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Semiconductors and SEMATECH: Rebirth of a Strategic Industry?

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ABSTRACT

Semiconductors and SEMATECH: Rebirth of a Strategic Industry?

by

LTC JACK DEMPSEY

In 1980, the U.S. semiconductor industry represented the pinnacle of technology, easily leading the world in the production of semiconductor computer chips. By the end of the decade, U.S. semiconductor manufacturers had suffered through a precipitous decline in the percentage of chips produced for the world semiconductor market. In ten short years, the capabilities of American firms compared with those of the Japanese had declined to the point were the positions of the two nations were reversed. In 1989 Japan was the irrefutable world class leader.

This paper examines the vital importance of the semiconductor industry to our national and economic security. It explores the Japanese business environment and philosophy plus their success in capturing the lead in semiconductor manufacturing and production.

The creation of SEMATECH, a consortium formed between the federal government and industry, provides a mechanism for the U.S. to regain the lead in semiconductor technology and production. Operations within SEMATECH draw upon the best characteristics of Japanese and American industry and produce dramatic improvements within the U.S. semiconductor industry. The SEMATECH success story offers a model for creation of other pre-competitive consortiums in order to regain a technology lead over our competitors.

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INTRODUCTION

So you think American technology was responsible for the rapid and successful conclusion of the Persian Gulf War. Not according to Shintaro Ishihara, a vocal member of the Japanese Parliament, who said:

> What made (the Americans') pinpoint bombing so effective was PTV, a high quality semiconductor used in the brain part of the computers that control most modern weapons. There were 93 foreign made semiconductors in the weapons used by the United States. Among them, 92 were made in Japan.[1]

This paper explores the remarkable growth of the Japanese semiconductor industry and its impact on American computer chip manufacturers. It will explain:

- The importance of semiconductors and why they are critical to our security;
- Japanese manufacturing strategy and its effects on the American semiconductor industry; and
- The United States' efforts to regain its manufacturing competitiveness.

Finally, it will reach conclusions and recommendations concerning the desirability of federal support for the United States semiconductor industry.

WHAT'S SO IMPORTANT ABOUT SEMICONDUCTORS?

The electronics industry is America's largest manufacturing sector with the production of semiconductors as its core. It employs over 2.5 million people, more than the automotive, aerospace, and steel industries combined.[2] The prospect of continually falling behind the Japanese in an industry that provides over 4 percent of our country's gross national product is extremely unsettling. Semiconductors, a key element in the electronics industry, are crucial to the security and economic health of this nation. They represent the critical components in both military and civilian applications ranging from weapon systems to information systems, aviation, and medicine. Semiconductors are used literally in every sector of modern society.

Military Security

The United States relies upon technical weapon superiority for defeating an enemy while absorbing minimal casualties upon its own forces. This superiority has been the result of an ever increasing reliance upon computer systems composed of semiconductor computer chips. The M-1 tank, with 1500 integrated circuits, is an example of today's modern technology. Its computer-controlled firing system enables the tank commander to achieve an amazing 60 percent first round kill probability. Computer chips were also the key ingredient behind the remarkable success of the Tomahawk and PATRIOT missile systems. Prolific use of semiconductors will continue. Estimated electronics' costs for the next generation of fighter aircraft will reach 40 percent of the aircraft's total cost. Unfortunately, our military technical edge could be lost through a lack of competitiveness within the semiconductor industry. Far more ominous would be the situation where a foreign source could deny shipping critical components to the United States due to a disagreement over policy matters. Mr. Ishihara raised this potential situation in his book, The Japan that Can Say No. He said "the global military balance could be completely upset if Japan decided to sell its computer chips to the Soviet Union instead of the United States."[3] The current political situation between the super powers has been defused but the potential for technology transfer to developing nations remains, possibly offsetting some of our technical advantage.

Economic Security

Japan realized the economic importance associated with the manufacture of semiconductors. The Ministry of International Trade and Industry (MITI) orchestrated the effort to achieve world dominance in the production of Dynamic Random Access Memory (DRAM) devices. DRAMs are technology drivers! They are used in extremely large quantities and can be easily mass manufactured compared to the more complicated logic semiconductor chips.

They are created using a circuit layout that's replicated millions of times on the same micro chip. Uniformity of design lends itself extremely well to the strengths of Japanese production engineers who strive for product perfection. Their effort in reducing the chip's conductor size (electrical connections) has resulted in a quadrupling of memory capacity every 18-24 months. Today, the Japanese are manufacturing 64 megabit memory devices with conductors measuring 0.5 microns in diameter. This is the equivalent of 1/100th the size of a human hair. Each half-size reduction in conductor dimension yields a four-fold increase in chip storage capacity. Today the race is on to develop 256 megabit and one gigabit memory devices, achievable solely through a reduction in conductor size. A DRAM functions as a technology driver since once a company learns how to reduce conductor size in less complicated memory chips, it can employ the same technique in making more advanced microprocessor chips. The enormous demand for memory chips provides manufactures an opportunity to recover their costs through volume sales.

To realize the true impact of semiconductors, you must understand that demand appears to rise at an exponential rate. This is a result of American industries attempting to remain competitive through increased productivity from automation and creation of new products. Failure to regain a technological edge could cascade into decreased productivity in many industries and a decline in our standard of living. Furthermore, as Shintaro Ishihara threatens, it potentially holds U.S. industry hostage to a foreign source for fundamental components.

Fall of a Strategic Industry

Semiconductors were invented at Bell Telephone Laboratories in the United States in 1947 and first used commercially in 1951. Until the mid 1970s, we dominated the world semiconductor market. Since then, we've fallen to second place behind the Japanese, achieving less than 38 percent of world market share in 1989. To explain this dramatic turn of events, we must examine Japanese business philosophy and the close relationship between industry and government in Japan. Understanding Japanese industry is the first step in reversing our decline and allowing the United

States to remain a world economic and military power.

UNDERSTANDING JAPANESE INDUSTRY

Both the United States and Japan believe in the free market theory of business. However, there are several unique Japanese philosophical beliefs concerning a free-market environment that need to be explored. These include:

- The Japanese believe that they are in an economic marathon race with the United States;[4]
- The Japanese are willing to accept economic inefficiency for the sake of economic security;[5]
- The Japanese believe in <u>eliminating</u> as many risks as possible versus our assuming acceptable risks;[6] and
- The Japanese take an anticipatory role versus our reactionary role to market failures.[7]

The Long Race

Because of the destruction of their country in World War II, the

Japanese view themselves as latecomers in a marathon race to achieve economic prominence. They are preoccupied with the thought of foreign dominance and feel a sense of urgency to master the fields against giants such as IBM, AT&T and Boeing. They feel that unless they become the master in a particular field, technology will continuously pass them by. The electronics industry offers a prime example of Japanese concerns. Consider the following chronology:

1945-1951	Japan makes great strides in improving its production of vacuum tubes
1951	USA markets the transistor
1950s-60s	Japan becomes top transistor producer
1959	USA invents the Integrated Circuit (IC)
1960s	Japanese manufacture Integrated Circuits
1971	USA invents Large Scale Integration of ICs
1985	Japan surpasses USA in the production of state-of-the-art integrated circuits

In viewing this historical trend, Japan found itself in the position of constantly catching up; production facilities were always one step behind current technology. Its aim was to become the technology leader, and to provide production facilities greater lead time to develop manufacturing techniques.

Accepting Inefficiency for Economic Security

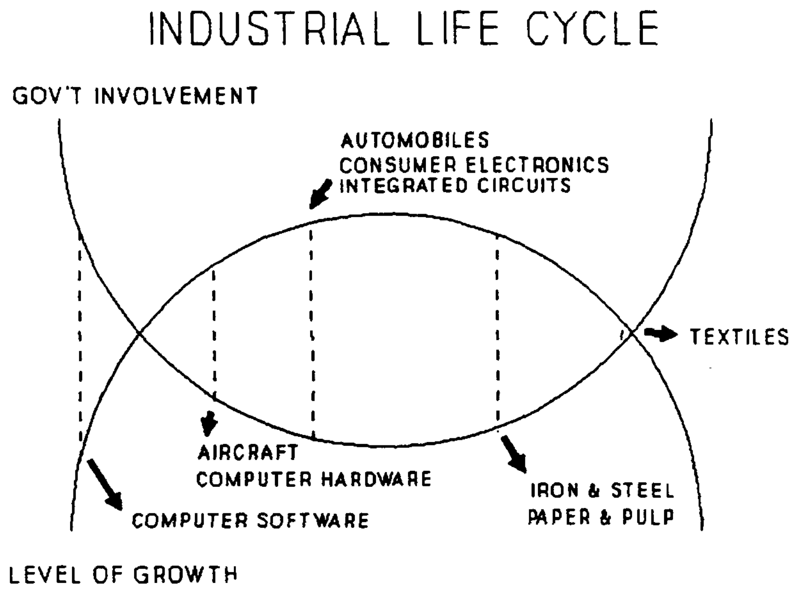
The Japanese have a long-term outlook on industrial matters. They are willing to accept short-term economic inefficiencies for the sake of long-term national economic security. They generally believe what is good for industry is good for the state and therefore good for the people. Under the attitude of collective good, the Japanese believe in protecting "infant industries" against foreign competition. A prime example is the aircraft industry, viewed as immature and needing protection to properly develop. Japan is producing F-15s and F-16s under foreign license instead of outright purchases from the United States. Although this option is more expensive, it provides Japan a means of encouraging growth and expertise within the industry. The P-3 Orion aircraft is also being produced by the Japanese under license from Lockheed. I expect the licensing programs to serve as a springboard for Japanese entry into the commercial aircraft manufacturing industry.

Eliminating Risks

The Japanese are far more pragmatic in their idea of monopoly and antitrust actions. Their feelings revert to the belief that what's good for business also aids in their goal of national catch-up, and must therefore be in the overall interest of the nation. They believe risk is reduced through consultation, consensus and voluntary compliance between the private sector and the government. By minimizing risk, industry can adequately plan for growth. Reducing risk aids in the protection of an especially important Japanese concept--belief in career-long employment with the same company. Under this philosophy, workers in Japan select their employers, not their occupations. The workers do whatever needs to be accomplished for the firm.[8] Dramatic swings within industry seriously affect the ability of manufacturers to retain workers in their jobs during large downturns in production. To offset this problem the Japanese believe in controlling market share.

Government Takes an Active Role

In Japan, the government believes in taking an active, anticipatory role in market changes. The Japanese interpret market failure on a much broader scale than we do in the United States. Therefore, the Japanese government is prepared to intervene much faster than the U.S. federal government. Figure 1 identifies two arcs associated with the Japanese industrial life cycle model. The top arc depicts the level of government involvement in providing assistance and guidance to an industry. The bottom curve represents the level of growth within the industry and starts with infancy on the left, building to maturity in the center and ending with declining industries on the right.



Source: <u>Between MITI and the Market</u>

FIGURE 1

In immature industries government involvement is very high, ensuring that they are protected through tariffs from foreign competition. As an industry matures and increases market share, government reduces its involvement. This is followed by increased involvement as the industry begins to decline.

Industries such as mining and nonferrous metals, whose market demand is subsiding, receive government attention and guidance to assist in gradually reducing plant capacity. Unlike the U.S. government, Japan does not fund ailing industries in an effort to save them.

ORCHESTRATING AN INDUSTRIAL STRATEGY

The primary government agency that ties together Japan's free market philosophy and national objectives into an industrial strategy is the Ministry of International Trade and Industry **(MITI)**. MITI works very closely with industry leaders to establish objectives that will result in greater economic development. MITI's objectives follow:[9]

- Raise productivity;
- Strengthen international competitiveness;
- Ensure the Nation's ability to move up the ladder of value-added products;
- Achieve efficiency of finite resources;
- Maintain good relations with trading partners; and

o Improve the quality of life.

Of the six MITI objectives, the middle two are the most significant in the emergence of Japan's semiconductor industry. MITI believes in a natural evolution within the industrial base moving from industries that require greater personnel assets to those requiring skill and technology (fig. 1). The textile industry is a good example of an industry low on the ladder of value-added products. Climbing the ladder, you progress through the smokestack industries such as steel, moving up past shipbuilding and automobile production. However, achieving success within Japan's heavy industry manufacturing sector introduces another problem. They consume large amounts of raw materials and energy, items Japan imports. The solution is to continue climbing the ladder of value-added products into the electronics and computer industries. MITI realized that entering the semiconductor industry offered tremendous benefits. Demand for the components was rising rapidly, particularly for use in the production of electronic consumer goods. Just as importantly, if the Japanese could exploit their semiconductor memory experience and apply it to manufacturing microchip processors, they would achieve dramatic inroads into the computer and software industries. This represented the next rung up the value-added manufacturing ladder.

MITI's Actions

To achieve its objectives, MITI has a great deal of latitude in selecting and employing the amount of influence needed for the task. However, some would say that MITI's greatest asset is a weak legislative body with little power to exert influence over the Ministry. This has enabled MITI to avoid the maneuvering normally associated with "pork barrel politics" by various interest groups, as happens in the United States. The true instruments at MITI's disposal include:

- Special Tax Provisions

- Subsidies

- Administrative Guidance

Special tax provisions: "The relative weakness of the Legislative branch of Japan and the Ministry of Finance's (MOF) policy-making authority over tax measures have produced more coherent, less distorted tax policies"[10] Under joint agreement, MITI and MOF establish a ceiling on aggregate special tax provisions. This allows MITI to distribute tax exemptions in the amount needed to achieve its objectives, as long as the incentives remain below the approved aggregate level.

Subsidies: Besides normal funds obtained through the Ministry of Finance, MITI has several other methods of obtaining funding and funneling them to selected programs. All income derived from supplemental taxes imposed on the import of energy products is disposed of by MITI. It's estimated that as much as 5 percent of MITI's total budget is the result of energy taxes. Additionally, MITI receives revenue from the national bicycle racing matches. Both examples represent "hidden" funding sources at MITI's disposal, to do with as it pleases.[11]

Administrative Guidance: MITI employs administrative guidance to help with short-range problems that threaten the public good. Administrative Guidance carries the weight of statutory law but doesn't pass through the legislative branch. This provides MITI a unique method to intervene in matters without having to worry about partisan politics.[12] Administrative guidance is normally associated with declining industries where MITI desires to achieve predictable downsizing in capacity.

IMPLEMENTING JAPANESE INDUSTRIAL STRATEGY

In the late 1960s and early 1970s, MITI recognized the potential of semiconductor technology and enacted a variety of programs designed to encourage growth within that industry.[13] The Japanese government took an active role in encouraging electronic firms to establish and aggressively pursue the objective of creating a world-class semiconductor industry. To achieve this objective, MITI initiated three major actions as listed below:

- o Protecting home markets by prohibiting importation of semiconductors;
- o Fostering cooperation among Japanese semiconductor manufacturers; and
- o Providing financial incentives to semiconductor manufactures.

Protecting Japanese Markets

During the early development of the Japanese semiconductor industry, MITI provided a secure environment in which the "infant industry" could grow and mature. To ensure this, MITI permitted importation of semiconductor chips only until equivalent Japanese devices became available on the market. Imports were then formally prohibited.[14] The Japanese domestic market was supported through local production using American technology and manufacturing equipment. U.S. semiconductor manufacturers desiring to compete in the Japanese market were forced to pay a high price for access -- they were required to license their latest technology to Japanese competitors. Formal import controls which restricted semiconductor imports to 10 percent remained in effect until 1975. However, informal import controls continue through the operation of Japanese Keiretsus.

Fostering Cooperation

A major factor in the success of the Japanese semiconductor industry lies in the structure of its business organizations. Japanese firms have traditionally organized themselves into powerful groups called keiretsus. Each group includes a range of vertically oriented manufacturing companies, a lead bank and a trading company. Members of a keiretsu hold significant equity in each others firms. This aids in the development of consensus and cooperation among all firms.[15] A keiretsu's vertical organization offers a ready market between manufacturers of semiconductors and those that produce consumer electronic goods. The tendency and desire to work through long-term associations within the keiretsu for purchasing semiconductors represent an informal (or defacto) establishment of import controls against U.S. semiconductors. After removing all formal semiconductor trade barriers in 1975, MITI encouraged market restructuring within the electronics industry to ensure protection for Japan's semiconductor industry. This realignment of semiconductor producers with semiconductor purchasers was seen as a method of "liberalization countermeasures."

The close financial and operational ties within keiretsus foster the extensive sharing of know-how between manufacturers and suppliers. These ties provide a unique insight into new product requirements and encourage product improvements through "in house" feedback.[16] Semiconductors represent a small portion of the cost for high-demand consumer electronic goods and contribute only 10 to 25 percent of total revenues within the vertically integrated firms.[17] As a result, the keiretsu is provided an opportunity to subsidize research and development of semiconductors in order to enhance its competitive position.[18] MITI has encouraged keiretsus as a method of achieving technological cooperation while avoiding duplication of research effort. The most ambitious project initiated by MITI was the four-year, $320 million very large scale integration (VLSI) program designed to "springboard" the Japanese into the world market for memory chips.[19] The program was a cooperative effort among Japan's five largest electronics manufacturers and firms representing associated chip manufacturing technologies. Under this cooperative arrangement, related firms such as Nikon were given access to the technical performance of all five firms. This permitted Nikon to refine its lithography techniques far more effectively than would have otherwise been possible.

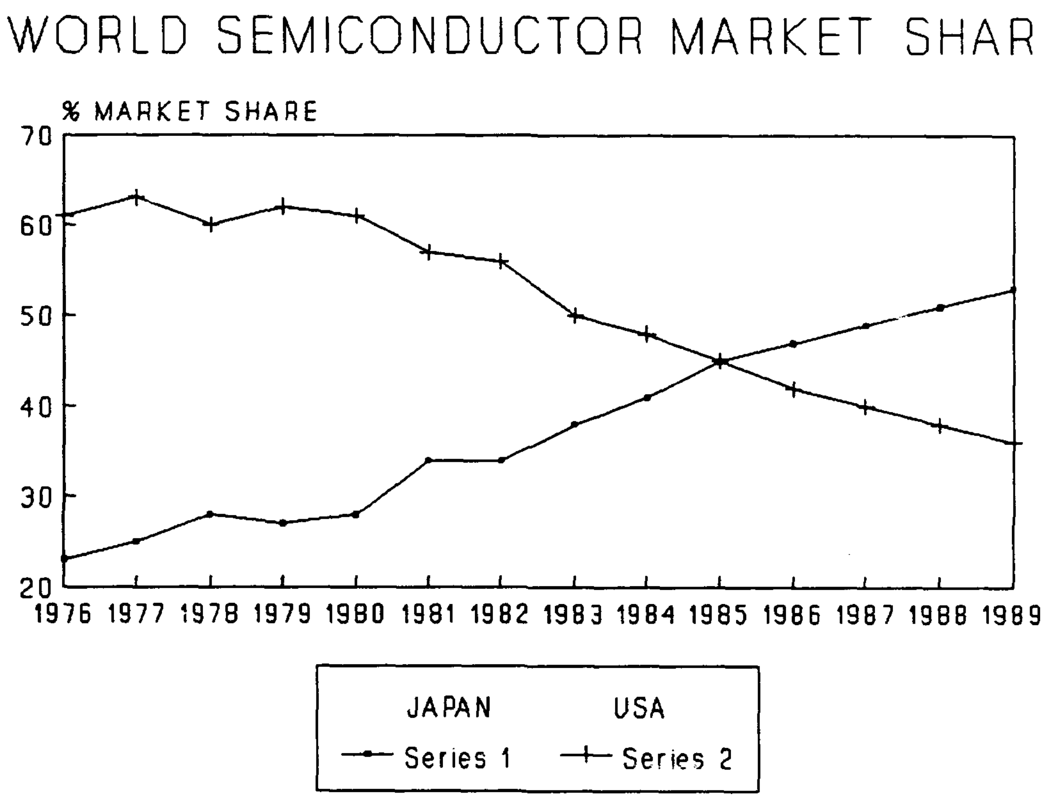
Providing Financial Incentives

Production of Semiconductors is a very capital intensive operation, even for major conglomerates. It's rapidly becoming a proposition in which you bet the life of the firm on a successful manufacturing outcome. This situation is amplified by the realization that over the last twenty years, new product improvements occur every 18 - 24 months. To encourage growth within the Japanese semiconductor industry, MITI has provided enormous tax incentives, subsidies and no risk loans (loans repayable only if the project is successful) to Japanese Corporations.[20]

Nearly 90 percent of the original acquisition costs of new semiconductor equipment in Japan can be written off for tax purposes in the first year of operation. This compares to a 20 percent write-off for firms doing business in the United States. When viewed against the rapid product improvement cycle for semiconductors, U.S. firms are at a distinct financial disadvantage in matching Japanese upgrades.[21] In its effort to increase semiconductor market share, MITI has sponsored and provided funding for research and development programs such as the VLSI project. Unlike the United States' military R&D requirements, Japan's research is focused strictly on commercial applications.

JAPAN'S SUCCESS

The result of Japan's efforts over the past fifteen years have been dramatic. Figure 2 provides a vivid picture of the situation.



Source: <u>Semiconductor Industry Association</u>

FIGURE 2

Industry analysts have attributed this reversal primarily on the Japanese higher level of investment, their attention to quality control and the ability of the keiretsu's consumer electronics firms to subsidize low investment returns within the semiconductor industry. The alleged subsidies by the keiretsus have enabled Japanese semiconductor manufacturers to sell computer memory chips for less than the actual cost of production. This has led to claims within the U.S. semiconductor industry that the Japanese are engaged in dumping practices. Today, the close working relationship within Japanese keiretsus is blamed for U.S. manufacturers' inability to penetrate the Japanese semiconductor market.

U.S. MANUFACTURERS ORGANIZE

By the late 1970s, the United States semiconductor industry felt that it was in trouble. In 1977, industry members joined together to form the Semiconductor Industry Association (SIA) with the intent of improving U.S. competitiveness in semiconductors. Since its inception, the association has been a very active force in sponsoring support for the industry. Major accomplishments of SIA include:[22]

1981 The Semiconductor Industry Association (SIA) is successful in lobbying for a Federal Research & Development Tax Credit.

1982 The Semiconductor Research Corporation (SRC) is established for the purpose of funding and directing semiconductor research at American universities.

1984 The SIA is successful in lobbying for the National Cooperative Research Act which encourages joint R&D consortia through the reform of the U.S. antitrust legislation.

1985 SIA files a 301 petition with the U.S. Department of Commerce accusing Japan of dumping memory devices in the U.S.

1986 Conclusion by the U.S. Department of Commerce that Japan was guilty of dumping memory devices on the U.S. market. (Estimates indicated that Japanese industry lost $4 Billion to gain control over the world DRAM market and in the process forced 9 of 11 U.S. manufacturers out of business.)

1986 The signing of a bilateral Semiconductor Trade Agreement between the U.S. and Japan to eliminate dumping and to open Japanese markets to foreign semiconductors. (Japan represents the largest market for semiconductors in the world.)

1991 Agreement by Japan to open its semiconductor market and to recognize a 20 percent foreign market share commitment.

In the mid 1980s, Japan's growing strength within the semiconductor manufacturing field began to alarm not only U.S. industry representatives, but the military and public sectors as well. By 1985 popular belief was that the industry was in serious trouble. Several studies documented the loss of U.S. leadership and our increasing dependence upon Japan for semiconductors. In February 1987, the Defense Science Board released a report that revealed the erosion of our industrial base and the inherent national security risk in our inability to produce a variety of military components. The report recommended formation of a jointly funded government/industry manufacturing program to produce DRAMS.[23]

Establishment of SEMATECH

Legislation to form a Semiconductor Manufacturing Technology (SEMATECH) facility was approved as part of Public Law 100-180 in the 1988 Defense Appropriations Bill. SEMATECH was incorporated on August 7, 1987 as a Department of Defense (DOD)/Industry partnership. Its focus was to develop world-leading semiconductor manufacturing within the United States. The initial organization consisted of 14 semiconductor manufacturing companies plus a representative from DOD's Defense Advanced

Research Projects Agency (DARPA). DARPA was to act as a "silent fifteenth partner" while the other consortium members provided leadership concerning the direction and goals of SEMATECH.

Initial start-up for the consortium was slow; problems were experienced in selecting a Chief Executive Officer (CEO), in identifying a location for its manufacturing facility and in enticing additional industry members into the consortium. By August 1988, members of SEMATECH had identified a CEO and started operations in Austin, Texas. Funding for the project was split between industry and the federal government. Congress authorized $100 million for the program and appropriated funds at the level matched by industry. Industry members were required to provide one percent of semiconductor sales revenue, with a provision that no firm could provide more than 15% ($150,000) of total consortium funding.[24]

SEMATECH STRATEGY

Members of the Consortium recognized the United States' weakness was in manufacturing technology, not in basic semiconductor design or research. Therefore, they established an overall goal to match Japan's manufacturing capabilities by 1993. To accomplish the task the consortium established an overall strategic plan involving specific missions and a phased period of implementation.

SEMATECH's Mission

The SEMATECH consortium identified three missions for the organization. These included: [25]

- Conduct research on advanced semiconductor manufacturing techniques.

- Test and demonstrate the resulting techniques (above mission) on a production line.

- Adopt proven techniques applicable to the manufacturing of a wide variety of microelectronic products.

Initially, SEMATECH viewed its second mission as a requirement to run the production line full time (seven days a week, 24 hours a day) in order to provide the military and civil sector with U.S. manufactured DRAMs. Member firms viewed the establishment of a full time facility as competition against their own interests and later modified the mission to reflect a requirement to demonstrate production capability for semiconductor devices.

SEMATECH's Phased Approach

To achieve the above missions, SEMATECH developed a six-year program that consisted of three concurrent phases corresponding to different circuit densities (conductor sizes).[26]

<u>Phase I:</u> Phase I focused on the near-term aspect of improving on current commercial manufacturing practices within the U.S. Its' purpose was to use current silicon technology rather than to experiment with other materials such as gallium arsenide. Phase I ran from 1987 through the first half of 1990 and targeted technology that could produce a minimum feature size of 0.8 microns.

<u>Phase II:</u> Phase II ran concurrently with phase I but extended the time period through 1990. Its goal was to concentrate on delivering technology that could produce conductors less than 0.5 microns in diameter.

<u>Phase III:</u> Phase III began in 1988 and will run through 1994. Its purpose is to produce manufacturing technologies that would be able to achieve a conductor size of 0.35 microns.

SEMATECH's Objectives

SEMATECH revised its strategic plan in 1989 in order to regain the leadership in semiconductor manufacturing. Consortium members identified the following eight objectives as their measure of success:[27]

- o Develop key process modules for member companies to integrate into proprietary flows and products. Establish a baseline integrated process for each feature size (i.e.; 0.8, 0.5 and 0.35 microns).

- o Reduce Member risk by delivering manufacturing processes and equipment models for use in future equipment decisions.

- o Develop at least one qualified, viable U.S. supplier for each key equipment module and manufacturing system.

- o Develop long-term strategic alliances with selected suppliers to provide the required capability on the required time schedule.

- o Provide preferential availability of all funded equipment, systems, materials, supplies and chemicals to member companies.

- o Drive standards and specifications for open architecture computer integrated manufacturing systems, including a generic cell controller.

- Continue to provide a forum for open communication.

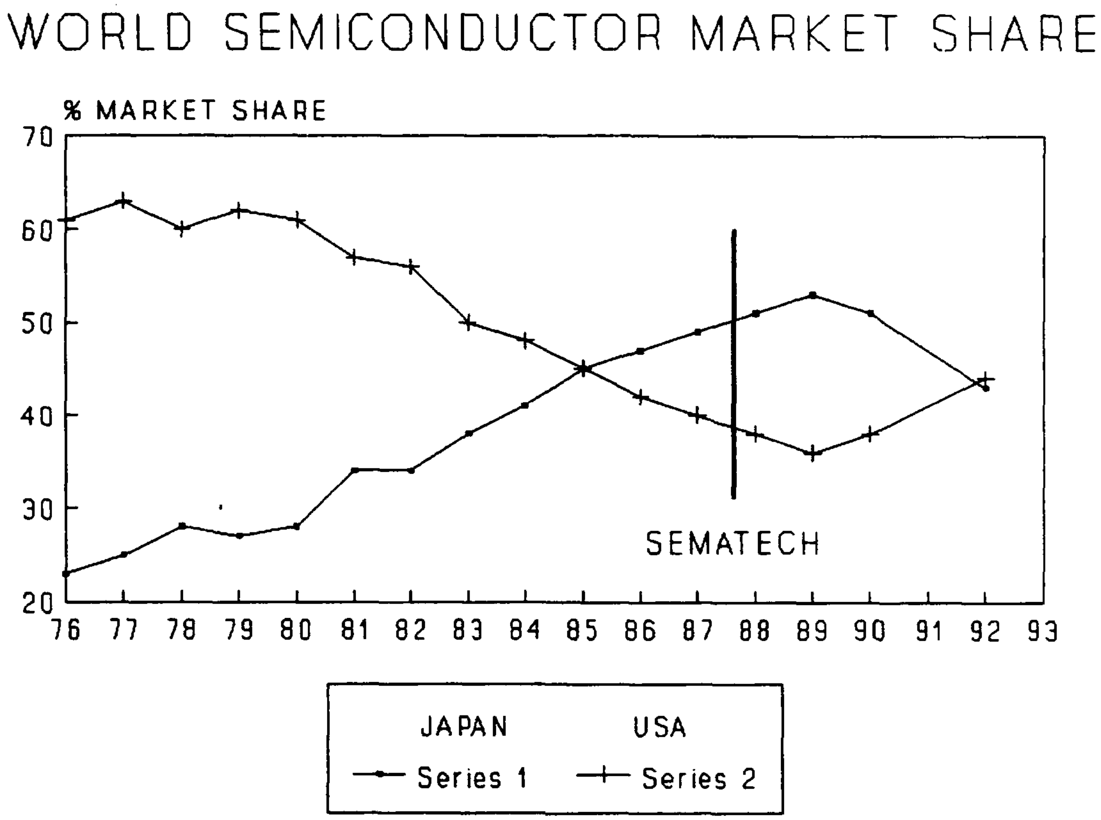
- Establish collaborative centers of manufacturing science at selected universities and national laboratories.

SEMATECH TARGETS SUCCESS

In the 4 1/2 years since the establishment (April 1988) of its manufacturing facility in Austin, Texas, SEMATECH has achieved remarkable success. Working in a precompetitive, cooperative environment, member firms successfully accomplished all of their objectives and re-established the United States as the world leader (fig. 3) in semiconductor production. The industry has met or exceeded Japan's performance in key areas such as technology development and quality control.[28] Additionally, our computer programming and modeling strengths have allowed the industry to achieve production economies of scale through manufacturing simulation programs.

Technology Development

SEMATECH has established and demonstrated baseline processes that have increased chip production by four fold on single silicon wafers. This was achieved solely through the use of American



Source: Semiconductor Industry Association and Washington Post

FIGURE 3

manufacturing equipment. Simultaneously, SEMATECH has achieved greater conductor density. The initial baseline was established using 0.8 micron and 0.65 micron geometries on 100 mm wafers. Transitioning through 0.50 microns on 150 mm wafers, they are now able to manufacture chips with 0.35 micron conductors on 200 mm wafers.[29] This represents parity with Japan's best semiconductor technology. In 1993, U.S. manufacturers are expected to surpass Japan through the introduction of a 0.25 micron manufacturing capability that has already been demonstrated by SEMATECH in low production runs. Further developments in the next few years are expected to reduce conductor size to 0.18 microns.

Quality Assurance

Paralleling the advances made in chip fabrication techniques are those associated with quality control. In the mid 1980s, U.S. manufacturers had 1000 defects for every million chips produced. During the same period, Japan's rate was only 60 defects per million chips.[30] Today, Motorola produces chips with less than 4 defects per million or a 15-fold improvement over the previous Japanese figure. Motorola believes that it can achieve its new goal of less than 4 defects per billion chips by 1998. U.S. firms now realize that high quality control saves money. Since 1987, Motorola estimates that it saved $2.4 Billion on factory rework, warranty repairs and inventory.[31]

Quality improvements in the production of semiconductors can be partially attributed to the equipment testing and improvement program within SEMATECH. The consortium's ability to test each piece of semiconductor manufacturing equipment on its operational production line has proven beneficial. It serves as a single standardized test facility for the entire industry which saves millions of dollars in redundant testing efforts. More importantly, it has provided equipment manufacturers a valuable mechanism for developing and exploring product improvements. Product testing at SEMATECH has led to one of its most important contributions within the semiconductor industry -- a manufacturing simulation program.

Manufacturing Simulation

SEMATECH took the United States' strength in computer software and applied it against the results from testing each piece of semiconductor production equipment. From this marriage, SEMATECH has produced a cost of ownership simulation program that allows manufacturers to identify the optimum pieces of equipment required to produce specific quantities of semiconductors economically. This information is particularly important for companies which produce limited numbers of application-specific devices and are not concerned with large production runs for items such as DRAMs. SEMATECH's automation efforts, have also led to the development of industry standards for open architecture in design of computer integrated manufacturing systems. The result has been greater automated material handling and control over the entire production process.

Cultural Change

SEMATECH's success can be partially attributed to the cooperative environment fostered between government, industry and educational institutions; all pursuing coordinated advances in semiconductor manufacturing practices. The consortium has developed working agreements with the national laboratories that represent the worlds largest research base. The laboratories have joined with 26 of the nations leading technical colleges and universities to create eleven centers of excellence. They are focused on improving our manufacturing capability. Industry has also played a key role. Currently 700 employees work at SEMATECH's fabrication facility in Austin, Texas. One third of the employees are on-loan from member firms. The assignees stay at SEMATECH an average of two years before returning to their parent companies. This arrangement greatly aids in the dissemination of information throughout the semiconductor industry.

During the past several years, member firms of SEMATECH have achieved multi-million dollar savings as a results of the consortium's technological advancements. However, Mr. Charles E. Sporck, president of National Semiconductor Corporation, believes that "SEMATECH's biggest benefit had been cultural" and that it created an "atmosphere of open dialogue between the semiconductor manufacturers." [32]

CONCLUSION

There is no doubt that we are witnessing the beginning of a remarkable recovery within the U.S. semiconductor manufacturing industry. Why? I contend that the reason is SEMATECH. It has consolidated resources from the federal government, industry and our educational institutions into meeting the challenge of a declining semiconductor production capability.

SEMATECH, as the coordinator of the effort, has taken several pages out of the Japanese "play book" while still operating within a precompetitive environment allowed by the federal government. It has moved U.S. semiconductor manufacturers from an adversarial position to one of cooperation. In the process, the consortium has eliminated wasteful duplication of effort in research, development and testing. Creation of a horizontal consortium has generated ripple effects throughout both the upstream and downstream sections of the electronics industry. Establishment of joint goals, objectives and standards by SEMATECH has reduced the level of risk throughout the industry.

Throughout all of its efforts, SEMATECH still maintains a capitalistic approach. Its efforts are focused at the precompetitive level and aimed strictly at the manufacturing process not in design and full-scale production of specific computer chips. This avoids the situation of having the federal government in the position of picking industry winners and losers. This position is further enhanced by the fact that DOD operates as a silent partner in the consortium.

A major question is: How long should the federal government provide financial support to SEMATECH? It appears that government backing offers two benefits to SEMATECH.

- The $100 million annual contribution represents the first benefit to SEMATECH. I see it as and offset to the continuing refusal of Japan to open their semiconductor markets to foreign sales. As discussed in this paper, Japanese industry willingly accepts U.S. imports only until equivalent Japanese devices become available. Japan's current import level of 16 percent falls short of the 20 percent agreement in 1991. Our technological advances will greatly aid in enticing Japan to open its markets.

- Second, and possibly more important in the long term, is that SEMATECH offers some protection from federal anti-trust action against member firms. With DOD as a major player, it's highly unlikely that the Justice Department will take legal action against the exchange of information among member firms.

RECOMMENDATIONS

The federal government should continue funding SEMATECH until Japanese industry fully opens its markets to foreign-made semiconductors. If the Japanese open their markets, then federal funding for SEMATECH should be gradually reduced over a three year period. This plan identifies a termination point for federal funding and provides SEMATECH members time to establish an orderly transition. It also provides an incentive to Japan to fully open its semiconductor market, thus establishing conditions for a free competitive marketplace.

The temporary R&E tax credit should be converted to a permanent tax credit. During the past five years, the R&E tax credit has been extended in six and twelve-month increments. Establishment of a permanent tax credit will permit long-term commitment and planning for programs that require large R&D investments.

The Federal government should reinstate the investment tax credit (ITC). The cost of building modern semiconductor fabrication facilities is rapidly approaching 1 Billion dollars. Without incentives such as an ITC, firms are unlikely to maintain state-of-the-art facilities that can compete openly with the Japanese.

The Federal government should revise current anti-trust laws. The United States is part of a global economy. The consumer is protected by competition that is generated by overseas firms. Allowing our industries to cooperate, and create a more cost-efficient operation does not injure the American consumer. The Justice Department must explore the world situation before initiating Anti-Trust action against U.S. firms.

The SEMATECH model of joint industry/government cooperation should be explored for possible use in other industries where the U.S. lags behind in current technology, such as in high definition displays. This method of industrial policy offers a model for the federal government to assist industry without being placed in the position of picking the winners or losers.

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