While the NTT project formally lasted only 3 years, NTT, which does no production of its own, continued to work closely with these firms on advanced chips after the project ended. These efforts led to many advances in developing 64K RAMs in the last half of the 1970s[168] and a 256K RAM in early 1980. "NTT played a great role in the development of VLSI technology," according to Sakai Yoshio, senior researcher at Hitachi's Central Research Laboratory.[169]

MITI's VLSI project targeted the development of the production equipment necessary for very large scale integration. Denser packing of integrated circuits, which increases speed and decreases cost, would be key to advances in electronics in general and computers in particular. The problem was how to develop equipment to draw narrower lines on wafers and thereby squeeze more circuits onto a wafer. To study these topics, MITI divided up the five firms involved in the project—Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba—into three groups and had them take seven different approaches to the same problem. The rationale was that there are always failures in R&D; if several firms approach a problem differently and agree to share their results, the time and money it takes to develop a successful technology can be cut substantially. The 4 year project cost Y72 billion ($360 million), of which Y30 billion was funded by the government.[170] "The timing of the project was critical," explained Shimizu Sakae, Senior Managing Director of Toshiba, "there was no electron beam [for drawing very fine lines] and we needed a breakthrough to get ahead. The firms did not have any of the equipment for producing VLSIs, such as the electron beam or testing equipment. "171 The firms would not have done research on such advanced chips at that time if not for the project.[172] Indeed, the project was too risky for firms to do without the government sharing costs and risks. As one maker put it:

> Because of the limited resources of a private firm, we domestic makers cannot allow a failure; we cannot deny that this [participation in MITI's VLSI project] was taking a big hedge against risk.[173]

Without MITI's VLSI Project, explained Matsukara Yasuo, General Manager of NEC's VLSI development division, each company would have had to spend five times as much on R&D to develop electron-beam technology.[174]

Several specialists point to the VLSI project results as being a critical ingredient in Japan's ability to enter the supercomputer market in the early 1980s.[175] Indeed, the speed of Japan's supercomputers today is largely the result of very advanced semiconductors. While Japanese companies' private efforts account for most of the advances in devices used in supercomputers, the VLSI project did allow them to get a foothold in this field at a critical time.

Japanese policies supporting the development of the computer and semiconductor industries were characterized by flexibility-making fast responses to new developments and supporting the firms that seemed strongest at various points in time-and strategic use of market signals to provide firms incentives to improve technology. For example, JECC only bought domestic computers that users specifically asked to rent. There was a direct tie to the market; if no one asked to rent a particular computer, JECC did not buy it. Those firms with the best machines got the most orders from customers and thus the most benefit from JECC. By managing prices, JECC helped the firms avoid destructive competition, but prices were set at levels competitive with IBM. Price cooperation pressured the firms to compete on other dimensions key to developing competitiveness-like cost, quality, and technology. R&D subsidies were important but the firms often had to match R&D grants and always had to contribute their engineers. This assured some degree of commitment from the companies, as well as direct transfer of technologies to the private sector. And subsidized R&D was tied to performance. If a company did not commercialize the results of a project, or in general became uncompetitive, it could expect to be left out of the next project. This happened to Oki Electric-it was left out of the VLSI project due to its failure to commercialize the results of the research it did in MITI's earlier 'New Series" project.[176] Finally, cooperation on R&D a step before the commercialization stage helped the firms but still left substantial room for competition, which provided incentives for rapid development and manufacturing efficiency.

TARGETING SUPERCOMPUTERS

As the earlier analysis of U.S. and Japanese supercomputers suggests, Japanese companies have almost caught up with (and maybe poised to move ahead of) their U.S. competitor (Cray Research) in the hardware for traditional supercomputers, though they lag in software (especially applications software) and in developing massively parallel processing machines. Government policies have been an important ingredient enabling them to rapidly close the technological gap with American companies.

The High Speed Computing System for Scientific and Technological Uses

The major R&D effort targeting supercomputers was the High Speed Computing System for Scientific and Technological Uses Project, 1981 to 1989.[177] It was clear to MITI and the computer companies that both high speed devices (components) and architectures (overall designs) that permitted many calculations to be done in parallel would be necessary to make better computers, and that these computers would have important applications.

> For nuclear fusion, nuclear power, energy exploration, weather and earthquake forecasting, and defense-areas related to national security-it is necessary to have a high speed computer [such as that to be developed in this project],

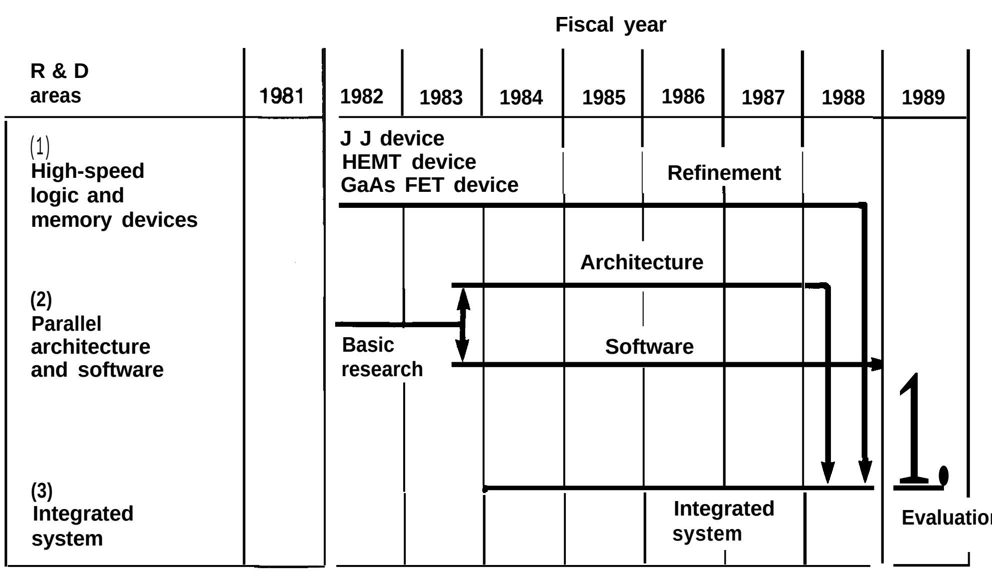
according to a MITI statement on the project.[178] MITI also knew that the R&D needed to make better computers would be useful in other industries as well:

> Completing the High Speed Computer System for Scientific and Technological Uses will have broad spillovers sharply raising the scientific and technological level of every industry. . . thereby contributing to our aim of establishing our nation as a leader in technology.[179]

The primary goal of the project was to help the firms acquire the technological building blocks for making their own supercomputers, but the formal goal was to develop a prototype;[180] in order to get money from the Ministry of Finance for projects, MITI needs to be able to show them something specific at the end.[181] The project was fully funded by the government; the initial budget was Y23 billion but in the end the government spent only Y18.2 billion ($121.33 men).1[82] It called for development of a 10-gigaflops parallel processing supercomputer, a speed that at that time seemed like a dream.[183] The six major vertically integrated computer/semiconductor companies-Hitachi, Fujitsu, NEC, Mitsubishi, Oki, and Toshiba-participated in the project (figures 6-3 and 6-4). Matsushita and Sony wanted to join the project but were not allowed in.[184]

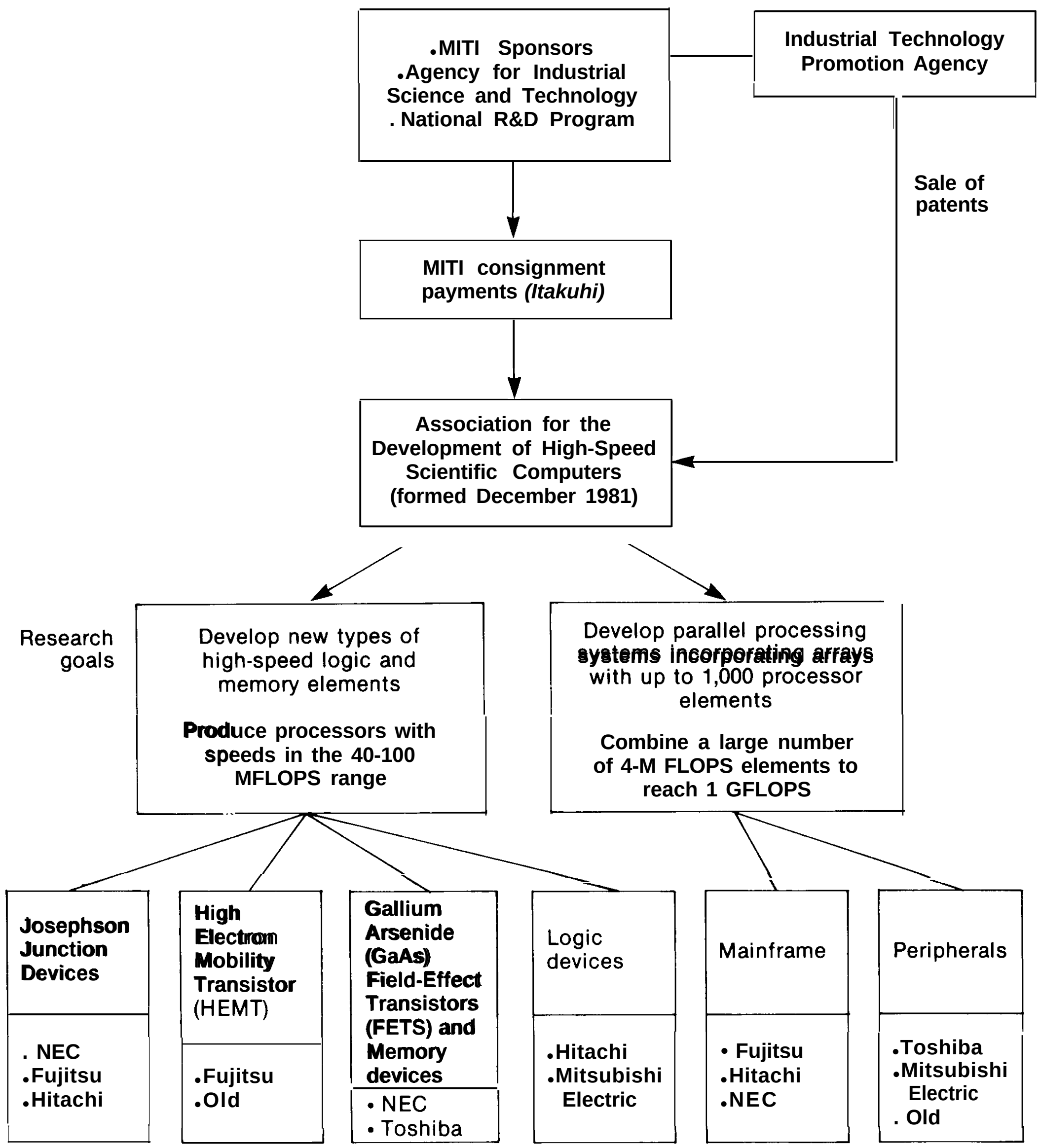
The project focused on high-speed devices and parrallel architectures. The research on high-speed devices was divided up among the six participating firms: NEC, Toshiba, Hitachi, and Mitsubishi researched gallium arsenide chips; 185 Fujitsu, Hitachi, and NEC, Josephson junctions; and Fujitsu and Oki, HEMT (high electronic mobility transistor) de-

Figure 6-3-Schedule of Research and Development for High Speed Computing System for Scientific and Technological Uses Project



SOURCE: MITI.

Figure 6-4-Organization of the Supercomputer Project, 1981-89



SOURCE: Dataquest, Inc.

vices.[186] Both U.S. and Japanese researchers agree that this project helped the Japanese firms gain proficiency in these technologies.[187]

The research on parallel processing was divided into three subgroups: the high-speed parallel subproject; the sigma-1 dataflow subproject; and the satellite image processing subproject. The high-speed parallel subproject was the most important. Aimed at quickly developing a four CPU machine, the subproject combined into one machine four of Fujitsu's already successful single processor machines,[188] which had an architecture based on that developed in an earlier MITT project.[189] Fujitsu focused on developing the software needed to get the four processors to operate in parallel. The prototype high-speed parallel system ran at over 10 gigaflops. The system was designed to accommodate up to 16 processors, but because of budget constraints only 4 were used.[190]

The second architectural subproject--Sigma-1 Dataflow subproject—focused on developing a machine with 128 processors, a precursor to one with 1,024 processors.[191] Dataflow machines were tried in the United States and were not very successful; thus most U.S. scientists do not expect this subproject to have a big impact on Japanese supercomputers.[192] The subpl-eject also had software problems, according to a U.S. researcher who visited the ETL (MITI's Electrotechnical Laboratory) in both 1989 and 1990 and saw little progress made on the software necessary to run the machine.[193] Nonetheless, the research group's successful completion of a 128-processor machine adds to the participants' understanding of massively parallel architectures.

The third subproject was the satellite image data processing system,[194] mother way of exploring parallel architectures; this system can be used for data processing of images and visualization. Three types of architecture were explored: Toshiba focused on a high-speed three-dimensional display processor using 16 very fast VLSI processors; Mitsubishi worked on a simpler machine aimed at processing image data obtained from satellites; and Oki worked on a two-dimensional display using 8 processors for use in global data processing networks.[195] These results will help these firms make parallel processing machines for voice and pattern recognition and visualization, areas considered increasingly important in the 1990s.

As early as the mid-1980s, people from the firms involved said that the project was helping them significantly;[196] but the big results of the project have yet to be incorporated into the firms' machines. The final prototype, completed in early 1990, demonstrates how the main technologies developed in the project work together, primarily the device technologies and the results of the high speed parallel subproject.[197] It is not, however, a prototype of a machine that could be directly commercialized. While Fujitsu was the main contractor for the prototype of a 10-gigaflop machine, doing the computing system and integration of all the parts, Hitachi did the operating system, and NEC the high-speed, large-capacity storage system.[198] Many concrete results were achieved: in the final prototype, gallium arsenide devices were used, though not as extensively as initially envisioned; Josephson junction devices were not used at all in the final prototype, although the project advances in Josephson junctions put Japan in the lead in this area, which is considered to have good prospects in the late 1990s and after.[199] Fujitsu used these results to develop a recently announced hybrid Josephson junction-VLSI device, which it plans to use in its next generation supercomputers, scheduled for the mid-1990s.[200] All in all, some 602 patents resulted from the project.[201] Licenses are available to all participating companies for a nominal fee and other companies for a higher though still reasonable fee.

Another contribution of the project was that it got Japanese computer makers to focus on supercomputers. The companies were not initially interested in the project because they thought there was not a large enough market for supercomputers.[202] 'When the project was started, there were few supercomputers in use worldwide, so we thought there was not enough demand. I do not think that one company would have made such a big effort in supercomputers [as the project has], " explained Oketani Kisaburo, section chief of Fujitsu's Market Planning Departrnent.[203] When asked why Fujitsu does not refuse to join MITI projects it is not interested in, Tajiri Yasushi of Fujitsu explained: ' 'If we ever said, 'forget about Fujitsu [for a given project] and do it with someone else, ' we would never be invited to join a government project again,'‘[204] a consequence Fujitsu was not willing to accept.

The government offered to fund the entire project and the firms went along. Supercomputer development might have happened eventually, but the project started things moving sooner, and, through cooperation, probably got the job done faster and more efficiently than if any one firm had worked on its own. "The Japanese industry and R&D institutes are very cooperative and often go on 'division-of-labor' arrangements. This gives us a considerable edge over IBM, which has to do everything on its own, ' ' stated Fujitsu Chairman Kobayashi Taiyu.[205]

The companies supplemented the project with their own research. A Japanese expert closely involved in the project said the three Japanese supercomputer makers are each spending three to four times the project budget on supercomputer research themselves,[206] suggesting spending of some $360 to 490 million investment by each of the three fins. This investment, along with the $121.33 million provided by this government project, pays part of the development of new generation supercomputers. Cray forecast that it would spend $100 million in development costs for its C-90 machine due out in late 1991.[207] Cray's spending should not be compared directly with the Japanese companies' spending during the High Speed Computing System project, for that project spans more than one generation of product development; moreover, it is not clear how many years Cray's $100 million expenditure on the C-90 covers. Nevertheless, the very rough comparison is instructive. The Japanese firms can outgun Cray in R&D, in part because of help from their government.

NTT has its own supercomputer project, which involves Fujitsu, NEC, and Hitachi.[208] In early 1985, the NTT lab successfully developed a 1K lead-based Josephson memory chip, which ranks as one of the fastest in the world, and also a pace-setting 4K gallium arsenide memory.[209] Unfortunately, it is impossible to get any further information on NTT's supercomputer project.

Other Government-Sponsored Projects Related to Supercomputer Technologies

Several other projects have contributed to Japan's ability to produce parallel processing machines. Indeed, there are over 70 projects exploring parallel and massively parallel processing in Japan's public and private sectors; about 25 percent focus on high speed supercomputing, 25 percent on artificial intelligence, and the remaining 50 percent on areas such as image processing, computer graphics, computer aided design (CAD), and databases.[210].

The largest is the Fifth Generation Computer Project, 1981 to 1991, a Y100 billion project, which the government is supporting with Y50 billion ($333.33 million). This project focused on developing parallel processing for artificial intelligence (as opposed to numerical computing applications). The goal was for a machine able to infer knowledge based on data stored in its memory, for example, a computer able to write its own software for new applications and able to process and understand a variety of symbols, including *kanji (the Chinese* characters that are part of the Japanese written language) and photographs. The initial expectation was that the fifth generation machine would be able to "reason" at an elementary level, and thus help managers, doctors, and others who analyze problems through complex sequences of inferences.

Eight companies (Fujitsu, Hitachi, NEC, Mitsubishi, Toshiba, Oki, Matsushita, and Sharp), along with NTT, have sent engineers to ICOT (Institute for New Generation Computer Technology), a central laboratory established in 1982 to conduct the research. (NTT also has its own fifth generation computer project, which it invited NEC, Hitachi, and Fujitsu to join.[211]) At ICOT, researchers from the different companies work side by side, something unusual in MITI projects. ICOT also distributes work among five other laboratories.

The Fifth Generation Project worked on both software and hardware. The Japanese companies originally did not want to join the cooperative effort because they believed that the goals were far too vague; they were particularly concerned that the project did not target an IBM-compatible machine.[212] But the government agreed to put up money to get the project started, and the firms went along and ultimately matched the government funding.

It is too early to assess the project's impact. It is generally believed that the project fell far short of its ambitious goal of creating a prototype "thinking machine." Some U.S. scientists in particular criticize the project's focus on logic programming and the fact that it has not produced any fundamental advances.[213] Even so, the project probably is not a dead loss. Speaking of one of the project's interim results-Mitsubishi's uniprocessor and 16-processor parallel inference machines, which were demonstrated at Argonne National Lab in Illinois-an Argonne scientist said:

> They are learning a lot about parallel processing. By working in this project, the companies have gotten their brightest people exposed to many issues in parallel processing and to the international scientific community. Now that the project is ending, these people will go back to their firms with this knowledge. The project has not been a total success but I expect a favorable long-term effect.[214]

Computer makers expect some spin-offs from technology researched in the project, according to Shimizu Sakae, Toshiba's Senior Managing Director;[215] some spin-offs have already been commercialized.

The project has played a role in pushing the industry to explore new technologies, especially non-IBM compatible machines. The industry was rattled in mid-1982 when IBM cooperated with the FBI in a sting to catch Hitachi and Mitsubishi stealing IBM's technological secrets. The Japanese firms have been forced to make licensing agreements with IBM involving large sums. Hitachi, for instance, reportedly paid IBM Y1O billion ($45.45

million) for the cost of a lawsuit and for past use of software similar to IBM's, and in the mid to late 1980s was paying some Y8 to Y12 billion ($60-90 million) a year for its use; IBM also received the right to inspect new Hitachi machines to confirm that Hitachi is keeping the agreement.[216] Japanese companies felt that, to survive over the long term, they would have to develop their own operating system standard. "We have to make a complete break from the IBM standard in order to survive," said Yamamoto Kinko, the Managing Director of the Japan Information Processing Development Center (JIPDEC).[217] "We've got to find another standard," agrees Tomioka Susumu, manager of Fujitsu's software division.[218] If Japanese companies do develop their own standard, and it is widely accepted, this could have serious consequences for IBM, as well as other U.S. systems and component producers.

Finally, the technologies investigated in the project will help Japanese companies to move towards massively parallel machines. In the interim stage of the Fifth Generation Project, Mitsubishi completed a prototype of a 64-processor parallel inference machine. The project is concluding with three prototypes: a full version 1000 VLSI processing unit made by Fujitsu, one with about 256 processors made by Mitsubishi, and a smaller version made by a third company.[219] It is too early to know how good these machines will be; but even though they are unlikely to be commercial successes, the firms and their researchers will have gained experience.

As a successor to the Fifth Generation Project, MITI is exploring a New Information Processing Technology Project (NIPT). This so-called "Sixth Generation Computer Project" is expected to focus on basic principles of massively parallel processing, three dimensional information, and visual and auditory recognition, aimed at developing a reliable computer with a million or more processors.[220] The project will continue the Fifth Generation project's focus on a "thinking" computer, one that performs tasks such as pattern recognition and intuitive information processing better than conventional computers. The goal is to be able to deal with ambiguous or incomplete information.[221] Though in July 1991 the project was still in the planning stage and had not yet been given the official go-ahead, it was expected to be approved, to be of the same scale as the Fifth Generation Project, and to follow an organizational structure such as that used by ICOT.[222] Two U.S. computer scientists familiar with this proposal argue that while there will be difficult problems in designing and building the proposed sixth-generation computer, it will likely serve as a magnet attracting Japan's top research minds.[223] The project would require a major software effort and further R&D on massively parallel processing architectures, areas where Japanese companies lag American companies.

Finally, there have been a few government projects to help Japanese companies develop software for supercomputers, another area of comparative weakness. One small national project run by the Fluid Dynamics Analysis System Research Association aims to develop fluid dynamics software for supercomputers. Started in March 1988, five companies, seven major users, and one software house are participating in this 4-year project; members include Asahi Kasei, Takenaka Komuten, Tokyo Electric Power, Toshiba, NICK, NEC, Hitachi, Fujitsu, Matsushita Denko, Marubeni, and Mitsubishi Heavy Industries. Some experts see the involvement of users in software R&D projects as a promising approach to ensure that the project will be commercially useful. The group has received Y1 billion ($7.7 million) from the government for the 4-year period from March 1988 to March 1992.[2X] Member companies are charged Y60 million each, and supporting members (which they hope to increase to some 200-300 fins) Y4.8 million.[225] Another small-scale software project that will have an impact on supercomputers is MITI's New Software Structuring Project, which aims to make it easier to maintain large software systems such as online systems for banks, companies, and government agencies. This project is expected to begin in 1991 with actual research starting in 1992; it will last 8 years and will be funded at about Y5 billion (about $35 million).[226]

The Japanese Government is playing a critical role in providing the seed money and the coordination necessary to get Japan's government labs, major companies, and universities to cooperate in developing very future-oriented supercomputer technologies, work that they would not be doing otherwise. When asked in the late 1980s whether government projects such as the Fifth Generation and supercomputer projects have any significance given that Japanese firms have become very strong in their own right, Kuwahara Yutaka, head of R&D Administra-

Table 6-8—U.S. and Japanese Supercomputer Companies' Share of the World Market

	Market share in percent (number of installations)					
Company	1980	1985	1986	1987	1988	1989
Cray	90%	56%	60.7% (148)	67%	64%	53.1% (219)
Fujitsu	00/0		15.5% (38)	1770	12%	21 .6% (89)
NEC	0%	24%	2.5°10 (6)	6%	4%	6.3% (26)
Hitachi	O%		4.5% (11)	4%	4%	7.8% (32)
CDC/ETA	10%	20%	16.8% (41)	6%	16%	11.2% *(46)*
Total	100%	100%	100% (244)	100%	100% (340)	100% (412)

SOURCES: *Kompyutopia*, December 1989, p. 76; Nikkei *Sangyo Shimbun*, Apr. 19, 1989, p. 3; *Los Angeles Times*, Sept. 4, 1987; *High Performance Computing and Communications: Investment in American Competitiveness*, Gartner Group, Inc., p. 69.

tion at Hitachi's Central Research Laboratory, replied:

> Government projects are significant because there are many things for us to challenge in the future, many of which can be better done in a government project than a private one. . . .When profit decreases. . due to the recession, the increasingly higher yen, and trade friction, we, in our [corporate] lab, are pressured to cut costs and to be more product-oriented. It is very difficult to propose a future-oriented technology because we will be asked, 'Is it necessary? How profitable will the results be?' So we believe that national projects are very very important when they are future-oriented-when they focus on very risky R&D that is very difficult for the private sector to challenge alone.[227]

JECC also provides implicit subsidies to Japanese supercomputer makers. A third of Fujitsu's supercomputers are rented through JECC, and "A substantial amount of our supercomputer business comes from JECC," stated Watanabe Tadashi of NEC.[228]

PROCUREMENT OF SUPERCOMPUTERS

A major aspect of targeting supercomputers has been the procurement of domestic machines by the government and the private sector. While companies in the United States and Europe bought American machines (which, until recently, performed much better and still have more software than Japanese machines), the Japanese Government and private sector bought Japanese machines (tables 6-8 through 6-10).

Table 6-9-U.S. and Japanese Supercomputer Companies' Share of the European Market, 1989

	Market share in percent (number of installations)
Cray	84% (73)
Fujitsu	9% (8)
CDC/ETA	6% (5)
NEC	(1)
Hitachi	O% (o)
Total	100% (87)

SOURCE: Cray Research.

Private Sector Procurement

Analysis of private sector procurement of supercomputers in Japan shows that a significant amount are purchases of a group member's machine. Of 12 machines owned by Fujitsu group companies, 10 are Fujitsus and 2 are foreign machines; of 11 machines owned by NEC group companies, 5 are NECs, 3 are Fujitsus, and 3 are foreign machines; and of 9 machines owned by Hitachi group companies, 3 are Hitachis, 3 are machines of other Japanese supercomputer makers, and 3 are foreign machines (table 6-11). (These figures do not include machines used internally by Fujitsu, Hitachi, and NEC.)

Keiretsu feelings are strong, and firms only go against them when they feel their survival is at stake. "We would like ideally to purchase the supercomputer of the maker in our group, but if we try to save the face of each firm in our group, we'd be defeated

Table 6-10-U.S. and Japanese Supercomputer Companies' Share of the Japanese Market, Installed Base

Company	Market share in percent (number of installations)			
	1987	1988	1989	1990 (3/90)
Cray	13.0%	11 .5%	10.1%	15.6%
	(7)	(13)	(14)	(23)
Fujitsu		54.O%	49.6%	49.O%
	(30)	(61)	(69)	(72)
NEC	13.0%	15.9'YO	16.6Y0	14.3%
	(7)	(18)	(23)	(21)
Hitachi	18.5%	17.770	23.0%	19.7%
	(lo)	(20)	(32)	(29)
CDC/ETA	—	0.9%	0.7%	1 .4%
		(1)	(1)	(2)
Total	100.0%	110.O'%	100.0%	100.O%
	(54)	(113)	(139)	(147)

SOURCES: *Dempa Shimbun*, Apr. 9, 1987, p. 1; *Nikkei Uotcha IBM-Ban*, Apr. 30, 1990, p. 22; and Advanced *Computing in Japan*, Japan Technology Evaluation Center, October 1990, p. 140.

Table 6-n—Purchases by Firms with *Keiretsu* Ties to Japanese Supercomputer Makers, 1980-90

Company group	Number of machines			
	Total purchases by group members	Purchases from affiliated makers	Purchases from other Japanese makers	Purchases of foreign supercomputers
Fujitsu's group	12	10	0	2
Hitachi's group	9	3	3	3
NEC'S group	11	5	3	3
Total	32	18	6	8

SOURCE: *Nikkei Uotcha, IBM-Ban,* Apr. *30, 1990,* pp. 21-24; *Kigyo Keiretsu Soran, 1991.*

in the severe competition we face, and we cannot afford to do that," explained one auto maker.[229] Many argue that supercomputers are driving the competition in automobile design today; for example, Toyota's purchase of a Cray after it learned that Nissan had made many key product development advances using a Cray supports this notion. Toyota had been using a Fujitsu, and the switch only serves to underline the superiority of Cray machines and their software (at that time) for auto industry applications.[230]

Mazda, which is heavily indebted to the Sumitomo group for bailing it out when it was threatened with bankruptcy, solved its obligation by a compromise; it bought an NEC machine to save face with the Sumitomo group and a Cray for its applications software.[231] Sumitomo Chemical did not make such a compromise; it completely went against NEC (its group computer maker) when, in September 1989, it bought a Cray because of Cray's better software.[232]

Nissan, which has a long relationship with Hitachi, bought two Cray supercomputers. But Nissan's first purchase of a Cray in 1986 only came after U.S. pressure. According to some reports, Nissan engineers leaked to the U.S. Embassy in Tokyo and to Cray's office there that they wanted a Cray but that top company executives had decided to purchase a Hitachi due to their "relationship." The leak had its intended effect; the United States Trade Representative (USTR) and Department of Commerce officials discussed the issue with MITI, which in turn pressured Nissan to purchase a Cray.[233] Since then, Nissan officials have frequently stated that Cray's simulations software and its UNIX-based operating system are the deciding factors in its purchase of Cray machines.[234] "For our needs, Cray performed the best," explained a Nissan manager.[235]

Automobile companies are the clearest example of a Japanese industry in which all the major actors have Cray machines. Of Cray's 26 Japanese installations, 10 are in the auto industry, which purchased the Cray machines primarily for their performance, especially the crash simulations applications software. Of less significance, Japanese auto companies are aware that purchasing foreign machines helps to balance their huge exports of autos to the United States, potentially reducing trade friction.[236]

While Cray has been able to attract some customers from the groups of Japan's supercomputer makers, its biggest Japanese market is firms that are not part of the groups to which NEC, Fujitsu, and Hitachi belong. Of all supercomputer purchases in Japan, 26 percent (46 of 172) have been by private companies unaffiliated with the groups of Japan's three supercomputer makers; 50 percent of the purchases of Cray machines were by such companies (13 of 26), compared to 25 percent for Fujitsu (21 of 85),23 percent for Hitachi (8 of 35), and 13 percent for NEC (3 of 24) (table 6-6). Toshiba is one such example. In 1989 it bought a Cray Y-MP8/4128 for its applications software and the fact that it worked on UNIX, which was compatible with Toshiba's engineering work stations.237 That many such companies have purchased Cray machines supports the notion that Cray is very competitive.

The fact that Japanese firms are vertically integrated and can use their own supercomputers in their semiconductor divisions also explains a chunk of private sector procurement. Of Hitachi's total sales of 35 supercomputers, 12 are used internally; of NEC's 24 supercomputers, 3 are used internally; of Fujitsu's 85 supercomputers, 9 are used internally (table 6-6). Finally, strong societal pressure to buy Japanese probably also tilts the market in domestic firms' favor.

It is very difficult to estimate how many foreign supercomputers would have been purchased in an open market. There are two issues: quality and price. On quality, most U.S. observers would say that at least through 1989 U.S. machines were superior. A more conservative approach is to say that, on the basis of quality alone, U.S. firms would have won all sales to the private sector through 1986, all sales to Japanese auto manufacturers through 1989, and the three additional keiretsu-related sales during 1987-1989. This amounts to 20 supercomputers. The U.S. machines would have cost substantially more, and it is impossible to know how many Japanese users would have paid to obtain a better foreign machine if the market had been fully open. However, on the somewhat tenuous assumption that the customers would have been willing and able to pay higher prices for foreign machines, Cray and ETA would have sold 20 more supercomputers. If three later upgrades of those machines are counted, the total lost sales amount to 23 machines.[238]

Public Sector Procurement

While Cray and CDC have faced *keiretsu ties in their* efforts to sell to Japan's private sector, public sector sales have been even harder to win. Of 51 government procurements of supercomputers, 5 have been of foreign machines (see tables 6-5 and 6-6).[239] This record ultimately led to two agreements between the United States and Japan over supercomputer procurement, one in 1987 and another in 1990.

The Japanese Government did not purchase any supercomputers until 1983, the year Japanese firms introduced their first models; the Cray-1 had been out since 1976 and Japan's private sector had purchased two foreign machines as early as 1980 (table 6-5). When Japan's public sector did start buying supercomputers, the U.S. Government and supercomputer makers realized that the public procurement process was not transparent-U.S. firms were never notified when a procurement would occur-and the Japanese firms gave deep discounts, which the U.S. Government and supercomputer makers maintained were some 80 to 90 percent off list prices.

The Japanese Government budget is a primary cause of the heavy discounts on supercomputers sold in public sector markets; the Ministry of Finance does not give the Ministry of Education a large enough budget to allow the public universities and laboratories to purchase supercomputers at or near list prices. A high level Ministry of Education official says that the Ministry has a responsibility to use taxpayer money with as much care as possible and thus to have universities purchase supercomputers as cheaply as Possible.[240] These discounts have the effect of decreasing net government aid to the supercomputer makers, though in ways that help them win sales in important markets.

Indeed, discounting to universities can make good business sense. IBM long ago began giving universities big discounts on its mainframes, and university users often develop software, which increases the demand for a machine. Also, when students accustomed to using a certain machine graduate and enter a company, they tend to want to continue with the same type of machine. A discount sale can also help to secure future business. Once a computer maker installs its machine, it has a very high probability of continued sales (though if the customer is a university, probably at discounts) in the future because of compatibility.

Small public sector budgets encourage Japanese makers to offer heavy discounts to universities and government laboratories or forego the business altogether. Discounts of 80 percent or more are considered natural. 'It's not that we like to give such discounts. If only the government would give [public institutions] a sufficient budget, then this would not have to happen, ' explained one mid-level Fujitsu manager.[241] But the benefits to Japanese makers still outweigh the costs: "When they use our new machine, it helps us improve upon the product in the future," explained a Hitachi manager; "When a university uses our machine. . . it improves our image,' adds an NEC manager; "We want to give assistance to Japan's researchers; not just in supercomputers, but in other products too; it [the heavy discounting of supercomputers] is the price of that business,' explains a Fujitsu manager.[242] Discounts also oblige university professors, who are closely involved in recommending their top graduates to recruiting firms, to give their best graduates to firms giving big discounts.[243] Aware of their weakness in software, firms see universities as helping them improve their software.[244] "Actually it would be fine to give it to them for free, but that becomes a gift and causes tax problems; that's why we take the approach of just giving them a big discount," explained a manager of a Japanese supercomputer firm.[245]

By late 1985 and early 1986, the United States started to express more forcefully its dissatisfaction with the lack of transparency and the lack of public procurement of foreign supercomputers. By 1986, the Japanese Government had purchased 22 supercomputers, only 1 of which was foreign, even though U.S. machines were far superior at the time. In response to U.S. complaints, Prime Minister Nakasone Yasuhiro assured the United States that NTT would buy another Cray supercomputer to improve the trade balance.[246] (The Ministry of Finance owned 100 percent of NTT's stock until April 1985; MOF has since sold some of its NIT shares but the company is still mostly government-owned.) According to Japanese documents, Nakasone's decision to have NTT buy another foreign supercomputer came at a time when NTT was at pains to increase purchases from the United States. Soon after, NTT President Shinto made a deal with the head of the Recruit Corp., a Japanese real estate/job-referral firm, to have Recruit repurchase the supercomputer NTT planned to buy from Cray.[247]

By late 1986, it was clear that no big changes in public procurement were forthcoming; discounting of up to 80 to 90 percent off list prices continued. After various negotiations among the USTR, Commerce Department, and State Department, the Administration decided to conduct an inquiry into Japanese procurement under section 305 of the 1974 Trade Act and to negotiate with Japan in the framework of the MOSS (Market-Oriented, Sector Selective) talks. From the beginning the U.S. Government made it clear that it wanted an open market, not a few token procurements.

Negotiations did not get off to a good start. In early 1987, talks with MITI vice-minister Kuroda Makoto were abruptly adjourned after a lunch meeting in which Kuroda allegedly stated that the United States would have to nationalize Cray or merge it with larger U.S. firms in order for it to survive in today's world of large vertically integrated fins, and that no matter how much the United States tried, it would not be able to sell supercomputers in Japan.[248] A month later, on March 26, 1987, the *Washington* Post printed a copy of a U.S. Embassy cable regarding this alleged Kuroda statement, which Kuroda immediately denied.[249] Whether or not Kuroda really said this, the sentiment is echoed in Japanese language documents that talk of Cray's dependence on Japan for memory chips and suggest that Cray will be overwhelmed by Japanese competition in the next few years.[250]

Japan responded immediately to the publication of the alleged Kuroda statement by announcing that NTT would purchase another Cray supercomputer. NTT, which was mostly government-owned, was reported to have said that the government pressured it to make this purchase to ease U.S.-Japan trade friction.[251] This supercomputer, like the one NTT had purchased in 1986, was resold to Recruit.[252] The two Crays that NIT purchased and sold to Recruit were token purchases; they did not signal a move towards more open public markets.[253] Ministry of Posts and Telecommunications (MPT) Minister Nakayama reportedly explained in a Diet committee that NTT's purchase and resale of a Cray to Recruit "was at a time when, as a policy to help U.S.-Japan trade friction, we were searching for someplace [that would take the supercomputer off our hands].''[254]

At the same time as this NTT announcement, the Japanese Government was hurrying to get approval of an emergency budget to provide bigger budgets for the universities.[255] Even before the alleged Kuroda statement hit the newspapers, Japanese Government officials knew the United States was upset not just over supercomputers but also about semiconductors-semiconductor trade friction would lead President Reagan to impose tariffs on some Japanese personal computers, power hand tools, and televisions in April 1987. In March 1987, MITI Minister Tamura told Prime Minister Nakasone that if Japan bought a couple of the Cray-2s, it would be very useful in alleviating trade friction.[256] A former U.S. Government official closely involved in negotiations on both semiconductors and supercomputers said that he received several calls from Japanese officials asking him if the United States would back off retaliation over semiconductor trade if Japan bought more supercomputers.[257]

In October 1987, after the emergency budget was approved, MITI's Agency of Industrial Science and Technology (AIST) and the Tokyo Institute of Technology (TIT), a public institution, announced that they would each buy an American supercomputer. The Japanese Government decided to have them purchase one Cray Research machine and one ETA, the latter because they felt CDC, the parent of ETA, might complain if only Cray machines were purchased.[258] The bidding was formally open but there was no chance for Japanese companies to win these bids because the emergency budget had been approved to alleviate U.S.-Japan trade friction.[259] A MITI official acknowledged that TIT's directed purchase of an ETA machine was contradictory to the principle of open competition that the U.S.-Japan agreement was to provide.[260]

With these two purchases the Japanese Government felt it had fulfilled its promise to procure supercomputers.[261] U.S. officials, however, saw two token purchases rather than a free competitive bid process. CDC's late delivery of its supercomputer, along with the machine's failure to operate at the speed promised, hurt the U.S. case.[262] ' 'The Americans never looked so foolish,' said one Japanese expert.[263] To this day TIT researchers vent their frustration at this CDC machine; CDC's withdrawal from the supercomputer business in 1989 only exacerbated their problem.

TIT researchers' complaints were not the only ones. Researchers in Japanese public sector labs voiced concern that purchasing more expensive foreign supercomputers would cut sharply into the rest of their research budget.[264] There was also concern about foreign supercomputers' compatibility with existing mainframes and peripherals, especially since Japanese supercomputer firms also made mainframes and peripherals while Cray Research did not.[265]

A formal agreement between the two countries was finalized in summer 1987 requiring that government institutions give full public notice of their intentions to procure a machine. The agreement did not deal with discounting; U.S. Government officials involved in the negotiations say that the U.S. administration believed that by charging discounted prices, the Japanese firms would only be hurting themselves. The United States also knew that it would be difficult to criticize Japanese supercomputer makers for discounting when IBM was actively discounting its mainframes for Japanese universities. There was also concern that European countries would object if the United States tried to limit discounting on sales to third countries.

The agreement was not effective. Since Japan's market was now formally open and U.S. makers were notified when public procurements would be made, they had to make bids (a costly process) or else look like they were not trying. But these bids were useless because the Japanese makers were still using very heavy discounts, selection did not have to be based on actual performance, and the Japanese universities preferred Japanese machines because of longstanding ties with companies.

The 1987 agreement did accomplish one thing: it hushed U.S. criticism for a time.[266] This allowed Japanese supercomputer companies additional time to improve their competitiveness. Other than the two emergency budget procurements completed before the agreement, there were no more purchases of U.S. machines until the start of new negotiations on supercomputer procurement in 1989.

The first public sector procurement *after the* 1987 agreement-Tohoku University's Large-Scale Corm puting Center's decision to purchase a supercomputer—is a good example of how the heavy discounts work. The bid was for a machine to replace the Center's NEC SX-1 model, so it was expected that NEC would win the bid; Cray nonetheless made a bid since the market was now officially open. NEC bid the SX-2 and Cray the Y-MP-832. The first bid was made in June 1988, with NEC offering a monthly price of Y48 million against Cray's bid of Y74.739 million. NEC appeared to have an unbeatable advantage, but instead of awarding NEC the contract, the university asked for a second round of bids trying to get a better discount. NEC cut its bid to Y40.1 million and Cray cut its slightly to Y74.73 million. When the university asked for a third round, Cray dropped out. The university did not give NEC the contract until the eighth round of bids. The final price was V14.6 million, a 70-percent cut from NEC's original bid and a 90-percent discount from the original list price.[267] The person in charge of the university's procurement said "to have to rebid is natural not just for computers; even making eight bids is not necessarily too many."[268] These low prices are possible for Japanese companies because of government aid to the industry and because the firms can funnel mainframe and semiconductor profits to support their supercomputer business. But to Cray, these are "market-shattering" prices, explained Jonathan Streeter of the Department of Commerce.[269] In numerous interviews with Japanese Government officials and industry people, all agreed that Japan's supercomputer makers are losing money on their supercomputers but that they are going for long-term market share rather than immediate profits. "We don't need to make a profit on our line of supercomputers,' admits Watanabe Tadashi, the major architect of NEC supercomputers; "whatever is spun off from our supercomputer R&D helps in other information-technology fields. ' '[270]

The Tohoku University case is not an exception. In 1988, Hitachi won a bid to Hokkaido University's Large-Scale Computing Center but only after five rebids, for a monthly rental price of Y15.75 million; the list price was Y89 million a month; including the peripherals and application software, the discount was between 80 and 90 percent.[271] A similar case was the Japan Railways Technical Research Institute (RTRI) purchase of an NEC supercomputer in 1988. Cray was interested in the procurement but "withdrew when RTRI demanded an 80 percent discount," explained Yoshikazu Hori, President of Cray Research's subsidiary in Japan.[272]

By early 1989 the United States, realizing that the agreement was not having its intended effect, started to consider targeting supercomputers under Super 301 of the 1988 Omnibus Trade and Competitiveness Act. This Act required the USTR to identify the highest priority offenders among countries that unfairly restrict the sales of U.S. goods and services, to investigate the practices involved, and to negotiate to eliminate the market barriers. If the barriers were not removed, sanctions could be applied (see ch. 4).

Trade friction between the United States and Japan worsened when in April 1989 NEC announced that Japan's frost 4 CPU machine, the SX-3, would be coming out soon. That machine had a theoretical peak speed of 22 gigaflops, far faster than any other.[273] Soon thereafter, CDC withdrew from the supercomputer business, and the United States' competitive position deteriorated. MITI reportedly scolded NEC, saying "Why are you irritating the United States by announcing a new advanced series of supercomputers] at a time when they are thinking about invoking Super 301 against Japan?' '[274] NEC then announced that it had decided to increase its use of U.S.-made semiconductors in its SX-3 series of supercomputers to help alleviate U.S.-Japan fiction over supercomputers.[275] It didn't work.

In late May 1989, the U.S. Government listed Japan under Super 301; in June it started investigating Japanese practices regarding supercomputers, wood products, and satellites. In this second set of supercomputer negotiations, the United States made it clear that it wanted to deal with the heavy discounting of supercomputers. Right after the U.S. announcement, MITI reportedly advised computer makers to keep their supercomputer discounts under 50 percent, although bigger discounts on mainframes were okay.[276]

The first Japanese public sector supercomputer procurement after these negotiations began (but before they were concluded) was the purchase of a Fujitsu machine by the National Astronomical Laboratory to replace its existing Fujitsu. The only bidder was Fujitsu, which offered a 60-percent discount off the list price for a system of 134 machines, including 3 mainframes, engineering workstations, and other equipment. Fujitsu was careful, however, to keep the discount on the supercomputer within the 50-percent limit and to give the entire product a 60-percent discount by discounting the mainframe parts of the system more heavily.[277]

Soon after, in early December 1989, Fujitsu won a bid for the Japan Atomic Energy Research Institute with a 25-percent discount off list price, a level that the government suggested would allow the firms to escape U.S. displeasure.[278] But this and subsequent "smaller" discounts were the result of Japanese companies cutting their list prices in order to make their discounts appear smaller (table 6-12). For example, in October 1989 NEC dropped the list price of its new SX-3 series machines by 35 percent,[279] Fujitsu and Hitachi had already lowered their list prices by 20 to 35 Percent.[280] When Fujitsu won the Japan Atomic Energy Research Institute procurement after lowering its list prices to give a lower discount, MITI Minister Matsunaga said that "Fujitsu's drop in list price is the result of the operation of competitive market forces."[281] This 25-percent discount was a 53-percent discount over the previous list price: the two Fujitsu VP26OO-10 supercomputers purchased had an original list price of Y80 million a month each, but had been dropped to Y50 million a month; the final bid was Y37.389 million a month.[282] The United States complained that dropping the list prices just made it look like a smaller discount and was in no way a solution to the problem,[283] but no further changes have been made.

Before the 1990 agreement was finalized, Tohoku University decided to buy a Cray machine for its Fluid Dynamics Research Lab. Formally, this was a first installation for the lab, but the researchers had been using the university Computing Center's NEC machine, so everyone expected NEC to win the bid. But NEC suddenly withdrew, citing government pressure aimed at easing U.S.-Japan trade problems.[284]

This strategy worked. A draft of the agreement was finalized in late March, and the U.S. administration did not target Japan for a second year under Super 301. The agreement was formally signed on June 15, 1990, a day before USTR would have been required to make a recommendation regarding sanctions.

> There was a consensus among the Japanese ministries to do the agreement to protect the U. S.-Japan relationship. SII [the Structural Impediments Initiative Talks] did not go well. Trade figures were bad. It was crisis management. The United States threatened retaliation under Super 301; without that threat, many ministries would not have gone along,

explained an official of the Ministry of Foreign Affairs involved in the negotiations.[285]

The primary difference between the 1987 and 1990 agreements is that the latter requires real performance criteria, not just theoretical peak performance data, to be used and that discounts be

Table 6-12-List Purchase and Rental Prices of Japanese Supercomputers

Vendor	Model	Old monthly rental price (yen)	Old monthly rental price (yen)	Percent of reduction	Date of price reduction
Fujitsu	VP-200E	Y56.oM	Y45.00M	19.6%	May 1989
	-2100/10	*38.0*	24.95	34.3	Dec. 1989
	-2100/20	*59.0*	39.05	33.8	Dec. 1989
	-2200/10	50.0	32.80	34.4	Dec. 1989
	-2200/20	77.0	50.60	34.3	Dec. 1989
	-2400/10	64.0	40.00	37.5	Dec. 1989
	-2400/20	91.0	57.80	36.5	Dec. 1989
	-2600/10	80.0	50.00	37.5	Dec. 1989
	-2600/20	170.0	67.80	36.6	Dec. 1989
Hitachi	S-820/20	Y38.0M	Y27.60M	27.4	Oct. 1989
	-820/40	50.0	35.60	28.8	Oct. 1989
	-820/60	62.0	44.70	27.9	Oct. 1989
	-820/80	89.0	66.40	25.4	Oct. 1989
NEC	SX-3/11	Y52.OM	Y34.00M	34.6	Oct. 1989
	-3/12	64.0	42.00	34.4	Oct. 1989
	-3/14	77.0	50.00	35.4	Oct. 1989
	-3/22	96.0	62.00	35.4	Oct. 1989
	-3/24	112.0	73.00	34.8	Oct. 1989
	-3/42	140.0	91.00	35.0	Oct. 1989
	-3/44	170.0	111.00	34.7	Oct. 1989

SOURCE: *Nikkei Computer,* Mar. 26, 1990, p. 97.

limited. In this regard, the agreement is an improvement. But virtually everyone agrees that the second agreement, like the first, is deeply flawed. First, the agreement may very well strengthen the Japanese supercomputer makers. MITI and the firms are happy with the agreement because it is better for the firms not to have to discount their machines so much. "Because discounts are only 20 to 30 percent now, the firms make more money, ' stated a Ministry of Foreign Affairs official closely involved in the negotiations.[286] Before the agreement was signed, a spokesman for a maker said, "there would be nothing better for us than to be able to sell our supercomputers at list price."[287]

Another problem with the agreement concerns reciprocity. As a strictly legal matter, reciprocity is not an issue. The agreement was intended to remedy Japan's violation of the GATT Procurement Code; Japan has not complained of any U.S. violation, so there is no need for the United States to change its procurement practices. While the United States has refused to buy Japanese supercomputers for defense purposes (e.g., for defense research at the national laboratories and in defense applications at NASA facilities), that does not violate the Code, which exempts defense purchases.

However, most U.S. Government supercomputer procurement is for defense purposes, and Japan could ask on grounds of fairness that the United States open that market for Japanese machines. Watanabe Tadashi, the chief architect of NEC's supercomputers, says, "The U.S. Government hasn't bought a single Japanese supercomputer; now you tell me who's being unfair."[288] Fujitsu chairman Yamamoto Takuma agrees that the United States is unfair in calling on the Japanese Government to buy U.S. supercomputers when the U.S. Government does not buy Japanese machines: "We do not intend to crush them under our feet; nothing can be gained by doing that. That is why Fujitsu has always tied up with a ~. S.] partner, and we will continue this strategy in the future."[289]

The Japanese not only see the lack of reciprocity as a problem, they also see the United States as having a double standard on discounts. Japan argues that the United States is complainingg about Japanese dumping of supercomputers because Cray Research, a relatively small one-product company, cannot afford to sell its machines at such low prices.[290]

Even if the agreement were perfect, however, it would be hard to overcome the effects of past preferential procurements. Public institutions with Japanese supercomputers in place would normally wish to replace their machines with an upgraded model from the same maker. "The most significant part of the agreement is for frost installations. Japanese first-time buyers will be able to choose the best company,' explained Jonathan Streeter of the U.S. Department of Commerce.[291]

The agreement's usefulness to U.S. manufacturers is also limited by university budgets; with higher prices, probably fewer machines will be bought. Total budgets for universities rise at only 10 percent a year (or less); thus, sharp increases in expenditures on supercomputers would require cutting another part of the budget. The fact that six public sector labs, four of which are universities, have delayed supercomputer procurements originally planned for 1990[292] suggests that the kind of government funding the U.S. Government and Cray Research are hoping for will not be forthcoming in the near future. Indeed, Japanese public procurement has plunged from 12 and 11 machines in 1986 and 1987, respectively, to 8,4, and 6 in 1988, 1989, and 1990.

The Japanese and U.S. Governments are publicly calling the 1990 agreement a success. "The Tohoku University procurement is the first application of the 1990 agreement. It is an example of the success of the talks. Cray's success is not artificial, rather Cray's machine fits the needs of Tohoku University," stated Kawamura Yasuhisa, a Ministry of Foreign Affairs official involved in the negotiations.[293] A few days after Tohoku University decided on a Cray, Kyoto University decided on a Fujitsu for a replacement machine of the same brand. "After the 1987 agreement there were no Cray purchases in the public market, and after the 1990 agreement there have been two purchases, one of which was a Cray. Cray has a 50-percent market share of purchases made after the agreement,' explained this same official.[294]

It has cost Cray Research a total of $158.1 million to develop the Cray-1, Cray-2, and Cray X-MP and Y-MP models; the company estimates that the C90 machine currently being developed will cost $100 million.[295] Had Japan's market been open, Cray might have afforded more R&D. As discussed, it seems reasonable to assume that the 20 Japanese machines sold to the private sector were inferior to available U.S. machines. This is also true for the 21 Japanese machines sold to the public sector through 1986. Thus, had supercomputers been selected on quality alone, the U.S. firms would have made 41 additional sales. But price is also a factor. The U.S. machines would have been much more expensive to public sector customers. Again, assuming the customers would have paid the higher prices, Cray and ETA would have sold 41 more machines. With subsequent upgrades, the total would be 56. Based on historical market share,[296] about 52 of these sales would have gone to Cray, the remainder to ETA. Cray's X-MP series available at the time was priced between $7 and $20 million, with the higher priced models selling the most. If the 56 machines cost an average of $13 million each (a conservative estimate), this would have meant $676 million in revenue for Cray. Cray invests about 15 percent of revenues in R&D each year, so this would have meant $100 million in extra R&D, which could have helped fund a whole new generation of supercomputers.[297]

OTHER FACTORS CONTRIBUTING TO JAPAN'S SUCCESS IN NURTURING A DOMESTIC SUPERCOMPUTER INDUSTRY

Industry and Corporate Structure

Japan's targeting and procurement policies helped Hitachi, Fujitsu, and NEC to build their supercomputer business, but the policies were not solely responsible for the companies' successes. In part, their success is related to the ways in which Japanese corporations are organized and run.[298] Japan also created apolitical and economic environment that fostered corporate arrangements giving Japanese companies advantages in international competition. The state's encouragement of interfirm cooperation on dimensions such as price, production, and R&D; government encouragement of the reemergence of industrial groups after World War II; and its centralized control over financial capital have led to the emergence of large, vertically integrated firms making supercomputers. All of them are miembers of Japan's large industrial groups.[299]

In targeting specific industries, the Japanese Government has usually given priority to such fins. In mainframe computers and in telecommunications, MITI and NTT have consistently favored Fujitsu, Hitachi, and NEC. "MITI promotes the larger, more stable, more promising fins, " stated Takashi Harumi, Director of International Research Exchange at MITI.[300]

Vertical integration gives Japanese firms making supercomputers several advantages. It allows them to cross-subsidize among divisions, using profits from healthy divisions to fund new areas such as supercomputers, and to keep divisions such as semiconductors alive despite their sharp boom-bust cycles. Second, it provides them with a relatively stable internal market, which affords greater ability to experiment with high speed integrated circuits that they can use in-house. Third, it provides an assured supply of components. For example, in 1988 and 1989, when semiconductor prices increased rapidly, U.S. computer and systems makers were scrambling to obtain enough memory chips that only Japanese firms produce in volume; Japanese makers were not similarly vulnerable. Finally, making production equipment in-house allows the Japanese firms to tailor-make production processes for their specific products, giving them a competitive edge.[301]

Japan's institutional environment encourages Japanese managers to view industries as belonging to an interdependent chain with valuable skill and knowledge spillovers for one another. Unlike their U.S. counterparts, Japanese companies do not necessarily stop making a product or bail out of a given industry solely because it does not provide as high a profit as investment of those same resources in another industry would. DRAMS are an example. Japanese companies regard the skills involved in producing DRAMS as important for other electronics components and systems; even if DRAMS are not in themselves highly profitable, they make a critical contribution to the bottom line in other ways that are less visible, though no less important. "The U.S. is going backwards in developing the components needed to make supercomputers. We want to make money and there is not a lot of money in those components, says Sidney Fernbach, a U.S. supercomputer expert.[302]

The view of many Japanese businesses of the interdependence of the different electronics industries is reflected in a statement by Ota Hideo of Mitsubishi: "We are not thinking of loss or profit just for computers, but for the whole company. And we use computers in all our businesses. When we cannot follow computer technology, we will be in trouble all over. ”303

There are heavy costs associated with this vertical integration and diversification; these high costs are part of the reason why several U.S. electronics firms that were vertically integrated and diversified in the 1960s and 1970s, such as Motorola, General Electric, and RCA, narrowed their focus to a few divisions and products. But Japanese firms are better able to bear these costs because of an environment that encourages long-term investment.

Japanese Industrial Enterprise Groups

Deep pockets are also the result of other institutional arrangements that help buffer Japanese firms making supercomputers from international competition and short-term market fluctuations. In particular, the fact that Fujitsu, NEC, and Hitachi are all members of or allied with *keiretsu* is an advantage. The U.S. Occupation had partially dismantled these groups, but by the late 1950s, the groups were rebuilding with government encouragement. A key motivation of both the firms and the government was that the groups would help keep out foreign products and investments at a time when Japan was under increasing pressure to liberalize its markets.

There are several advantages to membership in a *keiretsu. These* groups hold shares in other companies that are group members and agree not to sell them. This practice is known as *mutual* shareholding. In addition, large Japanese firms have *stable* shareholders, non-group firms who hold a company's stock and do not trade it. This combination of stable and mutual shareholding means that about 60 to 80 percent of member fins' stocks are never traded.[304] Thus managers do not have to worry about takeovers or short-term fluctuations in their stock prices; they have more latitude than U.S. managers to focus on long-term goals.

Second, these groups provide their members with somewhat of an assured market. This is particularly important when a fro's products are not yet competitive. As mentioned earlier, as of 1968 about half of the mainframe computers being used by firms in the industrial groups were made by their *keiretsu* computer firm.[305] Among firms with *keiretsu* ties to supercomputer makers, 56 percent of purchases (18 of 32, see table 6-11) were from the affiliate. Many argue that these groups are the most potent force protecting the Japanese market today. Their control over a significant share of Japanese business[306] raises barriers to entry-in many cases bars entry—to foreign firm in many major industries.

Third, these groups are centered around main banks, which helps group members get relatively easy access to capital; until recently, that also meant low-cost capital. Banks help out member companies during hard times.[307] The close ties between Japanese companies and their main banks are less important today, when so many Japanese companies are enjoying unprecedented success and market power, but it was very important in the 1960s and 1970s and is still important for firms involved in risky ventures such as supercomputers.

UNITED STATES POLICIES TOWARD THE SUPERCOMPUTER INDUSTRY

Consistent with their concern for the decline in U.S. competitiveness in supercomputers, most computer scientists and industry people, and many policymakers believe that the U.S. Government should support the industry more thoroughly. The U.S. Government had and still has an important role in the development and competitiveness of the supercomputer industry in America, though that role is far smaller than that of the Japanese government past and present. The primary forms of support the U.S. Government offers are procurement and the contributions of national laboratories and NASA in developing software. Procurement, in particular, is likely to diminish in value. While defense-related supercomputer purchases have been and will probably remain closed to foreign firms, other Federal procurements are open to foreign competition. As of mid-1991 Japanese supercomputer makers had not won any sales. However, as the Japanese firms catch up in performance and software, they are more likely to do SO.

The U.S. Government funnels some $500 million into advanced computing each year through the National Science Foundation (NSF), NASA, the Department of Defense, and the Department of Energy.[308] But there is growing agreement among supercomputer experts that it is not doing enough. “It could be too late unless we act and act forcefully; our infrastructure is going fast and the rest will go down with it,” argued one supercomputer analyst.[309]

One proposal for increased government support is the Federal High Performance Computing Program, presented to Congress in 1989, which called for an additional $1.917 billion in U.S. Government financing of research related to advanced computing technologies over a 5-year period.[310] The program has four parts. The first, high-performance computing systems, would provide Federal support for basic research in high-performance computer technology (including massively parallel systems) and its transfer to industry; in addition, this part of the program calls for the Department of Energy, NASA, and the Defense Advanced Research Projects Agency (DARPA), to continue to acquire the first production models of new high-performance computers. The second part, advanced software technology and algorithms, would encourage joint research (government, industry, and university) to improve the basic tools, languages, algorithms and associated theory for solving very complex, large-scale problems in science and technology, or the so-called Grand Challenges. The Office of Science and Technology Policy (OSTP) listed the following as examples of Grand Challenges:

- prediction of weather, climate, and global change;
- challenges in materials science (including semiconductor materials);
- semiconductor design;
- superconductivity;
- structural biology, including the structure and function of biologically important molecules;
- design of drugs;
- human genome mapping;
- quantum chromodynamics;
- astronomy, including manipulation of data gathered by Very Large Array or Very Long Baseline Array radiotelescopes;
- challenges in transportation, including modeling of airflows around aircraft, inside engines, and around ship hulls;
- reduction of vehicle signatures for low detection military vehicles;
- vehicle dynamics;
- nuclear fusion;
- efficiency of combustion systems;
- enhanced oil and gas recovery;
- computational ocean sciences, including development of a global ocean prediction model incorporating temperature, chemical composition, circulation and coupling to the atmosphere;
- speech as a communications interface with computers;
- machine vision; and
- undersea surveillance for anti-submarine warfare.

The third part of the High Performance Computing Program is the national research and education network, providing distributed computing that links the governmental research, industry, and higher education communities. The network, using fiber-optic trunks now being installed by communications carriers, will incorporate new switching systems and network protocols to support interactive graphics, nationwide data files, and high-definition displays. The fourth part is for basic research and human resources, supporting basic research in computer science and improved computational science education in universities.[311] For fiscal year 1991, the program received $489 million and was carried out by eight agencies,[312] with 71 percent coming from DARPA and NSF. In fiscal year 1992, the proposed budget is $638 million, with 69 percent from DARPA and NSF.[313]

Many computer scientists, industry executives, independent analysts, and policymakers argue that the U.S. Government needs to support more than this project if it is to stem the erosion of U.S. competitiveness in supercomputers and other high-technology areas, and that the focus needs to be on supporting commercial applications. Only in this way, they suggest, can supercomputer companies compete with Japanese companies and avoid dependence on Japanese suppliers in the long term. In the past several years, some U.S. high-technology companies have reported delays of supplies of either components or machinery from their Japanese sources. Complaints have become so numerous that the General Accounting Office has recently started exploring them.[314] While these U.S. companies tend to believe that delaying or withholding parts is unfair, it makes good sense for a company to supply itself and its related companies first, then its best domestic customers, and finally its overseas ones; it is neither unwise nor unfair to delay delivery of strategic components or machinery to competitors.

Because Crays are widely regarded in the United States as superior, and have a much larger library of software, there have been few procurements of

Japanese machines in the private sector; Fujitsu has sold two machines to the U.S. subsidiary of France's Schlumberger, but other than that the only procurement of a Japanese supercomputer was that of an NEC machine by the Houston Area Research Center in 1986, a center closely connected to NEC's U.S. supercomputer subsidiary, HNSX. More Japanese machines will undoubtedly sell in the private sector, for they are getting faster and already are very reliable. The financial resources of the Japanese companies leave little doubt as to their staying power in the industry; there is more doubt among U.S. supercomputer experts as to Cray's ability to stand up to this kind of competition in the long run (it should be noted that officials of Cray do not regard their company as endangered). As a result, public procurement in the United States is still an important issue.

Most experts agree that the U.S. Government's supercomputer procurement has been a key factor encouraging the growth of the supercomputer industry here, and the government remains a key customer. In the beginning, only U.S. companies made supercomputers, and developments in high-performance computing were tied to the needs of researchers in government labs. Most government purchases are still by institutions that use the machines for military purposes at least part of the time (national laboratories and NASA, for example), and it is consistent with the GATT Procurement Code for any Government to maintain an absolute preference for domestic goods in such purchases. In addition, many scientists in institutions that use the supercomputers feel that their support is necessary to keep Cray Research alive; although many would prefer that there were additional U.S. competitors, they do not want the field narrowed only to Japanese companies.

This opinion is not universally shared. Some U.S. supercomputer specialists argue that the U.S. Government should not protect U.S. supercomputer makers; rather it should protect the right of researchers to have access to the latest and most technologically sophisticated research tools.[315] 'User access to supercomputers is more important than the supercomputer industry itself; it is more important that U.S. petroleum, aerospace, and automobile firms have access to the best tools [supercomputers] than that Cray Research continues to exist.''[316] Larry Smarr, director of the National Center for Supercomputing Applications, adds that using national security considerations as a reason for barring Japanese competitors is contradictory and self-defeating. "Just count the number of Crays and IBM vector machines the Japanese manufacturers can study in Japan compared to the number of their supercomputers that we have access to in the United States. If the Japanese firms are truly our competitors, it would benefit us greatly to know everything we can about their design capabilities. The oldest rule in the book is to 'Know your enemy.' ''[317] Whether reliance solely on Japanese companies would eventually cost U.S. supercomputer users their ability to get first crack at the fastest, newest machines is a matter of disagreement among specialists.

Export control policy is another issue. Getting a license for exports of high-performance computers is often time consuming and difficult, and that can put Japanese companies at an advantage in selling in foreign markets. For small (relative to Hitachi, Fujitsu, and NEC) U.S. companies like Cray Research, streamlining the export licensing process as much as possible, consistent with national security, would be a big help. Since the first installation is particularly important in the case of selling supercomputers, speed in making changes to export control policy is also important to Cray. Third-country markets are growing fast and if U.S. makers miss out on these markets today, it could diminish their income stream far into the future.

1 This chapter is drawn extensively from two contractor reports: Marie Anchordoguy, "The Nature and Effectiveness of Japan's Postwar Industrial Policy," contractor report for the Office of Technology Assessment, February 1991; and Marie Anchordoguy, "Japanese Policies for the Supercomputer Industry," contractor report for the Office of Technology Assessment, February 1991.

2 These include hard work, good and universal education, financial policies that enabled Japanese firms to invest heavily and patiently in technology acquisition development and diffusion, and vigorous, if not free and open, competition.

3 The top merchant families were later to become the *zaibatsu*, some of which persist today in the form of *keiretsu*, or industrial groups.

4 Tessa Morris-Suzuki, *A History of Japanese Economic Thought* (London: Nissan Institute for Japanese Studies, 1989), p. 62.

5 Edward J. Lincoln, *Japan's Unequal Trade* (Washington, DC: The Brookings Institution, 1990), pp. 5-6.

6 See for example, Marie Anchordoguy, *Computers Inc: Japan's Challenge to IBM* (Cambridge, MA: Harvard University Press, 1989); and Phyllis A. Genther, "A History of Japan's Government-Business Relationship: The Passenger Car Industry," *Michigan Papers in Japanese Studies No. 20* (Ann Arbor, MI: Center for Japanese Studies, University of Michigan, 1990).

7 See, for example, Paul R. Krugman, ''Targeted Industrial Policies: Theory and Evidence,' *The New Protectionist Threat to World Welfare*, Dominick Salvatore (cd.) (New York, NY: North Holland Press, 1987), pp. 266-296.

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8 See, for example, Giovanni Dosi, Laura D'Andrea Tyson, and John Zysman, "Trade, Technologies, and Development: A Framework for Discussing Japan," *Politics and Productivity: How Japan's Development Strategy Works, Chalmers* Johnson, Laura D'Andrea Tyson, and John Zysman (eds.) (Cambridge, MA: Ballinger, 1989), pp. 3-38.

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10 See, for example, Charles Schultz, "Industrial Policy: A Dissent," *The Brookings Review,* fall 1983, and "Industrial Policy: A Solution in Search of a Problem," *California Management Review, summer 1983;* Komiya Ryutaro and Kazutomo Irie, "The U.S.-Japan Trade Problem: An Economic Analysis from a Japanese Viewpoint," *Japan' s Economic Structure: Should it Change?,* Kozo Yamamura (cd.) (Seattle, WA: Society for Japanese Studies, 1990) pp. 65-104; Gary Saxonhouse, "Why Japan is Winning," *Issues in Science and Technology,* spring 1986, pp. 72-80; and Hugh Patrick, "Japanese High Technology Industrial Policy in Comparative Context," *Japan's High Technology Industries,* Hugh Patrick (cd.) (Seattle, WA: University of Washington Press, 1986), pp. 3-33.

11 See, for example, Robert Z. Lawrence, "Imports in Japan: Closed Markets or Minds?," *Brookings Papers on Economic Activity, No. 2,1987,* pp. 5 17-548; Rudiger Dornbusch, "Give Japana Target and Say 'Import! '," *The New York Times,* Sept. 24, 1989; "Misguided Efforts Won't Open Japan's Market," *The Japan Economic Journal,* Dee. 16, 1989, p. 9; and Mordechai E. Kreinin, "How Closed is Japan's Market? Additional Evidence," *The World Economy,* vol. 11, no. 4, December 1988, pp. 529-542.

12 See Paul R. Krugman, "Introduction: New Thinking About Trade Policy," and James A. Brander, "Rationales for Strategic Trade and Industrial Policy," Paul R. Krugman (cd.), *Strategic Trade Policy and the New International Economics* (Cambridge, MA: The MIT Press, 1986), pp. 1-46.

13 Robert J. Ballon and Iwao Tomita, *The Financial Behavior of Japanese Corporations (Tokyo:* Kodansha International, 1988), p. 37.

14 Nakamura Takafusa, *The Postwar Japanese Economy, Its Development and Structure,* Jacqueline Kaminski, translator (Tokyo: Tokyo University Press, 1981), p. 44.

15 See, for example, Johnson, op. cit.; and Anchordoguy, *Computers Inc.: Japan's Challenge to IBM,* op. cit.

16 Genther, op. cit., p. 23.

17 Genther, op. cit., p. 80.

18 Genther, op. cit., pp. 81-82.

19 Merton J. Peck and Shuji Tamura, "Technology," in *Asia's New Giant,* Hugh Patrick and Henry Rosovsky (eds.) (Washington DC: The Brookings Institution 1976), p. 152.

20 Genther, op. cit., p. 47.

21 Genther, op. cit., p. 70.

22 This was done in the Extraordinary Measures Laws for the Promotion of the Machinery and Electronics Industries of 1956 and 1957 and their subsequent extensions.

23 Johnson, op. cit., p, 174.

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25 Johnson, op. cit., p. 210.

26 Johnson, op. cit., p. 211.

27 Nomura Research Institute, *NIR Review,* February 1991. The 1990 figure was a projection the 1989 figure was 32.3 trillion yen.

28 "Postal Savings Deposits Set Monthly Record," *The Japan Times,* Jan. 10,1990, p. 9; and Ministry of Finance, *The Budget in Brief, 1988,* Budget Bureau, 1989, p. 66.

29 Marcus W. Brauchli, "BanksFeudwithP ostal Service in Japan over Citicorp Proposal," *The Wall Street Journal,* Sept. 22, 1988, p. 35; and personal communication Marie Anchordoguy with local post office in Japan, January 1991.

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35 Yamawaki Hideki, "Tekko Gyo," (The Steel Industry), in *Nihon no Sangyo Seisaku,* Komiya Ryutaro, Okuno Masatatsu, and Suzumura Kotaro (eds.) (Tokyo: Tokyo University Press, 1984), pp. 258,263.

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38 Lynn, op. cit., p. 83.

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45 Walter Adams, "The Steel Industry," in *The Structure of* American Industry, Walter Adams (cd.) (New York, NY: Macmillan Publishing Company, 1977, fifth edition), p. 117; and *Tekko Jukyo no Ugoki* (Trends in the Supply of and Demand for Steel) (Tokyo: Kozai Kurabu) quarterly report, various issues.

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111 In part, that is because the R&D intensity (R&D expenditures as a percent of sales) is higher in the computer business than in any other. The Japanese companies may spend the same percentage (or even more) on R&D if only computer R&D and computer sales figures are counted.

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113 Interviews of supercomputer specialists, one who recently retired from Boeing,. Nov. 19, 1990; one who works at the U.S. Office of Naval Research, Sept. 27, 1990; one at Lawrence Livermore National Laboratory, Dec. 12, 1990; and one at a U.S. aerospace company, Dec. 12, 1990.

114 Interview of several supercomputer specialists, one formerly of Boeing, Nov. 19, 1990; one at Lawrence Livermore Lab, Dec. 12, 1990. Also James Browne, professor of computer science and physics at the University of Texas at Austin, cited in "Parallel Processing Computers Attract Crowd of Investors Despite Limited Uses," John R. Wilke, *The Wall Street Journal,* Oct. 5, 1990, pp. B1, B4.

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116 Supercomputer speeds are measured in megaflops and gigaflops, which are one million and one billion floating-point operations per second, respectively. A floating-point operation is one addition, subtraction, multiplication, or division of two numbers, where the numbers can have fractional components and can have as many digits as the computer memory accommodates. Cray's most sophisticated Y-MP machines come out on top of all Japanese supercomputers on the market (not including the one processor SX-3 of NBC, of which three have been shipped), in: 1) ONR Benchmark-LANS3D and ONR Benchmark-LANS3D-UP, Kozo Fujii and Yoshiaki Tamura, ' 'Capability of Current Supercomputers for Computational Fluid Dynamics,' Institute of Space and Astronautical Science, Kanagawa, Japan, U.S. Office of Naval Research, Bulletin no.1, Feb. 14, 1989; 2) Perfect Benchmarks done in December 1989 by the Center for Supercomputing Research and Development at the University of Illinois; 3) LINPACK Using all Fortran 100X 100 MFLOPS Benchmark, Jack J. Dongarra, "Performance of Various Computers Using Standard Linear Equations Software," Oct. 12, 1989, Computer Science Department, University of Tennessee, and Technical Memo No. 23, Argonne National Laboratory, Feb. 9, 1990. See Cray Research, Inc., "The Japanese Public Sector: Problems and Prospects for U.S. Supercomputer Vendors," May 1990, ch. 3.

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129 See discussion of the history of IBM's activities in Japan in Anchordoguy, *Computers Inc.: Japan's Challenge to IBM,* op. cit., p. 23.

130 Interview of Yoshioka Tadashi, a former MITI official involved in the promotion of the industry in the late 1950s through early 1970s and later the director of the Japan Electronics Industry Development Association (JEIDA), Nov. 27, 1987.

131 *Kompyutopia*, December 1973, p. 23.

132 Ibid., p. 24; "JECC Monogatari," segment 4, in *Kokusan Denshikeisanki Nyusu*, no. 120, Jan. 1, 1980, p. 6.

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135 Despite regulations restricting large transfers of foreign exchange, MITI allowed IBM Japan to repatriate 10 percent of sales as royalty in exchange for know-how and patents tranferred from the parent firm to the *subsidiary. Kokusan Denshikeisanki Nyusu, "JECC* Monogatari," segment 5, no. 121, Feb. 1, 1980, p. 3.

136 Uozumi Toru, *Kompyuta Senso (The* Computer War) (Tokyo: Aoya Shoten, 1979), p. 57.

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143 "Nihon IBM", in Dokusen Bunseki Kenkyukai (cd.), *Nihon no Dokusen Kigyo* (Japan's Monopolistic Enterprises) (Tokyo: Shin Nihon Shuppansha, 1971), vol. 5, p. 275.

144 **Imai Kenichi,** "Japanese Business Groups and the Structural Impediments Initiative," ***Japan's Economic Structure: Should It Change?*** **Kozo Yamamura** (cd.) (Seattle, WA: Society for Japanese Studies, 1990), p. 191. Fujitsu is the primary computer company in the **Daiichi-Kangyo** group but Hitachi has relations with this group as well as with the **Sanwa** and Fuyo groups. Data are not available on the percent of **Daiichi Kangyo** group machines that are Fujitsu or Hitachi; the only data is on the percent of both firms' machines-70 percent.

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146 Share of installed base, ***Kompyutopia,*** October 1989, p. 13. Foreign companies' market share in **terms** of sales was 25 percent as of 1988. ***Kompyutopia,*** April 1990, p. 63.

147 Interviews of **Tajiri** Yasushi, Deputy **Section Chief,** Marketing **Department,** Computer Systems, International Operations, Fujitsu Inc., Dec. 1, 1987; **Takeuchi Hiroshi,** Managing Director of the Long **Term** Credit **Bank of Japan,** Dec. 8, 1987; **Inaba Masahiro,** Assistant Manager, Business Coordination Department of the **Industrial** Bank of **Japan,** Dec. 4, 1987; and **Ishiguro** Ryuji, Director of the Japan Development Bank's Center for Research in Plant and **Equipment,** Nov. 12, 1984.

148 ***JECC IO Nenshi*** **(Ten** ***Year*** **History** of **JECC)** (Tokyo: **JECC,** 1973), pp. 50-51; ***JECC Kompyuta Noto, annual.*** For a detailed analysis of **JECC** see Chapter 3 of **Anchordoguy,** ***Computers Inc.: Japan's Challenge to IBM,*** op. cit., pp. 59-91; Anchordoguy, "Report on Japanese Policies for the SuperComputer Industry," op. cit., Appendix 1.

149 Aftera 15 month period, **the user could** return the computer at no penalty and the maker had to repurchase it from **JECC** at the remaining book **value.** This up-tint cash was thus in part returned to **JECC** when a machine was returned to the maker. This forced the firms to make better machines in order to encourage users to keep them longer and thereby increase the benefit of the up-front cash.

150 **Anchordoguy,** ***Computers, Inc.,*** op. cit., p. 61.

151 **Appendix,** total of entries in line 10 under "subsidies." The subsidy computed is the difference **between** the interest **JECC** paid on JDB loans and the interest it would have had to pay if it had borrowed money from commercial banks at prevailing interest rates. The calculation **from** 1961 to 1981 is shown **in** Anchordoguy, ***Computers Inc.: Japan's Challenge to IBM,*** op. cit., pp. *228-230* (Appendix C).

152 Interview, Dec. 1, 1987.

153 ***Denshi Kogyo Nenkan, 1970-71,*** p. **180;** ***JECC Kompyuta Noto, 1979, pp.*** 10-11.

154 ***Denshi Kogyo Nenkan, 1974,*** p. 419.

155 **Anchordoguy,** "Japanese Policies for the **Supercomputer** Industry," op. cit., Appendix 1.

156 Sales **data** are ***from JECC Kompyuta Noto, 1979,*** pp. **10-11;** ***Kompyutopia,*** January 1981, 1983, and other January issues; ***Fujitsu no Gaikyo, 1987,*** p. 18, and Ministry of **Finance** annual customs statistics for data on exports, Sales in the period from 1961-1%9 were **¥367.67 billion; ¥1,550.50** billion for 1970-1975; **¥5,441.12** billion for **1976-**1981; and **¥26.76** trillion for 1982-1989. This estimate of government aid as a percentage of sales is conservative in that sales **data** for 1982-1986 come in the form of domestic sales and exports, but export data also include exports of foreign companies, **especially** IBM Japan.

157 **Dokusen Bunseki Kenkyukai** (cd.), **"Nihon Denshin Denwa Kosha"** (NIT'), ***in Nihon no Kokigyo (Tokyo: Shin*** **Nihon Shuppansha,** 1973), pp. 134-135; also discussions with Professor **Uekusa** Masu of **Tokyo** University and Professor **Nanbu Tsuruhiko** of **Gakushuin** University.

158 Interview with **Tajiri Yasushi,** Deputy **Section** Chief of the Marketing **Department,** Computer Systems, International Operations, **Tokyo,** Dec. 1, 1987.

159 **Nihon** Denshin **Denwa Kosha** 25 **Nenshi Iinkai** (cd.), ***Nihon Denshin Denwa Kosha 25 Nenshi*** (Twenty-five year history of **NTT),** vol. 3, p. 249.

160 **¥2,980.1** billion at **¥220** to the dollar. Total government procurement (including **NTT)** of **telecom** products during this period was about $17 billion **(¥3,728.7** billion at **¥220** to the dollar). Data for 1980-1984 from ***Denshi Kogyo Nenkan*** **(Electronics** industry yearbook) (Tokyo: **Dempa Shimbun,** 1986), p. 449; data for 1985-6 ***from Fujitsu no Gaikyo*** (Fujitsu's outlook) **(Tokyo:** Fujitsu, Ltd., 1987), p. 11.

161 **Shimoda Hirotsugu,** ***IBM to no 10 Nen Senso (The*** **10-year War** with **IBM) (Kyoto: PHP Kenkyujo, 1984), p.158; interviews of Yamamoto Kinko,** Managing Director of the Japan Information Processing Development Center **(JIPDEC),** Feb. 28, 1986; and **Kuwahara Yutaka,** head of the **R&D Administration Office,** Hitachi's Central Research **Laboratory,** Dec. 9, 1987.

162 Interview **with Hitachi's** Kuwaha.raYutaka. The timing of the New Series Project was of particular importance: IBM had introduced a far more advanced series of computers, the 370 series; the United States was pressuring Japan to liberalize its computer **market;** and two sharp devaluations of the dollar were rapidly eroding the **competitive-**ness of Japanese products. **To** help the **firms** respond to IBM's new series of computers, the project gave subsidies to Fujitsu and Hitachi to develop large-scale computers, **NEC** and **Toshiba** to develop **medium-**scale machines, and Mitsubishi and Oki, small computers. No single Japanese firm had the resources to develop a **full** line to compete with IBM's, series which ranged **from small** to **large-scale** machines; the idea was that through the project the industry as a whole could respond as rapidly as possible.

163 Kenneth **Flamm,** *Targeting the Computer (Washington DC: The* **Brookings** Institution 1987), p. 134.

164 Letter in ***Fujitsu Nyusu,*** Fujitsu's internal magazine, November 1971, reprinted **in** ***Fujitsu Shashi,*** vol. 2, pp. 134-136.

165 **Raul Mendez,** "Japanese **Supercomputers," in** ***Vector Register*** **(Tokyo:** ***The*** Institute for **Supercomputing** Research), vol. 3, no. 1, October 1989, p. 4; ***Dempa Shimbun,*** July 1, 1987, p. 1, and Sept. 8, 1986, p. 4.

166 Interview ***in Bungeishunju,*** September **1982,** p. 101.

167 ***Toyokeizai,*** July 5, 1975, p. 72.

168 ***JECCKompyuta Noto, 1979, p. 232*** and 1981, **p. 283;** ***Denshi, vol. 19,*** no. 1, p. ***9,*** January 1979, and **vol.** 18, no. 5, p. 37, May 1978.

169 Interview, Dec. 9, 1987.

170 ***Denshi*** **(Electronics) (Tokyo: Nihon Denshi Kikai Kogyokai), July** 1976, pp. 9, 14.

171 Interview, Feb. 3, 1986.

172 **Shimura Yukio,** ***IC Sangyo Daisenso (The*** **IC** Industry's Big War) **(Tokyo: Daiyamondosha,** 1979), p. 3..

173 **Uozumi,** op. cit., p. 156.

174 ***The Economist,*** Apr. 5, 1980, p. 75.

175 See, **for example, Raul Mendez, "Japanese Supercomputers,"** op. cit., p. 4.

176 **Uozumi,** op. cit., pp. 128-129, 169-170; Interview of **Koezuka Masahiro,** Deputy Director of **MITI's** Electronics Policy **Division,** May 26, 1984; interview of **Yoshioka Tadashi,** former **MITI** official, Nov. 27, 1987. Oki ultimately got access to the patenta of the **VLSI** project (though not the know-how) through **NTT,** to whom it had close ties on telecommunications equipment.

177 This project was part of a series of projects done under the umbrella "Large Scale Project" of **MITI's Agency** for Industrial Science and **Technology.** The umbrella project has funded **research** on various topics including computers, pollution problems, and energy.

178 ***JECC Nyusu,*** Feb. 1, 1981, p. 1.

179 *SaisentanGijutsu noDoko* (Trends **in Leading-Edge Technologies), MITI's** Gyosei **Shiryo Chosakai,** 1983, p. 748.

180 Interviews of **Nishikawa Taizo,** Deputy Director, Industrial

Electronics Division, Machinery and Information Industries Bureau, MITI, and Furutani Takeshi, Deputy Director, Electronics Policy Division, Machinery and Information Industries Bureau, MITI, both on Sept. 25, 1990.

181 Interview of top Japanese computer scientist who is closely involved with several government-sponsored R&D projects, Sept. 25, 1990.

182 *Kagaku Gijutsuyo Kosoku Keisan Shisutemu no Kenkyu Kaihatsu ni kan suru Hyoka Hokokusho (The* Evaluation Report of the Research and Development Done in the High Speed System for Scientific and Technological Uses), MITI's Sangyo Gijutsu Shingikai; Ogata Gijutsu Kaihatsubu Hyoka Bunkakai; and the Kosoku Keisan System Hyoka Koiinkai, August 1990, p. 8. (calculated at ¥150 to the dollar).

183 *Denshi Kogyo Geppo* vol. 24, no. 9, pp. 42-47. *JECC Kompyuta Noto*, 1982, pp. 196-199.

184 Interview of Hideo Aiso, head of the project, Sept. 25, 1990.

185 NEC and Toshiba did research on gallium arsenide memory devices, Hitachi and Mitsubishi on gallium arsenide logic devices.

186 *Electronics,* Jan. 13, 1982, p. 71. Most of the research done in this project was done separately by the firms; there was no common lab except for the dataflow machine that MITI's Electrotechnical Laboratory (ETL) led. To make the parts compatible, the firms cooperated.

187 Koichiro Tamura, "General Remarks on the Achievements of the National R&D Program, High Speed Computing System for Scientific and Technological Uses," *Vector Register (Tokyo:* Institute for Supercomputing Research), vol. 3, no. 4, fall 1990, pp. 5-6; Kahaner and Kung, op. cit.

188 The processor used was the one from Fujitsu's VP-2600 machine. David Kahaner, "Japanese Government Science Structure and Computer Related Projects," a Report of the U.S. Office of Naval Research, Far East, July 30, 1990; *JECC Nyusu*, Aug. 1, 1990, p. 5, no. 247. Also in *Nikkei Sangyo Shimbun, Mar. 30, 1989,* p. 1; Interview of a U.S. scientist who works at the Office of Naval Research, Far East, Sept. 27, 1990; Interview of Nishikawa Taizo, Deputy Director, Industrial Electronics Division, Machinery and Information Industries Bureau, MITI, Sept. 25, 1990.

189 Fujitsu's M-380 mainframe and Hitachi's M-280H mainframe were used as the starting point for the development of their Fujitsu VP series of supercomputers and Hitachi S-810 supercomputers respectively; this architecture was originally developed during MITI's "New Series Project" from 1972-1976. Raul Mendez, "Japanese Supercomputers," *Vector Register, vol. 3,* no. 1, October 1989, p. 4; *Dempa Shimbun*, July 1, 1987, p. 1 and Sept. 8, 1986, p. 4.

190 *JECC Nyusu*, Aug. 1, 1990, p. 5, no. 247.

191 *JECC Nyusu*, Aug. 1, 1990, no. 247, p. 4-5. This is now being followed up with the "EM-4" project to improve the Sigma-1 machine, making it into a 1,024 processor machine. The idea is to improve upon the Sigma-1 machine by simplifying its architecture, putting several processing elements onto a single chip with a simplified network structure. [Kahaner, Report of the U.S. Office of Naval Research, Far East, July 2, 1990; *Nihon Keizai Shimbun*, July 16, 1988, p. 11.].

192 Kahaner and Kung, op. cit.

193 Olaf Lubeck, a researcher in the Computer Reserach and Applications Division of Los Alamos National Laboratory. Olaf Lubeck's notes in a report from the U.S. Office of Naval Research, Far East, Tokyo Office entitled "ETL Dataflow Project' written up by Dr. David Kahaner, July 2, 1990.

194 *JECC Nyusu*, Aug. 1, 1990, p. 5, no. 247.

195 Interview of Hideo Aiso, head of the project, Sept. 25, 1990; *JECC Nyusu*, Aug. 1, 1990, no. 247, p. 5; Koichiro Tamura, "General Remarks on the Achievements of the National R&D Program, 'High Speed Computing System for Scientific and Technological Uses,' " *Vector Register,* fall 1990, pp. 7-8.

196 Interviews of Kitagawa Noriyoshi of NEC's Second LSI Division, Feb. 3, 1986; and discussion with Hiyaguri Toshio, Director and General Manager of Fujitsu's Computer Group after he gave a talk on Fujitsu's Supercomputer efforts at the Tokyo Foreign Correspondent's Press Club, Dec. 4, 1985; Yamamoto Kinko, Managing Director of JIPDEC, Dec. 3, 1987; *Denshi Kogyo Nenkan, 1986,* p. 186.

197 Koichiro Tamura, a MITI's ETL scientist, "GeneralRemarks on the Achievements of the National R&D Program: High Speed Computing System for Scientific and Technological Uses," *Vector Register,* vol. 3, no. 4, fall 1990, p. 8.

198 Interview of Hideo Aiso, head of the project, Sept. 25, 1990; also, David Kahaner, "Japanese Government Science Structure and Computer Related Projects," Report of U.S. Office of Naval Research, Far East, July 30, 1990. According to an interview with Yoshio Shimamoto, a retired scientist at Brookhaven National Laboratory, Hitachi only did the programming language, while Fujitsu wrote the operating system.

199 *JECC Nyusu*, Aug. 1, 1990, p. 5, no. 247; Koichim Tamura, "General Remarks on the Achievements of the National R&D Program, 'High Speed Computing System for Scientific and Technological Uses,' " *Vector Register,* fall 1990, pp. 3-8.

200 *Nihon Keizai Shimbun*, Feb. 3, 1991, evening edition, p. 1.

201 *Kagaku Gijutsuyo Kosoku Keisan Shisutemu no Kenkyu Kaihatsu ni kan suru Hyoka Hokokusho (The* Evaluation Report of the Research and Development done in the High Speed System for Scientific and Technological Uses), MITT's Sangyo Gijutsu Shingikai; Ogata Gijutsu Kaihatsubu Hyoka Bunkakai; and the Kosoku Keisan System Hyoka Koiinkai, August 1990, op. cit., p. 15.

202 Interview of Fuchi Kazuhiro, project director of the 5th generation project, who is also familiar with the supercomputer project, Aug. 2, 1985, and Yamamoto Kinko, Managing Director of JIPDEC, Dec. 3, 1987.

203 Interiew of Oketani Kisaburo of Fujitsu, Dec. 1, 1987.

204 Interview of Oketani Kisaburo of Fujitsu, Dec. 1, 1987.

205 *The Oriental Economist,* January 1980, p. 29.

206 Interview, Sept. 25, 1990.

207 *The Japanese Public Sector: Problems and Prospects for U.S. Supercomputer Vendors,* Cray Research, Inc., May 1990, pp. 2-3.

208 Interview with Yamamoto Kinko, Managing Director of JIPDEC, Feb. 28, 1986; *Electronics,* Feb. 25, 1985, p. 31.

209 *Electronics,* Sept. 2, 1985, p. 11 and Feb. 25, 1985, p. 31.

210 Kurita Shohei, *90 Nendai no Kompyuta Uoozu* (Computer Wars of the 1990s) (Tokyo: Nikkan Kogyo Shimbunsha, 1988), p. 221.

211 Interview of Yamamoto Kinko, Managing Director of JIPDEC, Feb. 28, 1986. Unfortunately, it is impossible to get additional information about this project.

212 Interview of Fuchi Kazuhiro, director of the fifth generation computer project, Aug. 2, 1985, and Yamamoto Kinko, Managing Director of JIPDEC, Dec. 3, 1987.

213 *JTECH Report on Advanced Computing in Japan,* Japan Technology Evaluation Center (McLean, VA: Science Applications International Corp., December 1987).

214 Interview, Dec. 5, 1990.

215 Interview of Shimizu Sakae, Toshiba Senior Managing Director, Feb. 3, 1986.

216 Shimoda Hirotsugu, *IBM to no 10 Nen Sense,* pp. 60-61.

217 Interview, Feb. 28, 1986.

218 *Electronics Week,* June 10, 1985, p. 30.

219 Interview of Hideo Aiso, head of the project, Sept. 25, 1990.

220 Kahaner and Kung, op. cit.

221 Kahaner and Kung, op. cit.; and *Report of the Research*

Committee on the New Information Processing Technology, Abstract, April 1990, MITI's Machinery and Information Industries Bureau, Industrial Electronics Division.

222 Kahaner and Kung, op. cit.

223 Kahaner and Kung, op. cit.

224 *Dempa Shimbun,* Apr. 22, 1989, p. 5; *JECC Nyusu,* July 1, 1989, p. 7, no. 234.

225 *JECC Nyusu,* July 1, 1989, p. 7, no. 234.

226 Kahaner, op. cit.

227 Interview, Dec. 9, 1987.

228 *Business Tokyo, May 1990,* p. 8.

229 Kawabata Naohisa, *Kompyuta Gyokai gaAbunai,* p. 120.

230 "Supercomputer Bout," *Business Tokyo,* April 1990, p. 33.

231 Kawabata, op. cit., p. 121.

232 Kawabata, op. cit., pp. 120-121.

233 Interviews of former Cray employees involve& U.S. Embassy officials, and former USTR officials, September and October 1990. U.S. government and Cray employees also confirmed that there have been other cases in which university professors, especially those that have used Cray machines while working in the United States, have called Cray Research or the Embassy or both, with the idea of getting the United States to put pressure on Japan to give them a large enough budget for a Cray.

234 Kawabata, op. cit., p. 121; *Nikkei Sangyo Shimbun, Dec. 21, 1988,* p. 8 and May 1, 1989, p. 12.

235 Cited in "Supercomputer Bout," *Business Tokyo,* April 1990, p. 33.

236 *Nikkei Sangyo Shimbun,* Dec. 21, 1988, p. 8.; *Nihon Keizai Shimbun,* Apr. 21, 1988.

237 *Dempa Shimbun,* Sept. 26, 1989.

238 These include *keiretsu*-related purchases, auto firms' purchases of domestic machines despite Cray's clear superiority in this area, and all purchases of domestic machines by private institutiona up through 1986. (Eight are automobile companies: Nissan Diesel, 1987, Suzuki, 1986, 1989, 1989; Mazda, 1987 and 1989; Toyota, 1985 and 1988. The reruining 12 of the 20 initial purchases are by Tokai University, 1986 and 1989; Matsushita, 1985 and 1987; Fuji Electric, 1985; Sony, 1985 and 1988; Ishikawajima, Kawasaki Steel, Sharp, Shimizu, Mitsubishi, Olympus, Recruit, and Chiyoda Manufacturing, all 1986. The three upgrades are those of Tokai University, Matsushita, and Sony.)

239 This excludes the two purchases of Cray machines by NTT that were immediately sold to Recruit Co.

240 *Nihon Keizai Shimbun,* Dec. *4,1989,* p. 5.

241 Kawabata, op. cit., p. 115.

242 *Nikkei Sangyo Shimbun,* Aug. 24, 1988, p. 1.

243 *Nikkei Sangyo Shimbun, May 16, 1989,* p. 1.

244 *Asahi Shimbun,* Apr. 29, 1987.

245 Utsumi Ichiro, *San Nen go no Kompyuta Gyokai, Gekihen no Seiryoku Chizu (The* Computer Industry in Three Years, A Map of the Rapidly Changing [Corporate] Strength) (Tokyo: Besto Bukku, 1989), p. 24.

246 *Nihon Keizai Shimbun, Mar.* 11, 1989, p. 31.

247 *Kompyutopia,* January 1989, pp .12-19. Thia Cray was transferred to Recruit in December, 1986. *Nihon Keizai Shimbun, Mar. 6, 1989, p.* 1.

248 "Supercomputer Bout," *Business Tokyo,* April 1990, p. 34. Interview of a former USTR official, Sept. 18, 1990.

249 *Nihon Keizai Shimbun, Mar. 27, 1987,* p. *3.*

250 For example, it is discussed in: Kawabata Naohisa, *Kompyuta Gyokai ga Abunai,* pp. 123-128; *Asahi Shimbun,* Apr. 29, 1987; *Nikkei Sangyo Shimbun,* Sept. 8, 1989, p. 8; interview of a General Manager of Fujitsu's Marketing Department, Jan. 11, 1991.

251 *Nihon Keizai Shimbun, Mar. 27, 1987,* p. 3.

252 *Nihon Keizai Shimbun, Mar. 2, 1989,* p. 31. It was sold to Recruit in December, 1987. Recruit paid a 5 percent premium on both of these machines over what NTT had paid Cray, according to *Nihon Keizai Shimbun, Nov. 2, 1988,* p. 19.

253 *Nihon Keizai Shimbun, Nov. 2, 1988,* p. 19.

254 Ibid.

255 An emergency budget was necessary because the fiscal 1987 budget had already been set. *Nihon Keizai Shimbun, Mar. 29, 1987,* p. 1.

256 Ibid.

257 Interview, Sept. 18, 1990.

258 Utsumi Ichiro, *San Nen go no Kompyuta Gyokai, Gekihen no Seiryoku Chizu,* pp. 20-21.

259 *Nikkei Computer, Mar. 26,1990,* p. *98; NihonKeizai Shimbun, Mar. 8, 1988, p. 13.*

260 Nikkei Sangyo Shimbun, Oct. 20, 1987, p. 3.

261 Utsumi, op. cit., p. 21.

262 *NikkeiSangyoShimbun, Apr.27,* 1988, p. 7 and Dec. 21, 1988, p. 8; *Nikkei Computer, Mar. 26,* 1990, pp. 98-99.

263 Citedin "Supercomputer Bout," *Business Tokyo,* April 1990, p. 30.

264 *Nikkei Sangyo Shimbun,* Apr. 15, 1987, p. 24. For example, complaints were made that while a domestic system could be gotten for about ¥3 billion a U.S. system, including peripherals, etc., would cost some ¥5-6 billion.

265 *Nikkei Sangyo Shimbun,* Apr. 15, 1987, p. 24.

266 *Nikkei Sangyo Shimbun,* Apr. 27, 1988, p. 7. Interview of a U.S. Department of Commerce official, Oct. 22, 1990.

267 Utsumi, op. cit., pp. 26-27.

268 *Nikkei Computer, Mar. 26,* 1990, p. 96.

269 Interview, Oct. 22, 1990.

270 Cited in "Supercomputer Bout," *Business Tokyo,* April 1990, p. 34.

271 *Nikkei Computer, Mar. 26,* 1990, p. 96.

272 *Business Tokyo,* "Supereomputer Bcut," April 1990, p. 30.

273 This announcement was quite premature. NEC still baa not shipped any 4 processor SX-3 machines.

274 *Nihon Keizai Shimbun,* Apr. 23, 1989, p. 4. Also in *Nikkei Sangyo Shimbun,* Apr. 19, 1989, p. 3.

275 *Nihon Keizai Shimbun,* Apr. 28, 1989, p. 11.

276 *Asahi Shimbun,* June 2, 1989 and July 9, 1989; *Nikkei Computer, Mar. 26,* 1990, p. 98.

277 *Asahi Shimbun,* June 2, *1989. Nikkei Computer, Mar. 26,1990,* p. 98.

278 *Nihon Keizai Shimbun,* Dec. 14, 1989, p. 1.

279 *Nihon Keizai Shimbun,* Oct. 21, 1989, p. 8.

280 *Nikkei Uotcha, IBM-Ban,* Oct. 2, 1989, p. 3.

281 *Dempa Shimbun,* Dec. 6, 1989, p. 2.

282 *Nikkei Uotcha, IBM-Ban,* Feb. 5, 1990, p. 4.

283 *Asahi Shimbun,* Dec. 5, 1989, p. 1.

284 *Nihon Keizai Shimbun,* Feb. 3, 1990, p. 1, and July 24, 1990, p. 11.

285 Interview of Ministry of Foreign Affairs official, Sept. 18, 1990.

286 Interview of Ministry of Foreign Affairs official, Sept. 18, 1990. This same sentiment was strongly expressed in an article on supercomputers and the agreement in one of Japan's major computer industry magazines, *Nikkei Computer, Mar. 26,* 1990, p. 97.

287 Utsumi, op. cit., p. 37.

288 Citedin "Supercomputer Bout," *Business Tokyo* April 1990, p. 32.

289 In an article Fujitsu Chairman Yamamoto Takuma wrote for *Nikkei Computer,* Jan. 1, 1990, p. 103.

290 Utsumi, op. cit., p. 39.

291 Interview, Oct. 22, 1990.

292 *Nikkei Computer, Mar. 26,* p. 99. The six labs are: the Tohoku, Nagoya, and Kyushu University Large Scale Computer Labs; the Osaka University Laser Fusion Research Lab, the Fusion Science Lab, and the Meteorological Research Institute.

293 Interview, Sept. 18, 1990.

294 Interview, Sept. 18, 1990.

295 *TheJapanese Public Sector: Problems and Prospects for* U.S. *Supercomputer Vendors,* Cray Research, Inc., May 1990, pp. 2-3.

2% This estimate does not include all supercomputer purchases in Japan, but all those that were made while the performance of Cray machines was unquestionably superior. The private sector companies include keiretsu-related purchases, auto firms' purchases of domestic machines despite Cray's clear superiority in this area, and all purchases of domestic machines by private institutions up through 1986. (Nissan Diesel, 1987, Suzuki, 1986, 1989, 1989; Mazda, 1987 and 1989; Tokai University, 1986; Matsushita, 1985; Toyota, 1985 and 1988; Fuji Electric, 1985; Sony, 1985; Ishikawajima; Kawasaki Steel, Sharp, Shimizu, Mitsubishi Olympus, all 1986; Recruit, 1986, Chiyoda Manufacturing, 1986.)

The government procurements are the 21 domestic machines procured up through 1986, after which the Japanese makers started to come out with better, though still not technologically competitive, machines.

297 In current dollars, the estimate would be even higher.

298 For more detail on some of these issues, especially Japan's way of financing long-term investments and links between firms and industries, see *Making Things Better, Competing in Manufacturing,* Office of Technology Assessment, Congress of the United States (Washington, DC: U.S. Government Printing Office, 1990.)

299 The most comprehensive and insightful work on the institutions of Japanese capitalism is Johnson's *MITI and The Japanese Miracle,* op. cit. The information in this section draws in part on Anchordoguy, "A Challenge to Free Trade? Japanese Industrial Targeting in the Computer and Semiconductor Industries," *Japan's Economic Structure: Should it Change?,* Kozo Yamamura (cd.) (Seattle, WA: Society for Japanese Studies, 1990), pp. 301-332.

300 Interview, Apr. 7, 1989.

301 The importance of industry and corporate structure is discussed in Charles Ferguson, "Sources and Implications of Strategic Decline: The Case of JapaneseAmericanC ompetition in Microelectronics," working paper, MIT, June 30, 1987. Also see David J. Teece, "Capturing Value from Technological Innovation: Integration, Strategic Partnering, and Licensing Decisions," in Bruce R. Guile and Harvey Brooks (eds.) *Technology and Global Industry: Companies and Nations in the World Economy,* National Academy of Engineering Series on Technology and Social Priorities (Washington DC: National Academy Press, 1987), pp. 65-95.

302 Interview, Nov. 30, 1990.

303 *Electronics, Mar. 27, 1980,* p. 122.

304 Michael Gerlach, "Keiretsu Organization in the Japanese Economy: Analysis and Trade Implications," in *Politics and Productivity,* Johnson, et al. (eds.), op. cit., p. 158.

305 "Nihon IBM" (Japan IBM), Dokusen Bunseki Kenkyukai (ed.) *Nihon no Dokusen Kigyo* (Tokyo: Shin Nihon Shuppansha, 1971), vol. 5, p. 275.

306 As of 1984, Japan's six major industrial groups earned some 18 percent of the total net profits of all Japanese business, had nearly 17 percent of total sales, held over 14 percent of paid-up capital, and employed almost 5 percent of Japan's labor force. [Ulrike Wassmann and Kozo Yamamura, "Do Japanese Firms Behave Differently? The Effects of Keiretsu in the United States," in Kozo Yamamura (cd.) *Japanese Investment in the United States: Should We Be Concerned?* (Seattle, WA: Society for Japanese Studies, 1989), pp. 121-122.] These six groups are the blue chips of Japanese industry today. Though the 182 companies that make up the core of the 6 groups account for only about 10 percent of the companies on the Tokyo Stock Exchange, more than half of Japan's largest 100 companies are group members and virtually all Japan's top city banks, trust banks, insurance companies, and electronics conglomerates including all the supercomputer makers, are group members.

307 Gerlach, "Keiretsu Organization in the Japanese Economy: Analysis and Trade Implications," *in Politics and Productivity,* Johnson et al. (eds.), op. cit., pp. 141-174. It should be noted that this help during hard times is frequently unpleasant; banks often send bank officers to troubled companies, replacing company managers.

308 *A Research and Development Strategy for High Performance Computing,* Executive Office of the President, Office of Science and Technology policy, Nov. *20, 1987, p. 26.*

DARPA backing in several projects helped Intel recently come out with a custom-designed supercomputer-the Delta System-which is based on an array of 528 Intel i860 microprocessors. A consortium of 14 U.S. research institutions, led by the California Institute of Technology, recently announced a planned purchase of a Delta System. Intel has announced that the machine would have peak performance of 32 gigaflops, but this has not yet been tested. [John Markoff, "Consortium to Buy Intel Computer," *The New York Times,* November 13, 1990, p.C1.] For an overview of U.S. policies towards supercomputers see *Supercomputers: Government Plans and Policies, Background Paper, Office* of Technology Assessment, U.S. Congress, March 1986.

309 Interview, Oct. 22, 1990.

310 *The Federal High Performance Computing Program,* Executive Office of the President, Office of Science and Technology Policy, Sept. 8, 1989, p. 46. Sidney Fernbach, "A U.S. High-Performance computing Program," *The International Journal of Supercomputer Applications, vol. 4,* no. 1, spring 1990, p. 3.

311 This description of the High Performance Computing Program is taken from Executive Office of the President, Office of Science and Technology Policy, *The Federal High Performance Computing Program,* op. cit., passim.

312 DARPA, the National Science Foundation Department of Energy, NASA, the Department of Health and Human Services (National Library of Medicine), EPA, NIST, and the National Oceanic and Atmospheric Administration.

313 Office of Management and Budget, *Budget of the United States Government, Fiscal Year 1992* (Washington, *DC:* U.S. GPO, 1991), Part Two, pp. 48-49.

314 *Electronic Engineering Times,* Jan. 21, 1991, p. 2.

315 Ruder Finn, "The Influence of U.S. Prestige on Japanese Supercomputer Makers," *Perspective,* Japan Desk, vol. 1, no. 3, August 1989, p. 2.

316 Interview of a supercomputer specialist at the San Diego Supercomputer Center, Nov. 30, 1990.

317 Finn, op. cit., pp. 2-3.

Appendix 6-A—Government Financial Assistance to the Computer Industry and Its Size Relative o Private Sector n es men 1961-89
(billions of yen, millions of dollars)[a]

	1961-69 $1=360 Yen		1970-75 $1=330 Yen		1976-81 $1=200 Yen		1982-89 $1=160 Yen	
	Yen	Dollars	Yen	Dollars	Yen	Dollars	Yen	Dollars
I. Subsidies								
1. 1966 Project	6.37	17.70	5.63	17.06	—	—	—	—
2. DIPS—1 Project	5.00	41.67	15.00	45.45	—	—	—	—
3. DIPS—11 Project	—	—	5.00	15.15	—	—	—	—
4. Pattern Information Processing Recognition Project	—	—	8.45	25.61	13.47	67.35	—	—
5. New Series Project (includes subsidies for peripheral equipment and LSIs)	—	—	58.90	178.48	11.4	57 oo	—	—
6. Government money given to set up the I.P.A.	—	—	1.05	3.18	—	—	—	—
7. Annual subsidy to the I.P.A. (for software development consignment)	—	—	4. 8	12.67	14.17	70.85	16.39	102.44
8. Subsidies for R&D on important technologies (formerly called "Mining" subsidies [computer-related])	1.23	3.42	3.12	9.45	0.83	4.15	—	—
9. NTT's VLSI Project	—	—	6.67	20.21	13.34	66.70	—	—
10. Interest savings because of JDB low-interest loans to JECC	2.03	5.64	11.30	34.24	25.97	129.85	46.67	291.69
11. Development of a medical information system	—	—	0.92	2.79	2.85	14.25		
12. Development of a video information system	—	—	3.86	11.70	3.02	15.10	—	—
13. Software Module Project	—	—	3.00	9.09	—	—	—	—
14. Development of automobile traffic control system	—	—	3.05	9.24	4.35	21.75	—	—
15. Subsidies for putting trade-in computers into Chamber of Commerce offices	—	—	1.60	4.8	1.11	5.55	1.22	7.63
16. Development of trade information system	—	—	0.06	0.1	0.23	1.15	—	—
17. Special research on technology related to information processing (ETL Lab in AIST)	—	—	*.22	12.79	3.37	16.85		
18. Development of resource recovery system	—	—	4.30	3.94	6.55	32.75	0.06	0.38
19. Information processing technicians test	—	—	o.22	0.67	3.70	18.50	0.22	0.14
20. Software program survey register	—	—	o.02	0.06	0.01	0.05		
21. Surveys on the current and future direction of information processing	—	—	0 o5	0.15	0 0	o.5o	—	—
22. Survey on "systemization"	—	—	0 o3	0.09	—	—	—	—
23. Survey on computer purchases and trade-ins	—	—	0 o1	0.03	0 0	0.15	—	—
24. Survey on legal protection of software	—	—	0 o1	0.03	0 0	0.15	—	—
25. Survey on the formation of information networks	—	—	0 o1	0.03	0 0	0.05	—	—
26. Register on information-processing service firms	—	—	0 o1	0.03	0 0	0.05	—	—
27. Promotion of standardization	—	—	0 o4	0.12	—	—	—	—
28. Annual week for promoting informationalization	—	—	0 o1	0.o3	—	—	—	—
29. Promotion of information processing in the government	—	—	7 o4	21.33	—	—	—	—
30. Survey of the trends in technology development in the electronics industry	—	—	0.04	o.12	—	—	—	—
31. Subsidies for Japan patent information center	—	—	0.17	o.52	—	—	—	—
32. MITI's VLSI Project	—	—	—	—	29.14	145.70	—	—
33. MITI's optoelectronics project	—	—	—	—	3.40	17.00	12.39	77.44
34. MITI's supercomputer project	—	—	—	—	0.03	0.15	18.19	113.69
35. Basic technologies for next generation industries (new functional devices only)	—	—	—	—	1.8o	9.oo	11.12	69.50

[a]Some discrepancies may occur due to rounding.

Continued on next page

Appendix 6-A—Government Financial Assistance to the Computer Industry and Its Size Relative o Private Sec o Investment, 1961-89 (billions of yen, millions of dollars)[a]—Continued

	1961-69 $1=360 Yen		1970-75 $1=330 Yen		1976-81 $1=200 Yen		1982-89 $1=160 Yen	
	Yen	Dollars	Yen	Dollars	Yen	Dollars	Yen	Dollars
36. Basic technologies for next generation computers	—	—	—	—	3.69	68.45	8.48	53.00
37. Promotion of information processing in the government	—	—	—	—	6.26	31.30	—	—
38. Fifth generation computer project	—	—	—	—	0.02	0.10	36.41	227.56
39. Interoperable database systems project	—	—	—	—	—	—	4.46	27.88
40. Software industrialized generator and aids (Sigma) project	—	—	—	—	—	—	12.50	78.13
41. Superconductivity devices and materials development	—	—	—	—	—	—	2.93	18.31
42. Neurocomputer project	—	—	—	—	—	—	0.02	0.13
43. FRIEND 21 MITI project on distributive information processing	—	—	—	—	—	—	1. 00	7.38
44. Development of a sytem to aid in medical examinations (MITI Project)	—						1.45	9.06
Total subsidies	**24.63**	**68.43**	**144.97**	**439.29**	**158.89**	**794.45**	**73.94**	**1,084.36**
II. Tax Benefits								
1. Computer buyback reserve	3.70	10.28	37.80	14.55	8.20	91.00	160.00[b]	[illegible]
2. Special depreciation for equipment used in experimental R&D	51.50	143.06	99.40	301.21	118.00	590.00	588.00	3,675.00
() assuming 10% for computers	(5.15)	(14.30)	(9.94)	(30.12)	(11.80)	(59.00)	(58.80)	(367.50)
3. Special depreciation for equipment important o rationalization	58.30	162.00	97.80	296.36	88.60	443.00	231.00	1,443.75
() assuming 10% for computers	(5.83)	(16.20)	(9.78)	(29.63)	(8.86)	(44.30)	(23.10)	(144.38)
Total tax benefits:	**14.68**	**40.78**	**57.72**	**174.30**	**38.86**	**194.30**	**241.90**	**1,511.88**
Total subsidies and tax benefits:	**39.31**	**109.21**	**202.49**	**613.59**	**197.75**	**988.75**	**415.84**	**2,596.24**
III. Loans								
1. To JECC from JDB	50.70	140.83	74.00	527.27	267.00[c]	1,335.00	648.00[c]	4,050.00
2. JDB loans based on 1971 and 1978 laws (for computers)	—	—	6.86	20.79	15.72[d]	78.60	38.00[d]	237.50
3. Loans from IBJ, LTCB, JREB, for promotion of information processing	—	—	62.30	188.79	49.00	245.00	15.50	96.88
4. JDB loans for software development	—	—	14.50	43.94	—	—	—	—
5. JDB loans for promotion of domestic technology	—	—	122.90	372.42	240.30	1,201.50	513.90	3,211.88
() computers; assuming 50%			(61.45)	(186.21)	(120.15)	(600.75)	(51.39)	(321.19)
6. JDB loans for consolidation of the industry	—	—	4.65	14.09	—	—	—	—
7. JDB loans for structural improvement of the industry	—	—	5.97	18.09	32.00[e]	160.00	—	—
8. JDB loans for equipment for software development	—	—	6.54	19.82	—	—	—	—
9. JDB loans for the promotion of on-line information processing systems	—	—	5.01	15.18	—	—	—	—
Total loans	**50.70**	**140.83**	**341.28**	**1,034.18**	**483.87**	**2,419.35**	**753.22**	**4,705.57**
Total subsidies, tax benefits and loans:	**90.01**	**250.04**	**543.77**	**1.647.77**	**681.62**	**3.408.10**	**.168.73**	**7.298.81**

[a]Data for 1989 are not yet available; conservatively estimated at 20 billion yen, down slightly from 1988's 22 billion yen.
[c]These loans from JDB to JECC were primarily to facilitate computer rentals. From the late 1970s, small amounts of money were for other purposes, such as consolidation of the industry.
[d]Assuming 40% went to the computer industry.
[e]These data included JDB loans for software development.

Appendix 6-A--Government Financial Assistance to the Computer Industry and Its Size Relative to Private Sector Investment, 1961-89 (billions of yen, millions of dollars)-Continued

	1961-69 $1=360 Yen		1970-75 $1=330 Yen		1976-81 $1=200 Yen		1982-89 $1=160 Yen	
	Yen	Dollars	Yen	Dollars	Yen	Dollars	Yen	Dollars
IV. Private sector investment in computer-related R&D and plant and equipment								
1. Computer industry investment in plant and equipment (private sector)	41.78	116.06	129.40	392.12	153.60	768.00	1,338.80	8,340.00
2. Computer industry investment in R&D (private sector)	62.10	172.50	238.50	722.73	663.10	3,315.50	3,756.15'	23,480.00
Total private sector investment:	103.90	288.60	367.90	1,114.85	816.70	4,083.50	5,089.95	31,820.00
V. Subsidies and tax benefits as percent of investment (in percent)	37.8%		55.0%		24.2?!		8.2%	
V1. Subsidies, tax benefits, and loans as percent of investment (in percent)	86.6%		147.8%		83.5%		23.0%	

'Data for 1989 not yet available. Estimated at 25% growth based on previous years' growth rates.

SOURCE: *JECC Kompyuta Noto, Denshi Kogyo Nenkan; Kompyuta Hakusho*; various issues of the monthly magazine *Kompyutopia:Zeisei Chosa Kai, Zen Shiryo Shu, and Zeisei Chosa Kai Kankei Shiryo Shu*; Internal JDB and MITI documents without titles; *Nihon Kaihatsu Ginko no Genkyo; JECC 10 Nenshi*; JECC annual financial reports; *Shuyo Sangyo no Setsubi Toshi Keikaku*; Sorifu Tokeikyoku, *Kagaku Gijutsu Kenkyu Chosa Hokoku; Denshi Kogyo 30 Nenshi*, p. *82; Waga Kuni Denshikeisanki Sangyo no Mondai Ten to Sono Taisaku, 1970*, p. *72.*

This table is taken from Appendix 1 of the contractor document prepared by Marie Anchordoguy, "Japanese Policies for the Supercomputer Industry," February 1991, pp. 117-122 (Appendix 1) (OTA Contract No. N3-4955), modified as described below.

Subsidy No. 10 and loan No. 1 in the table give the subsidy value and loan value, respectively, of low-interest loans given by the Japan Development Bank (JDB), an agency of the Japanese Government, to the Japan Electronic Computer Co. (JECC). JECC is a nonprofit joint venture of six (originally seven) Japanese computer firms; the Japanese Government has no equity in JECC. See Marie Anchordoguy, Cornputers *Inc.:Japan's Challenge to* I/BM(Cambridge MA: Harvard University Press, 1989), p. 61.

Professor Anchordoguy's original calculations also included subsidy and loan values based on up-front payments by JECC to computer firms for machines that JECC rented out to users. Anchordoguy calculated that this program constituted a subsidy in the following amounts: 1961-1969, 8.10 billion yen, 22.50 million dollars; 1970-1975,6.22 billion yen, 18.85 million dollars; 1976-1981, 6,51 billion yen, 32.55 million dollars; 1982-1989, 8.6 billion yen, 53.75 million dollars. Anchordoguy also calculated that this program constituted a loan in the following amounts: 1961-1969, 97.01 billion yen, 269.47 million dollars; 1970-1975, 69.30 billion yen, 210.00 million dollars; 1976-1981, 72.60 billion yen, 363.00 million dollars; 1982-1989, 122.13 billion yen, 763.31 million dollars. For these calculations, she noted that "JECC data on computer trade-ins is not available from 1984-1989; it was estimated at 42 percent of annual JECC purchases as the average in the seventies and early eighties was 42 percent. This trade-in data is used to calculate benefits from the JECC system." The logic behind the calculations is explained in more detail in chapter 3 of her book (cited above).

OTA does not believe that these up-front payments represent a loan and subsidy beyond the loan and subsidy already conferred by the JDB loan to JECC, and eliminated these values from the table. The only way money flowed into or out of the Japanese treasury was through loans from JDB (the governnmnt) to JECC (the pr!vate sector).

The elimination of JECC up-front payments to firms makes a difference in the total loan, tax benefit, and subsidy values, especially in the late 1960s, but the conclusion is still the same. The value of government assistance to computer firms was and is substantial.