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DOMESTIC PRODUCTION AND NATIONAL SECURITY--
IS THERE A CONNECTION? A CASE STUDY OF
SEMATECH RESEARCH CONSORTIUM

by

Garry D. Moore

June 1989

Thesis Advisor: William Gates

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The objective of this thesis is to determine the need, if any, for increased Federal Government support of research consortia in encouraging domestic manufacturing capability of vital defense products.

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Domestic Production and National Security--
Is There a Connection?
A Case Study of SEMATECH Research Consortium

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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ABSTRACT

This thesis examines the relationship between domestic industrial production and national security as they relate to strategically-vital defense products. An analysis of the semiconductor industry through a case study of the semiconductor research and development consortium, SEMATECH, is conducted to determine the viability of this type of organization to bolster domestic semiconductor manufacturing.

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I. INTRODUCTION

Ever since man has found the need to defend himself there has been a defense industry. Even if it was only to fashion a club from a dead tree trunk, some sort of outward action to produce defensive or offensive weapons has been a fact of man's survival. At some point in time, man realized that a profit could be made making implements of war for others; hence, the modern defense-industrial complex was born. In this day and age, the complexities of technological advances and international relations highlights the need for government involvement in both the development and proliferation of state-of-the-art weapons systems.

During the first half of the 20th century, the United States enjoyed the fruits of its late 19th-early 20th century industrial expansion. This was especially true in the realm of defense-related acquisitions. The U.S., for the most part, was able to domestically produce all its defense needs with little or no foreign manufacturing assistance. There was little concern for the political considerations of allies with respect to the American arms industry. America could still defend itself with its own domestic production capabilities regardless of outside disfavor with American foreign policy.

Such is definitely not the case in 1989. The U.S. is dependent on foreign sources for many of the components of major weapon systems. This thesis will deal with one aspect of this dependence--the semiconductor industry. In this area alone, 23 major weapon systems contain semiconductors available only from foreign-owned, foreign-located sources. Some of these systems are at the forefront of the Reagan military expansion: GPS (Global Positioning System) which permits any military unit to geographically locate its position to within several feet, the F-18 fighter-attack aircraft, and the F-16 fighter-attack aircraft. [Ref. 1:p. 22] The majority of these technologically advanced semiconductors are produced in Japan; however, other source countries include Great Britain, France, West Germany, Italy and South Korea.

When discussing the implications of foreign-based producers of American defense components, one must consider several relational components. In particular. what aspects of our national security are at risk when foreign suppliers enter the market? Is it ever acceptable to rely on foreign suppliers and, if so, to what capacity? What avenues are available to preclude foreign domination of sensitive technologies?

A. BACKGROUND

Many firms spend a considerable amount of effort and expense reverse engineering products from other companies. However, the effort and expense in developing new technology is considerably higher by comparison. The incentive for firms to develop these new technologies is not always sufficient to warrant the investment. A substantial amount of the benefits of their investment in new technology can be readily captured by imitators. Hence, looking at the issue from a broad viewpoint, research and development is not always the most cost-effective means to achieve a profit. This is accentuated even more when foreign suppliers, who often times have governmental backing in investment and tax credits, are able to manufacture high-tech items at a fraction of the cost to American producers.

Take the Japanese for example. They have developed a long-term joint effort between government and industry to become a world leader in semiconductors. [Ref. 2:p. 4] These actions include:

- home market protection though Buy Japanese requirements;

- subsidization of cooperative R&D. The Japanese government provided funding, as of 1987, for over 60 major projects related to semiconductor research;

- industry actions to develop a highly integrated and interdependent industry structure.

The U.S., on the other hand, also provides substantial support to domestic high-tech industries through substantial DOD subsidies.

Whether or not one can conclude that these actions were a major contributory factor in eventual Japanese domination, the facts speak for themselves: semiconductors are the principle and dominant component of Japanese microelectronic production today. In particular, Japan holds 90% of the world's share in the 256K DRAM market and is planning on marketing very shortly its own 1MB DRAM [Ref. 2:p. 3]. However, one must remember that DRAM production, relative to other types of semiconductor production, is on the low-technology end of the spectrum.

The West has nothing to compare with this level of mass production for the merchant semiconductor market. Where is the incentive for U.S. firms to invest heavily in R&D when they can either purchase the products directly or reverse engineer the products themselves? In either case, short-term costs are reduced. However, dependence on foreign-based sources will only be exacerbated if this continues.

B. NATIONAL RISKS OF TECHNOLOGICAL DEPENDENCY

The issues of national risk are two-fold: the direct threat of a disruption in supply (either through willful embargoes or blocked transportation routes), withholding crucial defense produces, and the spillovers to the defense and domestic economy as a whole, specifically concerning the ability of Americans to successfully exploit and understand leading-edge technology.

Should foreign suppliers continue to expand in the American defense arena, American foreign policy could be severely compromised, according to the Defense Science Board [Ref. 3:p. 94]. What would prevent the government of a country in which critical U.S. components are manufactured from stopping production/export in response to dissatisfaction with American foreign policy, they ask? Contingency plans for just such a scenario have already been developed for strategic raw materials. Much of the U.S.' strategic minerals (i.e., chromium, nickel, platinum, etc) come from such countries as South Africa, Brazil and Australia. The U.S. has been stockpiling strategic minerals for years in the event that these sources are prevented from fulfilling their contracts for whatever reason, political or military blockage.

The area of high-technology dependence, however, is more expansive. In this situation, the raw material in question could be considered to be the semiconductor. If dependent on foreign sources, this raw material would not be present within the borders of the U.S. to the degree required. More importantly, though, according to many industry and government officials, the ability to design, produce and even use these components could gradually dissipate. [Ref. 2:p. 2] The U.S. could conceivably become similar to many Third-World nations who currently rely on U.S. technological training for their state-of-the-art military expansion.

This dependence on foreign-based sources also precludes a great deal of spillover into other aspects of the national economy. Spillovers include such aspects as the increased electronic emphasis in many of today's consumer products or the use of hybrid materials in the auto industry. Economic studies have shown that the rate of return of R&D to society as a whole is double the return to the individual firms performing it [Ref. 4:p. 4]. This means that as R&D increases domestically, it can be expected that a plethora of offshoot industries will benefit. Specifically concerning the semiconductor industry, R&D in universities and industry help preserve the U.S. base level of human knowledge, thereby ensuring future domestic engineering exploitation and expansion.

Concerning the question of whether it is ever acceptable to rely on foreign suppliers, one must consider two issues: are there alternative foreign sources for the same product and what is the extent to which the product is of vital or non-vital importance to national defense?

If a product had only one source, say Japan, and if the supply routes from Japan to the U.S. were disrupted, then a shortage could ensue. However, if there were multiple sources for the same product (i.e., Korea, Taiwan, Mexico, etc), then the likelihood of all sources simultaneously becoming unavailable becomes increasingly unlikely. In this situation, therefore, it might be permissible to rely on foreign sources.

For the second issue, one must determine the extent to which the product in question is of vital or non-vital importance to national defense. For example, if tactical training in the future relied critically on the ability to geographically locate oneself within a few feet, then the GPS network would be vital to successful prosecution of a conflict. Should the foreign supplier fail to provide necessary vital components for maintenance or establishment of the GPS network, for whatever reason, then American defense readiness would be in doubt. This could have severe repercussions in an aggressor's perception of his ability to win a conflict with the U.S.

On the other hand, if radios for Army jeeps were procured from foreign sources, any blockade of this supply line could probably be overcome with replacement by domestic models, assuming no specialized components were required. In this case, the non-vital radios could continue to be supplied by foreign sources with no threat to national security. The determination of vital vs non-vital components is one that would need to be made at the highest levels of DOD.

C. ALTERNATIVE POLICIES TO REDUCE TECHNOLOGICAL DEPENDENCY

If it is determined that foreign-source domination of key defense related components is not in the national interest, what are some of the alternatives to remedy the situation? Clearly, precedence has been set with the imposition of tariffs, quotas and anti-dumping legislation. In addition to these negative measures other more positive actions could be: strategic stockpiling, Buy American DOD policies, dedicated DOD production facilities and federal subsidies for domestic production. These alternatives may answer the short-term, limited aspect of DOD concerns; however, the crux of the matter is that these measures are a stopgap at best.

A major area of emphasis that this thesis will explore is that of various federal intervention practices with regard to domestic industrial production: protectionist policies and their effects on the defense industry. When dealing with trade restrictions, the term protectionism inevitably comes into play. Protectionism is the regulation of exchange by noncontracting parties. Generally, it is governmental regulation of the terms or conditions on which one person may trade with another. More specifically, and how it is normally defined in the macro sense, it is the regulation of trade between the residents of different countries for the supposed benefit of certain home-country residents.

Various methods of regulation have been devised, including the following:

- *tariffs*--schedules of duties on imports, not as prevalent as in past years due to international agreements;

- *non-tariff barriers*

- *additional charges*--above and beyond the normal customs duty, on certain imports;

- *import quotas*--which directly limit the amount of a commodity that may be imported during a given period of time (consumers do not enjoy lower prices when import quotas are enacted while domestic producers essentially receive a quota profit in addition to maintaining a secure and less competitive market for their product);

- *export quotas*--in the name of national security, certain products are restricted in both numbers and destination if exported (one of the more publicized examples was the ban on sale of various computer systems to Eastern Bloc nations imposed by the Reagan administration);

- *voluntary export restrictions*--rather than risk even sterner measures, some countries voluntarily restrict exports to other countries (Australia, New Zealand and other beef producing nations voluntarily restricted exports of beef to the U.S. from 1968-1971 rather than trigger automatic quotas under the Meat Import Act; Japan voluntarily restricted its export of cotton textiles to the U.S. during the 1950s and, most recently, Japan cut back on its exports of automobiles to the U.S. in reaction to U.S. pressure;

- *Buy American rules*--since the Great Depression, various legislation has required government agencies to buy their supplies from domestic sources unless any additional cost is deemed unreasonable;

- *anti-dumping legislation*--dumping refers to the sale in foreign markets of products below prices charged in home markets for the same products (according to Article VI of the General Agreement on Tariffs and Trade (GATT), such sales are only considered unfair and subject to anti-dumping duties when they are also injurious to U.S. producers of similar products).

Other measures, though not commonly recognized as protectionist in nature, are: exchange controls and multiple exchange rates, licensing requirements, health and sanitary standards and customs-valuation procedures. Each of these areas will be thoroughly explained as to their impact on the defense industrial base, positive or negative as it may be.

In the case of the semiconductor industry, DOD accounts for only 3% of total domestic output of semiconductors [Ref. 1:p. 9]. Because of this, efforts to promote DOD independence from foreign suppliers do not necessarily enhance the domestic industrial production capabilities as a whole. What the Federal government has proposed, and what this thesis will explore, is the concept of federal involvement in a combined DOD-industry research consortium. Known as SEMATECH or Semiconductor Manufacturing Technology Institute, this consortium would enable the semiconductor industry to perform basic and advanced research into various semiconductor manufacturing techniques, an area of increasingly diminished U.S. ability. As envisioned, the Federal government's involvement will be limited to initial structure of the organization and follow-on funding for the six years currently planned for the organization's first project. Numerous problems, both from the organizational viewpoint and the financial one are yet to be resolved, yet SEMATECH promises to be a major player in the domestic semiconductor industry.

The remaining portion of this thesis is divided into seven main areas: an historical background of various protectionist policies is provided in Chapter II; a variety of national security implications relating to domestic manufacturing production will be expounded upon in Chapter III; an examination of the research consortium as a means of resolving the research and development problems associated with foreign competition is discussed in Chapter IV; an in-depth analysis of SEMATECH research consortium, the federally backed semiconductor consortium recently organized in Austin, Texas is provided in Chapter V; a summation of conclusions elicited from the data researched is presented in Chapter VI; and Chapter VII lists several areas for further research.

II. HISTORICAL PRECEDENCE FOR PROTECTION OF DOMESTIC INDUSTRY

Government intervention in trade policies of individual industries in the U.S. in varied and widespread. Consequently, it is not unexpected to believe that a protectionist bent would be likely in as vital an industry as semiconductors. In this chapter, a number of examples of just such protection will be examined along with the consequences they had for their respective industries. The protectionist policies considered include tariffs, Buy American regulations, anti-dumping legislation, and governmental subsidization.

A. REASONS FOR PROTECTIONIST SENTIMENT

Protectionism is the regulation of exchange by noncontracting parties. Generally speaking, it has come to mean the regulation of trade between the residents of countries to the benefit of certain home-country residents. Reasons for protectionist sentiment are varied, yet specific to the situation in which a nation finds itself. Some of these reasons are:

- to protect against cheaper foreign goods, which are made possible because of foreign government subsidization or cheaper foreign labor. These cheaper goods supposedly will take away market share from domestic producers of these same goods;

- to support domestic industries in order to save jobs at home;

- to prevent monopolization of an industry by foreign firms through dumping actions;

- to ensure overall health of domestic economy;

- to ensure a national product standard;

- to prevent national security problems from occurring.

Each of these reasons has specific, and often times overlapping, means of achieving their goals. These terms are explained further.

B. MEANS OF PROTECTION

Examples of protectionist methods are as varied as are the industries they protect. One of the most preponderant methods has been via tariffs. Tariffs are duties imposed on imports. The lowering of tariff barriers due to international agreements in recent years has avoided this volatile political method. However, to replace the void, varied non-tariff modes have been developed. The European Economic Community (EEC) imposes variable levies on agricultural products which it imports from countries providing government farm subsidies. Obviously this is to protect the EEC farmers who do not necessarily enjoy the subsidies of their peers in other countries. [Ref. 4:p. 3] Another example is in the domestic distilled spirits industry of the U.S.. Here, while an excise tax is imposed on all distilled spirits, it is imposed in such a manner that foreign made products end up paying proportionately higher rates than domestic producers. In this case, while Americans are taxed based on the proportion of proof of their products, foreign spirits are levied a flat rate for all products of 100 proof or less. In some cases, Americans may pay only 50% of the tax a foreign producer does for the exact same product. [Ref. 4:p. 3]

Buy-American rules are also another means of restricting the use of foreign products. Legislation has been passed at numerous points in U.S. history requiring Federal agencies to only use domestically produced products even if it meant paying a higher price [Ref. 4:p. 7]. In some cases, DOD accepts higher prices for domestically produced products, even if they are 50% more expensive than equivalent foreign-made products.

Anti-dumping legislation has provided some of the most publicized and emotional examples of protectionism found anywhere. These laws permit domestic industries to require higher duties on foreign products by showing the existence of foreign subsidies or injury due to below-fair-value sales of these products in the U.S.. It is believed that the foreign producer is attempting to drive out the domestic producer by underselling him. Ultimately, once this is accomplished, the foreign producer will allegedly monopolize the industry and begin charging higher prices because no competition now exists. Anti-dumping legislation became such a widespread problem that international trade agreements finally were required to curb its abuse and legitimize the context in which it could be enacted. However, Article VII of GATT, which clarified anti-dumping circumstances, is thought by some to overly favor domestic producers at the expense of domestic consumers [Ref. 5:p. 70]. There is no evidence to believe that Japanese TV manufacturers are attempting to drive Zenith or RCA out of the U.S. TV market because they sell their products at lower prices than their U.S. counterparts. It could be simple and rational profit-maximization behavior. Unfortunately, this may not always be the case.

Even if the avowed reason is not to necessarily drive U.S. producers out of the market, some types of dumping can certainly do this. Case in point: the massive influx of cheap semiconductors by the Japanese in the early 1980s. Having mastered an inexpensive mass production technique, Japanese firms sold huge amounts of their products on the U.S. market to the dismay of domestic producers. Not only could they not compete, many of the smaller firms went bankrupt. Finally, Congress investigated and determined, based on Article VII of GATT, that dumping did occur which warranted anti-dumping legislation.

An interesting example of direct government intervention in protecting a domestic industry would be that of the British Government and ICL (International Computers Ltd), a British computer firm. The United Kingdom provides two types of subsidies to the computer industry--industry-wide and firm-specific. ICL competes with numerous American-owned firms which have subsidiaries on British soil such an Honeywell, NCR, IBM, etc. In addition, numerous smaller British-owned firms operate in the United Kingdom. The governmental industry-wide subsidies apply to all computer firms which gain income inside Great Britain, irregardless of ownership. This subsidy is to encourage importation of advanced technology into the British market. Firm-specific subsidies benefit only British-owned companies; hence, ICL enjoys double subsidization. The problem with this type of double standard is the danger of alienation of the foreign firms to the point of their withdrawal. A fine balance continues to be met in this situation. [Ref. 5:p. 55]

British Airways provides yet another example of direct governmental involvement in protectionism. Since British Airways is a nationalized firm, essentially owned by the British taxpayer, it is of substantial interest to Her Majesty's Government to encourage as much domestic involvement as possible in all aspects of its operations. This includes the procurement of aircraft. Since there is no substantial domestic commercial passenger aircraft industry in Great Britain, British Airways looked for foreign-produced aircraft. In a bid between three U.S. firms (Boeing, McDonnel Douglas, and Lockheed) and a Franco-German consortium, Boeing ultimately won. However, British Airways insisted that Boeing use Rolls Royce engines in these planes. This certainly increased the eventual price to British Airways, but it also directly aided a domestic British firm--protectionism at its best!

Nor is protectionism limited to industries of a strictly commercial nature. For example, West Germany strongly subsidizes their aircraft, space, nuclear and computer industries on the basis that they contribute significantly to the overall health of the German economy and are too sensitive to allow free market control. The problem with this reasoning is the ability to correctly ascertain what constitutes significant contribution. In each of these industries a national defense argument could be brought forth, and rightly so, by German government. In the case of the American semiconductor industry, just such an argument is especially germane.

Protectionism is not simply limited to saving a particular domestic industry from unfair competition, but also as a means of enforcing a national product standard. For example, after the '73 Arab Oil Embargo, Americans began turning away from their traditional big cars and looking seriously at purchasing a small car. At the time, Detroit was unable to satisfy this American desire and consumers increasingly began looking at foreign-made products. Some of the most fuel efficient small cars in the world at that time were Fiat's 500 and 600 models. However, the U.S. refused permission for domestic sale of these models because they did not meet national safety standards [Ref. 5:p. 60]. This determination was very fortunate for Detroit indeed, since it would have been unable to compete realistically. These standards exemplify the two guiding principles behind a policy of setting national product standards: (1) the belief that domestic products are higher in quality than foreign goods; (2) that the consumer must be saved from his own ignorance of this fact through protectionist rulings.

The U.S. is not alone in using protectionism to enforce a national product standard. The French believe that they are entitled to good wine, which means only French-grown wines are allowed in French government circles. The Dutch prohibit the sale of any product containing corn syrup because of supposed health concerns. This may appear innocent enough since it encompasses domestic as well as foreign suppliers. However, upon closer inspection, this ban effectively restricts the importation of chocolates, fruit purees, pastes, most jams, jellies, marmalades, etc. These are some of the very products that the Dutch are well known for themselves. Therefore, since foreign imports are essentially nonexistent, the domestic industry can thrive without competition.

C. PROTECTIONISM AND NATIONAL SECURITY

One argument which has gained substantial legitimacy, especially in recent years, is that of the national defense aspect of certain domestic industries. Arguments center on the fact that some import-competing industries may not be in the position to provide for the national defense need in case of all-out war. If the competing import had the advantage economically over its domestic counterpart then there would be the perpetual danger of a reduction in imports due to any number of wartime scenarios. If this import were deemed militarily significant, the U.S. would be at a disadvantage. [Ref. 6:p. 15]

Is there a precedence for just such a supposition? Has the U.S. been in such a position and what were the outcomes, if any? The following examples will help to clarify just such questions.

One of the most recent examples of the danger to the national security is the 1973 Arab Oil Embargo. The almost 50% dependence of the American economy on imported oil resulted in unprecedented rises in the price of petroleum products which quickly spread to all aspects of the national economy. As a result of the embargo, a small import fee was imposed. Prior to this, import quotas were imposed. In retrospect, even though these quotas were imposed to encourage domestic production, they also encouraged the draining of the most easily recoverable oil fields at just such a time when imported oil was relatively inexpensive. In the long run they may have harmed the very industry they were designed to protect and placed the U.S. in a position of extreme vulnerability. In this case it can be argued that protectionism did more harm that good.

D. CHOICE OF PROTECTIONIST POLICY

As explained in the preceding section, there are numerous types of protectionist policies. However, matching these with the problem at hand is the difficult issue. Government officials must weigh the potential fallout from inhibiting the free market in their economy against the survival of their own domestic industries. For example, import quotas for DRAMs, negotiated with the Japanese in 1986, had significant adverse effects on the computer and electronics industries, but did not seem to help the U.S. DRAM industry [Ref. 7:p. 552].

Some choices are more apparent that others. Obvious dumping practice by a foreign firm might reasonably warrant anti-dumping measures. On the other hand, a simple tariff might be more reasonable if government wishes to encourage a fledgling domestic industry from being overrun by foreign competition at its inception. If government wishes to maintain domestic preeminence in a certain field, it may decide to subsidize that industry (i.e., U.S. agricultural subsidies). Whatever the reason, the choice must fit the circumstances. It would be considered inappropriate for a government to enact anti-dumping legislation for a product which caused no injury to domestic industries. It also may not be appropriate for a nation to impose tariffs for fear of counter tariffs against unrelated vulnerable domestic products which have foreign markets.

In any case, these decisions ultimately rest on the politician's judgment, based on the perceived facts. The major points here are that the semiconductor industry has appealed to each of the major reasons for protectionist sentiment listed. Some of these appeals drew attempted remedies which, for the most part, have failed. The latest appeal has been the national security fear of foreign dependence and its implications.

Since the argument of national security is so vital to the logic behind creation of SEMATECH, an in-depth analysis of just what national security implications are present is needed. Chapter III will describe the defense technology base, the national technology base and how national security is connected to both.

III. NATIONAL SECURITY IMPLICATIONS

The previous chapter discussed various justifications for protectionist policies which governments could, and have, used to support measures to ensure viability of domestic industries. One of these reasons used potential national security degradation as the basis for inhibiting foreign-made products from entering the national economy. The semiconductor industry is using just such an argument in the development of SEMATECH. An examination of the various issues relating to these national security implications will now continue.

A. DEFENSE TECHNOLOGY BASE

When discussing national security and technology, one must necessarily define the defense technology base. This is the combination of people, institutions, information, and skills that provides the technology used to develop and manufacture weapons and other defense systems. It depends, to a great extent, on the interrelationships between national laboratory facilities, commercial and defense industries, venture capitalists, universities and other science and engineering professionals. It also draws on the work of scientists in other countries and is both formal, as through written contracts, and informal, as through seminars, contacts within specialized communities, etc.

B. DOD TECHNOLOGY BASE PROGRAMS

The DOD technology base programs are not the same as the defense technology base. The defense technology base is, as explained above, an accumulation of scientists and engineers, knowledge and facilities while the DOD technology base programs are a group of individual projects funded specifically through DOD's budget.

The Department of Defense has organized its technology base programs into three basic categories: (1) basic and applied sciences; (2) exploratory development of practical applications of that basic research; (3) the manufacturing of prototypes to demonstrate the results of application. The road to obtaining satisfactory results from each of these categories is substantially different and applicable mainly within the DOD environment. More relevant are the issues dealing with the broader-based defense technology base.

C. DIFFICULTIES IN UTILIZING DEFENSE TECHNOLOGY BASE

The defense technology base gleans its data from the national technology base as a whole, since it theoretically has access to all ongoing research and development. However, this is not necessarily the case. A number of situations limit the availability of research for defense purposes. [Ref. 8:p. 15] Commercial industries developing new technology tend to be reticent in giving up their best technology immediately (DOD policies to encourage competition in acquisition essentially require firms to make proprietary technology available to competitors in the form of technical data packages). Cutting edge technology, therefore, is not always available to DOD as quickly as would be desired. Some scientists have moral qualms concerning defense related research and refuse to participate, creating a dearth of top-notch scientists in some fields. Finally, governmental regulations are often times so confusing to companies with no prior defense experience that they become very reluctant to participate in such endeavors. Therefore, while theoretically able to draw from the entire national technology base, in fact, the defense technology base is somewhat restricted.

D. DEFENSE AND NATIONAL INDUSTRIAL BASE

Only a handful of large defense contractors do the majority of defense related research in the U.S.. These defense contractors, by and large, primarily design, develop and produce weapons and other defense systems and can be considered part of a defense industrial base. This defense industrial base draws on its own internal technology as well as technology developed elsewhere. In other words, the defense industrial base is a subset of the larger national industrial base. The national industrial base is comprised of both commercial and government-sponsored industries. In some areas, the commercial aspects of research lags behind the defense aspects; however, in others it is just the opposite, the commercial sector is well ahead of the defense sector. DOD exerts considerable influence over those contractors with defense background, but very little on those which spend their efforts primarily in the commercial sector. Defense is an extremely small part of their overall revenue infrastructure. The market dictates the extent and rapidity of their technical growth. These so-called "dual use" industries are a vital part of the overall national industrial base and, consequently, the defense industrial base. The semiconductor industry is a prime example of just such a dual-use industry. Although primarily a civilian-use product, semiconductors play a basic role in all defense systems. The availability of such products transcends simply the commercial field; it is a substantial concern to national security.

E. UNITED STATES NEED FOR TECHNOLOGICAL SUPERIORITY

One of the principle means of keeping the U.S. militarily ahead of the Soviet Union has been through the use of technologically superior weapons systems. For years this has enabled numerically inferior NATO forces to balance numerically superior Warsaw Pact forces. However, in recent years, indications are that this edge is beginning to erode. Through a variety of mechanisms, the technology advantage which the U.S. has enjoyed has diminished to near parity with its opponents. Is this a cause for concern? And if so, what particular industries are of main importance? Both issues shall be studied accordingly.

For over three decades, the U.S. has relied on technological superiority as the crux of its national defense planning. If the U.S. cannot maintain this technological lead there are only a few choices to be made, assuming no fundamental changes in competition between America and her rivals: (1) accept a significantly decreased level of security; (2) rely more on allies; (3) make major increases in military forces. [Ref. 9:p. 109]

F. TECHNOLOGY LEAD

When discussing technological lead, one can consider a variety of levels. However, ultimately the advantage is realized only on the battlefield, in fielded military hardware. Maintaining a technological lead in fielded military hardware is much more difficult than catching up. Maintaining a lead requires an innovative and dynamic national technology base whereas catching up can be accomplished through imitation. Imitation is much less expensive than innovation because it can essentially use all the tricks in the book, including espionage, reverse engineering and buying technology. The Soviets, in particular, have "significantly reduced the lead previously held by the U.S. and its allies in technologies of military importance" [Ref. 9:p. 110].

American commercial and defense technology tends to be complex and costly. Successful innovation requires that substantial amount of time be spent training operators and maintenance personnel for the new equipment as well as getting the "bugs" out of every new system. Less time and money is therefore available for production technology.

Efforts are focused on design technology. Herein lies the issue at stake in the semiconductor industry. Although American basic research technology is virulent, manufacturing expertise continues to be the Achilles heel of the commercial and defense semiconductor technology base.

G. AN INTERNATIONAL INDUSTRIAL BASE

The issue of availability of strategically vital products brings to the forefront the question of foreign dependence. This is inextricably intertwined with the increasing international competitiveness of important civilian high-tech industries. Since the U.S. is part of the global economy, it may be cost effective, some say, to buy what it needs from this global market. In certain high-tech industries, other nations lead the U.S. both in production and basic research of products vital to important defense systems. Partially due to the substantial economic aid to allies after World War II, this phenomenon has the potential to undermine America's own economy if protectionist policies become the norm, say many economists. [Ref. 8:p. 22]

The problem with this situation is that there may be trade-offs between the best economic choice (foreign sourcing or domestic sourcing) and national security. While giving DOD the control and certainty desired, total domestic sourcing most likely will risk losing access to important technological developments which are produced overseas or which can only be produced in this country at a prohibitive cost. More and more, the global economy is witnessing such phenomenon as international cooperative development projects (i.e., Iguazu Dam between Brazil and Argentina, SST between France and England, etc), co-production agreements (FSX in Japan), and licensing (P-3s in Japan and F-16s in Israel). As more of these actions occur, the national economies will become more and more intertwined and interdependent. Synergism, therefore, takes place when the strengths of various national economies are focused on a common project.

H. NATIONAL SECURITY CHOICES

Assuming one believes the premise that it is permissible to share defense production, and even to rely on foreign sources for certain vital defense needs, the question becomes a matter of choice. Which industries are so vital that foreign sources cannot be permitted to dominate and which are not as vital? Similarly, if foreign sources are acceptable, which source or combination of diverse sources will minimize the national security risks? Ultimately, these are political decisions, but ones which must be based on both the realities of the present economic and political global situation and on a reasonable forecast of future conditions.

Semiconductors have a long tradition of dominance for the American portion of the global economy. It is not surprising, therefore, that U.S. industrialists and government officials, accustomed to being number one in this field, would feel that national security is in jeopardy if foreign firms should dominate. Investing time and effort to encourage legislative approval for foreign sourcing may be very difficult, politically, as compared to an American source option.

Therefore, foreign dependence can be either harmful or good, desirable or not desirable, avoidable or unavoidable, or a mixture of these. The circumstances under which one option or another might be undertaken must take all these facets into consideration. Unfortunately, no clear cut answer is ever possible in these situations.

The following chapter will examine the increasingly popular phenomenon of the consortium. What is it, how did it begin and what are the implications for American industry? The semiconductor industry is relying heavily on just such an organizational form. SEMATECH, with its emphasis on semiconductor manufacturing technology is the most recent semiconductor consortium. Earlier on-going consortia include the Semiconductor Research Corporation (SRC), which emphasizes basic semiconductor research in universities, and the Microelectronics and Computer Technology Corporation (MCC), which emphasizes applied semiconductor and computer research. Are consortia, in fact, the best forum for resolving the industry's problems?

IV. THE CONSORTIUM: PANACEA OR BUST?

As mentioned in the previous chapters, protectionist sentiment is varied and full of emotion at times. To say the least, it can stir heated arguments in international circles and make bedfellows of hawk and dove alike. Another topic of controversy is the increasing resort to, and effectiveness of, the consortium in American industry. Since DOD is funding just such an organizational form, via SEMATECH, a discussion and explanation of the benefits and dangers from consortia will follow. Initially, a breakdown of the various types of consortia will be listed, organized by the goals each has. Secondly, the issues unique to consortia, such as technology transfer and setting of agendas, and their relative historical success,will be shown, while a comparison of matching types to activities in both the U.S. and Japan will follow.

A. CONSORTIA STRUCTURES

The basic organizational structures of consortia are somewhat varied but can generally be identified in one of three ways [Ref. 10:p. 64]. These include consortia designed solely to conduct long-term research, those associated with universities, and finally, those formed to promote uniform standards in their industry.

The first category includes those consortia organized to conduct long-term research. These have full-time permanent employees as well as loaners from the member companies who work for a period of time and then return to their parent firm, presumably taking with them the technology developed via the consortium. Examples of this are Bell Communications Research, Inc (Bellcore), a cooperative program between Bethlehem Steel and U.S. Steel, Microelectronics and Computer Technology Corporation (MCC), and finally Semiconductor Manufacturing Technology (SEMATECH).

The second category more closely resembles the pre-1984 type of consortia: those organized to conduct or encourage research through university-type settings. Usually these consortia have very small staffs and no laboratories themselves. They provide funding and set basic goals to focus the research. Examples include Semiconductor Research Corporation (SRC),a group of about fifty hi-tech firms interested in furthering basic research on semiconductors in universities, and Computer-Aided Manufacturing International, which is a consortium of over 100 firms interested in improving industrial productivity in computer systems and software. Another example is the Geothermal Drilling Organization which sponsors research into techniques for improving drilling and geothermal exploration. The main theme behind these consortia is the emphasis placed on external organizations (universities and the like) for their research.

The third category includes those consortia that test for adherence to standards or regulations or which develop and promote certain standards. Examples include: the Center for Advanced Television Studies (defining an ideal TV transmission system), the DEET Joint Research Venture (sponsors research on the effects of the pesticide known as DEET and provides results to Congress and other legislative bodies for incorporation into regulations concerning DEET's use), National Association of Home Builders Research Foundation-Smart House Project (designed to coordinate home control and energy distribution systems with telecommunication and enhanced safety features). Other examples are the Motor Vehicles Manufacturers Association of the U.S. and the Plastics Recycling Foundation which sponsor research into measuring automotive fuel emissions and improved recycling of all plastic materials, respectively.

B. COMMON ISSUES

Consortia have a body of issues which are common to other forms of industry organizations. However, they must also deal with a set of circumstances (both beneficial and disadvantageous) which are unique only to them. First, the benefits industry gleans from consortia will be explained. Then, two of the more critical issues, agreeing on a common agenda and transferring technology to member firms will be discussed.

C. BENEFITS

Because the consortium brings together a diverse set of similar firms, not every firm will benefit exactly as the others. However, generally speaking, the following points are common to all consortia:

- individual firms will spend relatively less for the technology coming from the consortium than they would if the same research were conducted internally;
- a pooling of intellectual talent permits more innovative technologies to be realized at a faster pace than otherwise expected for internal R&D efforts;
- smaller firms will generally gain relatively more from their participation because their own R&D funding would probably never come close to matching the consortium's;
- huge, nation-wide projects, such as the Manhattan Project or Apollo Moon Program would be very difficult to achieve without a consortium-like organization. [Ref. 10:p. 63]

These benefits must be weighed against the potential problems and disadvantages which consortia also possess.

D. AGENDA FORMATION

Setting an agenda is not easy task for the consortium. It must take a diverse set of individuals, many of whom are successful experts in their fields, and agree to common goals, timetables for achieving them, and methods to employ along the way. Furthermore, consortia members want to ensure that the cooperative research projects are somehow coordinated with their own internal research projects. Some consortia send representatives who meet and decide for their respective firms as a group on an as needed basis. Other consortia choose a core of semi-permanent individuals who are authorized to act on the firm's behalf at the consortium site itself. This is not an easy task as member firms often times have different visions on where their industry should expand. It takes a dedicated and adroit facilitator to coalesce these sometimes divergent viewpoints into a compromise agenda.

E. TRANSFERRING TECHNOLOGY

Each type of consortium also has its own unique mechanisms set up for transferring technology. However, it is easiest for the second category of consortia to do so. These firms, which provide funding for university research, usually would provide funding for this same research on their own. It is, therefore, in their best interest to jointly support a more expanded research effort by members having the same basic goals. Leverage is gained by joining forces. For the type of basic research sponsored by this category of consortia, technology can be transferred relatively successfully, through conferences, seminars, symposiums, and research papers.

These types of consortia are generally successful, however, they can fail if management is incompetent or the firms are forced to support research they do not want. Neither of these cases are commonplace, though.

The third type of consortia has the hardest time dealing with the issue of technology transfer. Here the basic question is whether or not firms which normally compete can agree on standards which would affect their individual firms. They must accept as true the premise that what is good for the industry is also good for their individual firm. This can be a hard pill to swallow for some.

The Corporation of Open Systems (COS) is an example of how this technology is successfully transferred. Formed to support legislation or protocols to enable different computers and electronic equipment to be interconnected, COS sets standards which member firms must then engineer into their individual products. This centralized standardization has provided savings for American industry since individual firms need not devote substantial R&D for applicable software. The first set of standards was implemented in 1987 and is available to member firms free of charge (via dues required) and for a substantially higher fee to non-members. [Ref. 10:p. 65] COS appears to be working successfully thus far. Only time will tell if it remains viable in the long run.

The technology transfer question is a critical issue for the first category, those firms banding together for long-range R&D purposes. Once competitors agree on the research agenda, will they accept the results? Furthermore, as technology becomes more product and process oriented, the know-how becomes more embedded in individual researchers. This makes it harder to transfer through conferences, seminars, and technical papers.

An example of how one consortium has attempted to resolve this issue can be illustrated by examining MCC. MCC was organized by a group of American computer firms to counter the threat from the Japanese Fifth-Generation Computer Program in 1982. Once the research agenda was codified, technology transfer problems had to be rectified.

MCC's technology transfer policies include technical reports, formal written notices to member firms, and employees returning to their parent firms with new technology in hand. For example, over 800 technical reports have been disseminated to member firms in more than 30 technologies. These include such areas as software, algorithms, computer language, and equipment design. While it can still be debated whether or not MCC was successful in transferring its technology to member firms, an indication of success is the amount of adoption of technology by member firms. Examples include Honyewell's plan to use an artificial intelligence program developed at MCC for production of multilayer printed-circuit boards and Boeing's plan to use packaging technology transferred from MCC in its Seattle laboratories. In fact, the first commercially-produced product using MCC-derived technology is NCRs Design Advisor, an expert system for designers of integrated circuits, placed on the market in June 1987. [Ref. 10:p. 66]

F. OTHER POTENTIAL PROBLEM AREAS

Resource pooling and elimination of wasteful duplication are among the substantial benefits that first category of consortia (MCC and SEMATECH) can potentially provide for producing new technologies. However, agenda setting, technology transfer, and other associated issues still remain as potential problems.

Once again, the problem of member firm acceptance of consortia-developed technology is not a trivial one. Many firms are inherently distrustful of technology which is not developed in their own laboratories.

Professional jealousies play a part as well. Company researchers may tend to feel that consortium research is not the same quality as their own. Also, they may tend to resent this research especially because it may take away from company internal research funding they would be receiving instead. However, most of the large-scale projects cannot be supported solely by a single firm. Joint research is especially imperative and financially productive in these cases. Furthermore, it is almost impossible for a single firm to acquire the necessary talent to be able to compete with other large sources such as universities and government agencies.

In short, this non-acceptance of consortia-produced technology will continue to cause problems unless mechanisms are implemented to counter it. One such mechanism currently in use is that of shadow programs [Ref. 6:p. 15]. Shadow programs are in-house programs which parallel or complement work being done in the consortium itself. In this manner, a company can trust, somewhat more, the external research being provided.

G. UNITED STATES EXPERIENCE WITH CONSORTIA

The use of consortia is not a new concept in the history of American technology. The Aerospace Industries Association, for example, was organized 30 years ag to help develop software for numerically controlled machine tools. Prior to this, the Manhattan Project and Radiation Laboratory of MIT were organized to utilize scientists and engineers for specific projects--both were highly successful in their own right. In fact, the success of these projects in developing nuclear weapons and radiation applications proved to private industry the necessity of cooperation in large endeavors. These projects simply could not have been completed by only one or two scientists in one company. [Ref. 10:p. 63]

Other examples of governmental involvement in large-scale projects have been the Apollo Program, the Space Shuttle Program, and the European Space Program. These projects have had a tremendous impact on the way R&D has been conducted in this country. The issue, however, is whether or not this same intensity of effort can be transferred to the private sector. The private-sector R&D consortium, unlike its government-sponsored cousin, is usually limited to an R&D function and does *not* have production or manufacturing responsibilities. Therefore, it is somewhat critical that the technology developed be adopted by the sponsoring members for eventual inclusion into their individual manufacturing processes. This is one of the critical questions regarding the private-sector R&D consortium concept. Will the sponsoring members accept the technology developed through the consortium and how can it be transferred effectively to all members? Prior to 1984, universities played a prime role in the R&D arena. Oftentimes at the center of the consortium, universities were able to avoid the risk of being harangued on antitrust grounds because of their prime emphasis on research rather than production. However, with passage of the 1984 National Cooperative Research Act this fear among private firms was essentially nullified. Since 1984, more than 60 registered consortia have come into existence as compared to about 20 prior to 1984. [Ref. 10:p. 64]

H. JAPANESE CONSORTIA EXPERIENCE

Even though there are definite advantages to consortium produced research, is it a viable entity for the private sector in this country? Some would point to the alien concept of cooperation in this country, as compared to Japan and some European countries where long term support by government and mutual cooperation among firms is somewhat more common. The tendency in the U.S. has been for consortium member firms to come in for a relatively short period of time, expect high returns, and then depart. [Ref. 6:p. 15] The Japanese and European models point to a much more patient approach.

If consortia are alien to the American culture, what makes the Japanese model so successful? Perhaps the emphasis they place on the problem or goal they wish to achieve, and not on the actual organization itself, provides a clue. The Japanese effort in the semiconductor field tends to focus on specific objectives selected by a number of independent firms and promoted by MITI. The consortium itself only exists for a predetermined period. Once the goals of the group have been met, the consortium disbands totally. There are no reasons to maintain the consortium intact, in the Japanese mind, if the pre-consortium determined goals are achieved. [Ref. 7:p. 551]

I. CAN UNITED STATES CONSORTIA BE SUCCESSFUL?

With the points in this chapter as ingredients and menu for the consortium soup, can the U.S. cook its own success story? Perhaps, but it must take into consideration a number of factors.

The consortium concept can still be considered to be somewhat alien in this country. While the Japanese ethic is "company first", Americans think of their "individual" rights first as a whole. In order for consortia to become effective in the U.S., the mutual suspicion of competitors will have to be resolved. A concern, therefore, would be that these consortia might produce highly specialized products, unreasonably expensive and non-competitive with foreign sources. Such is the case with many defense contractors. Fortunately for them, they do not have to compete on the open market. In essence, their market is built-in for them.

The use of a MITI-type subsidization of an industry can be effective if introduced at the appropriate stage.

Support of these growing industries can cut prices, increase consumption, and speed the sharing of R&D. In the early 1970s, for example, MITI began its support of the Japanese chip industry, a growth industry at that time. U.S. governmental intervention of an embattled industry such as is the semiconductor industry currently, may not be as effective, however. The dynamics of troubled industries, where the firms involved have well established roles and relationships, are quite different. In these situations, consortia have never been proven effective. [Ref. 11:pp. 65-66]

Governmental subsidization (MITI-like) might be an effective mechanism in a new, upstart technology in the U.S., though. Technology such as superconductivity, HDTV, and stealth could all benefit because there is no dominant force on the market at this time.

J. PREDICTIONS

As seen by the number and variety of consortia, this form of conducting research by private sector firms is on the upswing in the U.S.. However, is it really worth the investment or are the individual firms simply protecting themselves against being left behind the crowd should a significant research breakthrough be discovered? In addition, the thorny issue of successful technology transfer is not inconsequential.

Therefore, arguments that consortia are the wave of the future simply because there have been upsurges in their numbers in recent years is too narrow a view. American industry may or may not be able to utilize this type of format successfully. The independent entrepreneur, for one example, would probably never agree to consortium-backed R&D involvement. In fact, just this type of entrepeneurism has brought about a great majority of high-tech products in use. Hundreds of small American chipmakers have found a highly lucrative niche in the specialized memory chip arena. This arena may be where America is best able to utilize its intellectual talent, the small, but innovative, custom chip market.

Analysis of the consortium as a possible R&D organization leads one to conjecture concerning the types of industries best suited for consortia R&D. In fact, one of the most intensively research-oriented industries is semiconductors. The marriage of semiconductors and consortium-organized R&D seems too good to be true. Is it?

The case for the government-subsidized, industry-backed SEMATECH consortium will be addressed in the following chapter.

V. THE CASE FOR SEMATECH

Up to this point, discussions have dealt with rather broad-based issues, albeit focusing of these issues has become narrower and narrower: protectionism, national security reasoning for protectionism, and the consortium as one possible mechanism to enhance R&D in the U.S.. The preceding chapter acknowledged the benefits of the consortium and its synergistic effects on the member firms. However, numerous problems were also shown to be possible, depending on how the consortium is organized and managed. A detailed study of just how the government-subsidized semiconductor research consortium, SEMATECH, came to be and its organizational make-up will now be addressed.

A. REASONS FOR DOMESTIC SEMICONDUCTOR INDUSTRY DECLINE

While subject to much controversy and opinion as to why, many well-meaning individuals argue that the American semiconductor industry, as a whole, is now substantially behind foreign-owned firms (especially the Japanese) in total market share and overall viability. In their opinion, this decline is mainly attributable to the loss of the high-volume DRAM market. This loss is believed to have been caused by some of the following reasons:

- early Japanese government support for their domestic semiconductor industry;

- Japanese governmentally imposed trade barriers restricting Japanese market penetration by foreign firms, mainly American owned;

- dumping practices;

- natural evolution via the life-cycle theory of trade patterns;

- fundamentally different industrial practices between Japan and the U.S. (i.e., MITI involvement with industry);

- differences in industry structure (i.e., vertical and horizontal integration by many Japanese firms).

While each of these reasons are important, the final two are particularly interesting in that they point to a divergence in overall industrial philosophy. If these were the primary causes, it would provide an opportunity for comparing the relative success of one system over the other. This shall be examined later.

B. HISTORICAL BACKGROUND

For quite some time now, observers have been noticing the rather steady decline in American competitiveness in the semiconductor field. In particular, the subset of integrated circuit production has been a controversial subject due to the once dominant level of worldwide shipments which the U.S. enjoyed. In 1975, the U.S. possessed 58% of worldwide merchant production of integrated circuits. At that time, America's closest competitor was Japan with only 19%. Since then, a combination of occurrences has caused Japan to greatly increase her share of the market to a 1986 level of 45%. During this period, the U.S.' level has fallen to 45%. In other words, as of 1986, the U.S. and Japan were at parity in merchant integrated circuit production. [Ref. 12:p. 1] Even more dramatic is the comparison of world market share of Dynamic Random Access Memory (DRAM) chips. In 1975, the U.S. controlled 90%, but by 1986 it had only 5%.

This would seem, to most free market economists, to simply be a result of the natural competitiveness of the free market system. The consumer could only benefit from such actions, and in fact, he has. The cost per bit for DRAM has substantially decreased from 1 cent/bit in 1973 to 1/1000 cent in 1985 [Ref. 12:p. 5]. To a great extent this has been caused by competition which resulted in better and more abundant DRAMs.

Because of the perceived market share loss by American firms, the U.S. semiconductor industry has lobbied for legislative action to counter this decline. Unable to compete successfully, the industry's most recent endeavor is the creation and federal funding of a manufacturing research consortium known as SEMATECH (SEmiconductor MAnufacturing TECHnology). The reasons behind creation of such an organization and its effectiveness to date shall now be examined.

C. DEFENSE SCIENCE BOARD REASONING

In early 1986, the Defense Science Board was commissioned to study the issue of dependency of the military on foreign-produced semiconductors. Based on results of their inquiry, a recommendation was made to support formation of a consortium of U.S. semiconductor manufacturers. What brought the Board to this specific conclusion?

The impetus behind this investigation was the growing belief in foreign domination of so-called "generic" semiconductor production. These generic chips, specifically DRAMs, are ubiquitous throughout the computer industry. That is, they are used by almost all types of computers throughout the electronics industry. In particular, they are important components in most advanced military systems.

One of the basic premises stated in defense journals is the strategic reliance of the U.S. on technological superiority over its potential adversaries. This technology relies primarily on weapon systems containing a high number of electronic components. Of course, the reasoning continues, electronics have the ubiquitous semiconductor as their backbone. Since the semiconductor no longer is produced primarily in the U.S., American defense products necessarily contain foreign-produced components (semiconductors).

The Defense Science Board concluded that this could lead to a dangerous situation: American defense needs relying on foreign sources. Two reasons for this conclusion included: (1) in case of conflict, foreign governments might restrict the sale of vital semiconductors to U.S. defense industries if they disagree with American actions; or (2) the ability to produce defense systems in general may degenerate to the point where Americans would lose the know-how to apply technology to defense needs. In either case, the results were unacceptable according to the Defense Science Board.

If the hypothesis is that semiconductors are vital to American defense needs, how is their availability to be assured to defense contractors? Defense requirements for semiconductors are small compared to commercial requirements (DOD accounts for only 3% of total DRAM sales). If DOD requirements are to be met, two possible outcomes are:

- utilize domestic, commercial semiconductor industry production, taking steps to ensure that sufficient capacity exists for national emergency purposes;

- accept foreign-source semiconductors.

If the second option is unattractive for the reasons stated above, then it follows that the domestic commercial industry must be encouraged to produce, in sufficient quantities, the products that DOD needs. Domestic merchant DRAM producers cannot currently meet these requirement. The issue of captive market producers (i.e., IBM, AT&T) is certainly a factor in deciding if there will exist a domestic-based supply line available in time of war. However, this concern will be addressed later.

A strong requirement by DOD alone will not cause private, merchant market firms to invest the time or capital to meet DOD's need by themselves. Since DOD accounts for such a small portion of the market, private firms must be attracted by the commercial benefits inherent in the industry. SEMATECH proposes to do just that.

D. REASONS FOR JAPANESE SEMICONDUCTOR ADVANCES

Some of the Japanese industrial practices which have contributed to successful growth of their domestic semiconductor industry have been:

- investment of a larger fraction of sales into plant and equipment than U.S. firms (1970-1985);
- high emphasis on R&D investment as compared to U.S. firms (13% vs 10%);
- R&D emphasis has been on technology development which will bring long-term returns vice American R&D emphasis on the shorter-term design of new products to be placed on the market as rapidly as possible;
- a high degree of mutual cooperation between fiercely competitive firms under the direction of the Ministry of International Trade and Industry (MITI) or Nipon Telephone and Telegraph (NTT).

Differences in industrial structure are also important to note: (1) most Japanese semiconductor firms are substantially larger than their American counterparts; (2) most Japanese semiconductor firms are vertically integrated and horizontally diversified. Size and horizontal diversification provides internal R&D funding on a much larger scale, allows for economies of scale and permits Japanese firms to weather the frequent severe downturns in the semiconductor industry (non-semiconductor portions of the firm can subsidize the semiconductor portion). Vertical integration allows the profitable computer and consumer electronics sales to subsidize DRAM production and manufacturing technology development. Many Japanese firms (Hitachi, NEC, Toshiba) consume up to 20% of their own production. [Ref. 12:p. 2]

In addition to the apparent differences in industrial structure and practices, other more basic differences may explain the surge in the Japanese semiconductor industry; these may be related to overall economic and labor variations. For example, lower productivity per worker, and demand for higher wages in the U.S. work force place another barrier in the industrial race for superiority. Also, the tendency in the U.S. market to emphasize adversarial relationships between labor, management, government, and academia create reluctance for cooperation among these same parties. This is just the opposite of what occurs in Japan. Furthermore, employee loyalty is much greater in Japan. This tends to mean the employee becomes experienced in his field, while continuing the normal Japanese business practice of rotation between departments. Experience and loyalty engender a desire for quality which manifests itself positively in the final product. Of course, this same tendency for Japanese workers to remain in the same firm may in turn quash innovation. This issue will be dealt with later.

E. BENEFITS OF UNITED STATES SEMICONDUCTOR PRODUCTION LEADERSHIP

While subjective by nature, several benefits are thought by some to be particularly useful to the U.S.. These include: the previously mentioned national security aspect; R&D uses by other parts of the electronics industry; and strengthening of the entire national economy, particularly the science fields. Of specific interest is the relationship of semiconductor leadership to overall national economic standing.

Studies indicate that the rate of return to society of R&D in electronics is greater than that to the individual firms [Ref. 13]. This would include, according to researchers, an increase in the domestic human talent pool in the sciences due to utilization of these individuals by high-tech industries. Conversely, the decline in numbers of domestic high-tech industries would consequently mean a lack of positions for new employees and a concomitant decline in the talent pool.

Semiconductors will continue to play an ever increasing role in all types of manufacturing processes. As artificial intelligence and robotics become increasingly capable, more and more industries, not only the electronics industry, will utilize their technologies. The heart of AI/robotics will continue to be the semiconductor and its ability to rapidly absorb and transmit massive amounts of information.

Assuming the logic behind the arguments for a strong domestic semiconductor production capability, what recommendations did the Defense Science Board make and what actions did Congress finally take?

F. THE SEMATECH PROPOSAL

To reverse the trend of a decreasing U.S. semiconductor market share, the DSB recommended that the Department of Defense subsidize creation of a consortium of private firms designed to study and create new manufacturing technologies for the semiconductor industry, particularly for the next generation DRAM chips. The output of this combined R&D effort would initially be made available to the member firms, and later, to the entire industry. An infusion of approximately $200 million/year for a total of six years was the initial mandate. This was thought to provide enough impetus to the industry to see it through to its initial goal of producing a 64-MB DRAM chip and transferring this technology to member firms. It was felt that a specific goal (the 64 MB chip) would focus R&D efforts as well as allow sufficient quantification in order to monitor goal attainment. At the end of the six years, federal involvement would essentially cease and SEMATECH would continue only insofar as member firms continued to finance its existence.

A primary concern of SEMATECH would be the discovery/implementation of techniques to transfer the technology it developed to its member firms; not a small task in that all member firms are fiercely competitive outside of the consortium environment. SEMATECH has devised what it calls "transfer teams": individuals from each member firm who are trained, during group sessions, on how best to return the technology developed to their parent firm. It is also thought that the organizational culture engendered by SEMATECH will promote open and frank communication. Hence, additional transfer methods will exist simply because of the professionalism resident in the employees themselves. In addition, SEMATECH has developed a common format and language to complement training of transfer teams as well as common processing and qualification database languages. Each of these steps will necessarily reduce misunderstanding and speed communication; however, only time will really tell if they are a success.

1. SEMATECH Strategies and Tactics

Based on personal interviews with SEMATECH personnel, the organization has devised from its charter a number of specific and general strategies and tactics to achieve the goals envisioned. These are formed around the basic premise that SEMATECH was formed to strengthen America's capability to manufacture semiconductors with totally domestic production content. [Ref. 14]

These strategies include:

- implementation of programs to develop/demonstrate advanced semiconductor manufacturing techniques;
- demonstrating cost effective manufacturing capability on competitive, leading-edge manufacturing demonstration vehicles;
- transferring technology developed to member firms and ultimately to all domestic semiconductor firms.

Tactics developed to implement these strategies include the following:

- periodic group workshops to plan goals and milestones for each step of the process;
- demonstrating manufacturability of each unit process and manufacturing system on appropriate production lines;
- building a generic manufacturing plant for use as a laboratory to demonstrate processes developed;
- emphasizing environmental, health and safety considerations in the development of state-of-the-art manufacturing processes with regard to hazardous materials, effluents and waste;

- utilizing only U.S.-owned, U.S. located suppliers of equipment and materials;

- providing coordination for academic research in eight major universities throughout the country to complement SEMATECH's hands-on R&D;

- utilizing outside sources as much as possible for specification of standards, selecting vendors, and co-development of all required systems in place of SEMATECH personnel.

2. Funding

As mentioned earlier, the estimated operating budget for SEMATECH is $200 million per year. Fifty percent of this comes from the Department of Defense, via DARPA (Defense Advanced Research Projects Agency). The other half if raised by annual dues required of member firms. Currently 13 firms comprise the core body of SEMATECH. Each of these firms pays a minimum of $1 million annually, with many paying more depending on whether they are a merchant or captive producer, end-user, or non-semiconductor member. In addition, each SEMATECH member must agree to join the Semiconductor Research Corp (SRC), which has its own separate dues ranging from $65,000 to $2.4 million, depending on company size, plus a one-time sign-up fee of $62,000.

Therefore, member fees are not solely constrained to the $1 million minimum required by SEMATECH. They may be closer to $2 million. [Ref. 15:pp. 30-34] For small, upstart companies these fees may be prohibitive.

3. Employees

At the onset, employees of SEMATECH came from each of the individual member firms in order to facilitate start up and lend experience in the technical and leadership areas. As time progresses, SEMATECH expects to direct hire approximately 50% of its employees, with the remainder consisting of loaners from the member firms. Each firm assigns individuals based on the proportion of funding it is providing, up to a ceiling of 10% of the total. Salaries are provided by the individuals' parent firm while assigned to SEMATECH, although this amount is credited to the firm's account when assessed its annual membership fees.

4. Member Firms

As of May 1989, SEMATECH consisted of 14 semiconductor corporations, the majority of which are well known. They are:

- AMD
- AT&T
- INTEL
- IBM
- DIGITAL EQUIPMENT

- HARRIS
- HEWLETT PACKARD
- NATIONAL SEMICONDUCTOR
- ROCKWELL
- LSI LOGIC
- MICRON
- MOTOROLA
- NCR
- TEXAS INSTRUMENTS

The network that SEMATECH has developed does not, of course, end here. Several dozen other supplier companies provide basic components to SEMATECH. One of the most critical of these is Monsanto's Electronics Materials Company (MEMC), based in Palo Alto, CA. MEMC is the U.S.' sole producer of 8-inch silicon wafers, which are the basic cutting blocks from which semiconductors are produced. SEMATECH plans to rely upon MEMC's 8-inch wafers because it is the only domestic producer of this raw component.

The problem which has now developed, however, is that as of April 1, 1989, MEMC is owned by a foreign firm, Heuls AG of West Germany. This would seem to run counter to SEMATECH's basic premise of utilizing only domestic suppliers. In allowing the sale of MEMC to the West

Germans, the Bush Administration heeded the recommendations of the Committee on Foreign Investment in the U.S. (CFIUS) which agreed that "the Heuls acquisition represents the best opportunity to strengthen this business and provide a strong manufacturing base and research and development effort in the United States." [Ref. 16:p. 1]. Apparently an exception would be made to the rule of domestic-location, domestic-ownership. It can only be theorized that CFIUS felt this particular sale would cause no national security problems in the area of restricted supplies. An apparent loophole in this requirement is that foreign-owned suppliers are not eligible to participate in SEMATECH if an American-owned producer is available. Obviously, there is no other American-owned producer of 8-inch wafers, therefore, inclusion of MEMC in the SEMATECH organization is legitimate. However, this raises basic questions as to the future reliability of such a policy of foreign exclusion. Where in fact do you draw the line? What happens when Hitachi buys out a major American producer? Is it allowed to continue as a SEMATECH supplier? Adequate evaluation of possible long-term implications are required.

5. SEMATECH Accomplishments

As stated in its own words, SEMATECH's accomplishments since inception have been numerous. These include:

- ability to construct cost-effective, world-class fabrication facilities capable of manufacturing 0.5 micron technology;

- production of 64K Static Random Access Memory (SRAM) chips;

- completion of 27 different workshops throughout the country to focus specific technological targets;

- organizing the relationship between DARPA and SEMATECH in the face of legal issues such as antitrust, taxation, proprietary rights, etc.;

- coordinating the foundation of Centers of Excellence at six American universities to study specific topics: Contamination/Defect control, Lithography and Pattern Transfer, Single Wafer Processing,Plasma Processes, On-Line Analysis and Metrology, and Sub-Micron CMOS. In addition to these research areas, each university agreed to develop curricula to emphasize manufacturing disciplines at the graduate and undergraduate levels;

- establishment of Semi/SEMATECH. Members of Semi/SEMATECH are suppliers of materials vital to SEMATECH's R&D efforts. Mainly small businesses, membership permits these firms to receive timely notification of SEMATECH developed initiatives and standards for incorporation into their own production lines.

6. DOD and SEMATECH

While DOD has the already mentioned objective of ensuring the long-term viability of the domestic semiconductor industry, SEMATECH literature also states the following as having potential DOD value:

- because SEMATECH is a unique organizational form for American industry and government, its success could facilitate future innovative industry/DOD efforts that avoid the costly DOD procurement procedures;

- factory modernization will ensue from enhanced production technology;

- R&D tends to be stable since membership is required for a minimum of four years precluding premature loss of funding by dissatisfied firms;

- increased DOD savings due to emphasis on lowering manufacturing costs;

- quality control is a prime requirement for any technology developed, minimizing the need for extensive after-production testing;

- reduced need for DOD defense specifications and special processes in manufacturing due to SEMATECH's emphasis on generic technology;

- rejuvenation of domestic technology skills and education.

7. Risks

SEMATECH certainly possesses the normal risks associated with any new, unknown organization--success or failure are not guaranteed. However,this is not a unique situation. More specific potential problems and their risks will be:

- Rate of Diffusion of Developed Technology. Slow rate of transfer of technology will cause technology to be outdated before its use. Statistics bear out the fact that leading-edge technology is oftentimes outmoded after 6-12 months of use. On the other hand, a too rapid rate of diffusion might imply utilization by foreign competitors, thereby undermining the basic reason for SEMATECH's creation. In addition, U.S.firms with access to SEMATECH produced technology might decide to incorporate this technology in their overseas facilities with possible spread to competitive, foreign-owned firms. Even if foreign-owned firms do not acquire timely technology, the foreign subsidiaries of U.S. firms might be given these advanced manufacturing techniques, thereby further exacerbating the movement of the semiconductor industry to foreign shores;

- Collusion. SEMATECH member firms might decide to try and corner the market on technology developed in the consortium. This would certainly lead to advantages for member firms. However, the SEMATECH charter requires developed technology to be made available to nonmember firms after a sufficient period of time (through royalty fees). Theoretically, collusion should not occur;

- Centralization of Research Agenda. Innovation by individual firms on non-agenda research will tend to be very difficult. Diversity tends to be lost in order to avoid research duplication;

- Organizational Riskiness. Due to the limited level of experience in the U.S. with consortium arrangements, historical precedence cannot be counted upon to extrapolate possible conclusions;

- Involvement of federal government. Federal participation is currently limited to funding and providing advice to management. However, there is always the possibility that should SEMATECH either fall behind schedule or fail to meet required milestones, the Federal Government could step in and dictate policy to protect its vested interest in SEMATECH's success.

G. INDUSTRY/GOVERNMENT OPINIONS AND VIEWPOINTS REGARDING SEMATECH

From the onset, SEMATECH has had its proponents and critics. A review of the literature brings forth a wide spectrum of opinions, often with contradictory facts and conclusions based on extrapolated data from various sources. The following is a brief synopsis of the general cross-section of industry, government and academic writings regarding SEMATECH and its espoused goals.

H. PROPONENTS

Jon Cornell, senior vice president of Harris Corp's Semiconductor Sector and a SEMATECH board member, believes SEMATECH is the only choice U.S. chip makers have for survival. Government involvement is essential, he states, because "the semiconductor industry does not have the resources to get the SEMATECH effort promptly underway and keep it moving speedily towards its objectives". Cornell indicates that the U.S. defense program and America's entire industrial base is at risk if the dearth of domestic semiconductor production capability is not addressed. The concerns of smaller companies that SEMATECH's focus and membership costs are unrealistic is unfounded in Cornell's opinion. Not all small companies need to participate in such an endeavor, he says, but if they do, the fees are an investment in a highly leveraged opportunity. A small member firm would realize a multiplier effect in its R&D capability by joining SEMATECH, Cornell believes. Cornell states that SEMATECH is probably the only means for the industry to survive at this point, even though cooperation between firms competing for the same technology is unnatural. Entrepreneurship will not carry this industry into the future by itself. [Ref. 17:pp. 11-13]

Charles Sporck, president of National Semiconductor Corp, was one of the earliest lobbyists for government-industry collaboration and the chief architect of the SEMATECH concept. Sporck believes that only an organization like SEMATECH can infuse the industry with the required amounts of funds to devise techniques for manufacturing tomorrow's superchips. Sporck's tactic in convincing reluctant Administration officials to take this path was a warning that the Reagan Administration had to make a difficult choice: either a strong economy or free trade. Sporck believes that free trade is at the root of America's economic woes. "No country can tolerate open markets if that means losing its most advanced technology and its ability to sustain its standard of living", declared Sporck.

He believes the long-term solution should be managed trade, in line with the 1986 semiconductor trade agreement with Japan. However, with lack of a clear consensus on such a radical economic approach, SEMATECH is the best alternative, he believes. [Ref. 18:p. 116A]

Gilbert Amelio, president of Rockwell's Semiconductor Products Division, states, "Their (the Japanese) strategy was intentionally devised to overwhelm anything that private industry can do by itself". This was in response to the comment that for two decades the Japanese model of industry-government collaboration has targeted and then dominated selected markets such as compact cars, cameras and consumer electronics. According to Amelio, SEMATECH is the latest move by domestic chipmakers to fight back against devastating competition from Japan Inc (Japan Inc is the term used for the conglomeration of large Japanese firms and Japanese government supports backing these firms). Amelio counters critics' arguments that American industry will never be able to successfully cooperate on such a large scale with the fact that firms came to him with pledges of financial support even before he solicited them. Amelio was president of the Semiconductor Industry Association (SIA), SEMATECH's parent organization, at the time. He believes patriotism has been aroused and that this groundswell of support will overcome parochial jealousies. [Ref. 19:pp. 62-63]

George Schneer, a vice president for Intel Corporation, states that "The U.S. semiconductor industry is basically at the brink of starvation because of a lack of manufacturing competitiveness". He explains that U.S. chip companies have fallen anywhere from three to five years behind their Japanese counterparts and that this has been particularly devastating in the commodity markets, where manufacturing is crucial. [Ref. 15:pp. 30-34]

Andy Grove, CEO of Intel, discounts the once perceived problem of Japanese "dumping" of chips on the American market, "...the American computer industry is not at a disadvantage because of the suitcase (dumping) problem). The biggest danger the computer industry faces is the disappearance of its principal domestic supplier. In fact, the U.S. computers would be in mortal danger if American semiconductors were destroyed". He goes on to state that "The industry has become very brutal, very heavily financed by every government - ours being the last to get involved." "The Sematech consortium is a way for the industry to support its suppliers by defining clear targets to shoot after, so that we do not, in turn, get too dependent on overseas vendors for manufacturing tools. Members will get a degree of security for development and direction." [Ref. 20:pp. 43-45]

Bob Noyce, co-founder of Intel and CEO of SEMATECH, is aware of the difficulties inherent in organizing SEMATECH to overtake Japanese IC production. However, he indicates that if successful, SEMATECH will probably set the pattern for future government-industry endeavors, "What we've seen in the Japanese model is that a consensual society can do some things better than a strongly competitive society". [Ref. 21:pp. 76-79]

I. JAPANESE INTEREST

Japanese firms, for obvious reasons, are closely scrutinizing SEMATECH's progress as well. Expectations are that SEMATECH will likely endanger Japan's superiority in memory chip production. In addition, it is believed that this portents increasing difficulty in obtaining U.S. technology which is crucial to the design of basic software that determines the functions of semiconductors, especially memory chips (Texas Instruments provides many of the basic designs). It is foreseen that Japanese chipmakers will no longer be able to rely on their superior and more efficient production techniques. Rather, they will have to strive for basic improvements in circuit design and software issues. [Ref. 22:p. 1066]

J. OPPONENTS

While the above opinions are essentially pro-SEMATECH, there were a number of misgivings as well. One issue was the apparent lack of support SEMATECH was receiving from the numerous small chip makers. Zilog Corporation's Ed Sack believes, "...SEMATECH is missing the point". Cypress Semiconductor's T.J. Rodgers thinks that SEMATECH is nothing more than a plot by the large firms to "...take care of their real competition: the smaller firms." "It's going to be hard to take the market away from the Japanese, where they are doing well, and it is dumb for the government to undertake it. Our Strategy (at Cyprus Semiconductor) is to stay where we are strong. And that is in innovative design and quick, value-added marketing", he adds. Others seem to be indifferent, such as Gordon Campbell of Chips and Technologies, Inc., who say, "We don't care very much about manufacturing.", he adds. Even Charles Sporck acknowledges the divergence in success between large and small firms: the large ones declining in power, while the small, upstart firms are increasingly capturing the next generation of technology, particularly through their use of customized chips. Most of these innovators do not plan to participate in SEMATECH, which could, in the long run, undermine SEMATECH's ability to produce state-of-the-art technology.

Larry Jordan of Integrated Device Technology Inc., also strongly objects to joining SEMATECH, "We are not able to realize any gains from industry associations. We run at the front edge of technology now. ...We're ahead of everyone else." Tom Longo of Performance Semiconductor Inc., feels that, "We'll end up giving away more than we are getting."

Even the basic direction of SEMATECH is cause for concern by some. Zilog's president, Sack, believes SEMATECH "is not a decisive element in the solution to the problem we are facing." He argues that manufacturing is not the issue, rather the lack of vertical integration which causes poor return on capital.

Others fear government involvement, no matter how non-intrusive. "If government funding means government management, then I have a problem with that", states Performance Semiconductor's Longo. Federal involvement, specifically DOD, is even thought by some to be a major cause of American loss of competitiveness. Scholars interject that military spending has siphoned off large numbers of engineers and scientists to work on defense-related projects (missiles, high-energy lasers) at the expense of commercial products like VCRs, printers, etc where the Japanese concentrated their efforts. "It's not DARPA's mission to provide aid to industry", says Michael Borrus, Deputy Director of the Berkeley Roundtable on the International Economy at UC Berkeley. Even more to the point is Brookings Institution senior fellow, Kenneth Flamm, who believes civilian industry should be supporting the Pentagon, not the other way around. "Some of those national security rationalizations are just that--rationalizations", he says [Ref. 23:p. 8].

In defense of DARPA, however, it must be stated that historical precedence seems to be in its favor. DARPA has long been the leading provider of Federal funds to universities for computer research. In fact, many fundamental computer technologies in use today can be traced to its backing, such as the graphics techniques used in the Apple MacIntosh, time-sharing, and packet-switching used in local area networks. With these kinds of success stories under DARPA's belt, SEMATECH could do much worse with a different federal agency.

K. RELATED ISSUES

1. Technology Loss

Concerns over probable technology loss are also issues confronting SEMATECH. Critics argue that SEMATECH's edge will diminish as developed technology leaves the organization via member firms' offshore facilities, direct deals between member firms and foreign firms, and resignation of employees with access to the latest technology. Mechanisms to ensure adequate domestic harvesting of data may or may not be possible.

2. Is SEMATECH's Emphasis Correct?

Arguments espousing a different direction than that taken by SEMATECH merit further consideration. SEMATECH currently focuses on the memory-chip market, one which Japan clearly dominates, and where Japan appears to enjoy comparative advantage over the U.S.. From a commercial viewpoint, it might make more sense for DOD to strengthen markets where domestic industry already has the lead: low volume, high-performance products. These also tend to be where the military requirements are found--customized designs in low volume.

L. OTHER GOVERNMENT-SPONSORED PROGRAMS

Outcomes of government support programs for other declining domestic industries might provide clues as to the viability of SEMATECH. Recent voluntary restraint agreements (VRAs) designed to give domestic auto and steel industries a chance to adjust to increased foreign competition have done little to reverse the declining U.S. market share. While temporary improvements occurred in the auto industry(imports dropped to 23% at the height of the VRA period), they rebounded to 29% upon completion. [Ref. 24:p. 50] The steel industry's actions are equally as dismal. Even after the 1984 Steel Import Stabilization Act, carbon and specialty steel shipments continue to decline, as do profits and employment. The more nebulous areas of R&D, where SEMATECH is focused, might be even more difficult to guarantee success based on the results of these latest government endeavors.

Governmental involvement in the VHSIC project also shows a possible scenario for SEMATECH. The very high speed integrated circuit program was developed to design radiation-resistant microelectronics technology and production capabilities. While a 1986 Office of Technology Assessment report indicated attainment of basic goals, the actual production line establishment fell well short of requirement and delays of up to a year occurred due to unrealistic goals. It might be possible that similar delays will occur when SEMATECH's member firms attempt to apply to high-volume production lines the medium-volume techniques developed at SEMATECH. In the dynamic environment of semiconductors, after a 6-12 month delay, technology may already be outdated. [Ref. 24:p. 51]

M. SEMATECH: CAN IT WORK?

As can be discerned from the myriad of opinions, alleged facts, and precedence, a likely outcome of the SEMATECH project will be difficult to predict at best. So-called experts on both ends of the spectrum hold strongly to the viability or the foolishness of such an organization. What is clear, however, is that several issues have not been addressed satisfactorily. Are the goals too ambitious? Did the Defense Science Board, which recommended the SEMATECH proposal, adequately consider alternatives? Is the national security reasoning employed by industry executives an actual threat in today's interdependent world or merely a ruse to gain political leverage? Is American corporate culture even able to assimilate the radical concept of competitive cooperation or will individualism present problems?

Japanese society tends to be efficient, diligent and homogenous. American society in many ways is unique and draws it previous successes on the concept of entrepreneurship. Is it realistic to think that the Japanese model will be assimilated into the American scheme as easily as SEMATECH would propose?

These and other points will be analyzed as to their merits and possible deficiencies in the final two chapters. Possible outcomes and predictions will be detailed in the concluding chapter. While no definitive answer may be possible, one can theorize with a fair degree of confidence some possible scenarios and their likely solutions.

VI. CONCLUSIONS

As mentioned previously, several points deserve special investigation when considering both the intent in establishing SEMATECH as well as the long-term viability of such an organization. These include the rationale behind national security implications, possible alternatives satisfying DOD fears, and both the short and long-term viability of SEMATECH's organizational structure itself. Each has merits which may have influenced the ultimate decision to form SEMATECH or which may provide clues to SEMATECH's future.

A. SEMICONDUCTOR/NATIONAL SECURITY OVERLAP?

Do current trends in the semiconductor industry pose national security risks? In other words, is national security really jeopardized if a majority of the semiconductors used in defense products come from foreign sources?

The U.S. has been involved in several international conflicts in recent years (Lebanon, Grenada, Persian Gulf, Libya). While these were relatively short duration conflicts, there have never been any repercussions or restrictions of vital foreign-sourced weapons components. Does this mean such restrictions could never happen? Obviously not; however, the interdependence of military cooperation between the main chip suppliers such as Japan and the European community, and the U.S. military, is substantial.

Until recently, even the Pentagon itself appeared unconcerned with the implications of foreign-produced electronics. As an example, in 1986, either to cut costs or reward its allies, the U.S. awarded more than $9 billion worth of contracts to foreign firms--approximately 6% of total procurement. [Ref. 24:p. 47] In October of that same year, the Air Force purchased a major weather tracking and flight scheduling computer system of foreign origin. While the company may have been American (Honeywell), the system itself utilized mainly NEC (Nippon Electric Corporation) supplied semiconductors, processors, and circuitry.

B. CONFLICTING RESPONSES

An interesting example of what might be an underlying reason for the semiconductor industry emphasis on national security is the attempted Fairchild-Fujitsu sale.

In late 1986, Fujitsu revealed plans to purchase 80% of Fairchild Semiconductor. At that time, Fairchild was the second largest supplier of chips to the U.S. military. Since these chips were used for advanced computers, military systems and nuclear-weapons communication systems, both industry officials and politicians alike claimed a potential national security risk if Japanese control were permitted. Politicians, in particular, decried the loss of jobs they believed would occur and possible antitrust violations which would ensue. Finally, after it saw the writing on the wall, Fujitsu withdrew its offer.

Was the takeover bid indeed a threat to national security? Over 95% of the products provided by Fairchild to DOD were available from other domestic producers. Also, the loss of jobs issue might not, in fact, have occurred at all. Fairchild had been doing so poorly in the previous seven years that it had already laid off 20,000 employees. The infusion of fresh capital by Fujitsu might even have increased employment.

As it turned out, National Semiconductor subsequently purchased Fairchild for a fraction of the Fujitsu offer. Due to this merger, National Semiconductor became the 6th largest semiconductor manufacturer in the world, thereby increasing its own potential for antitrust violations. However, the semiconductor industry historically has been calling these antitrust rules too strict, not lax, thereby inhibiting cooperative R&D ventures.

Finally, why was there not a national security outcry in 1979 when Fairchild was purchased by the French-owned company, Schlumberger Corporation? Is there a double standard or do the semiconductor industry and Congress really feel that they have nothing to fear from French dissatisfaction with U.S. foreign policy? Robert Christopher, author of *Second to None: American Companies in Japan*, notes that "Any suggestion that the French are more responsive to American defense concerns than are the Japanese is patently absurd." [Ref. 24:p. 49]

There are also misgivings as to the validity of the statistics used to show America's overall decline in semiconductor production. While the Japanese have made substantial increases in certain areas of the chip market, notably in the low-profit, high-volume commodity-chip field, this amounts to only about 15% of the total U.S. market for semiconductors. Even this figure may still be misleading since it does not include domestic captive producers such as AT&T and IBM. Including these two firms alone, the U.S. world market share rises from 44% to about 57%. [Ref. 25:p. 9]

In particular, the Japanese only lead the U.S. in production of the DRAM at this stage. This is the most basic and commonly produced type of chip and demand fluctuates, sometimes drastically, for it. In 1986, the top five Japanese DRAM chipmakers--Hitachi, Toshiba, Mitsubishi, NEC, and Fujitsu--had drops in profit of from 50% to 80%. On the other hand, as earlier noted, U.S. firms have substantial leads in the specialty chip market and next generation chips. Some industry analysts even feel that the Japanese may have made a strategic mistake by concentrating so heavily on this one aspect of the semiconductor industry, DRAMS, at the expense of future changes in technology. [Ref. 25:p. 10]

It is also interesting to note that those firms crying the loudest when the specter of Japanese dumping occurred in 1985-86, were just those medium-sized firms whose main impetus continued to remain in the DRAM market. Unable to compete with the monolithic Japanese makers, these firms lobbied and won approval from Congress for protectionist legislation. Could it be that these firms had simply "missed the boat" on what consumers desired and were trying to protect their substantial capital investment? Charles Sporck, CEO of National Semiconductor (one of the firms directly affected by the Japanese DRAM invasion), became the prime industry spokesman for government intervention via the SEMATECH avenue and a vehement critic of the Japanese intrusion into the U.S. market. His motives could have been as much self-preserving as altruistic.

As it stands now, the world's most profitable semiconductor firms are the small start-ups who are focusing on the limited production, but custom-made, chip. The trend in electronics is toward smaller and smaller chips with more densely packed transistors-more storage capability/chip, in other words. It is not the chip manufacturing aspect which holds the future, according to some analysts; rather, it is the design of new, more sophisticated chips [Ref. 25:p. 10]. This follows the trade pattern of product life cycle. As a product becomes more standardized, firms find that less developed countries may offer competitive advantages as production locations. In other words, the production of DRAM chips will best be performed in countries such as Korea and Taiwan where labor costs are even lower than in Japan, and certainly lower than in the U.S.. [Ref. 26:p. 202]

In particular, this emphasis would greatly benefit the military whose weapons and other applications require custom designs produced in low volume. It, therefore, is highly debatable as to whether SEMATECH's espoused goal of regaining the American lead in manufacturing technology for national security reasons will even be valid in the future. Could SEMATECH become a dinosaur even before its original 6-year mandate is completed? Some think so.

C. CONCERNS

One of the prime concerns of the DSB, in recommending to fund SEMATECH, was the belief that the semiconductor industrial base should conform to a certain norm: domestic ownership and domestic production. This means American owners and production facilities physically located on U.S. territory.

Other possible scenarios where chips could enter the merchant market are:

- foreign ownership, domestic production. In the auto industry, Honda and other Japanese firms have plants throughout the U.S..
- domestic ownership, foreign production. National Semiconductor possesses this type of relationship in Japan.
- foreign ownership, foreign production. Obviously,this is how a majority of the DRAM chips enter the U.S. market.

Why is the first scenario (domestic ownership/location) the only acceptable alternative for defense critical chips? For instance, it seems that the foreign ownership/domestic production scenario would be just as reasonable. If the foreign owner was restricted by its government in selling these components, the U.S.could still ensure supplies through nationalization of the plant. While admittedly a fairly radical solution, it does ensure open supply lines in time of crisis. The Fujitsu-Fairchild pact would have been such a scenario. The Monsanto Electronics Materials Co. relationship with SEMATECH is an example of just this type of scenario, since MEMC is now German owned. Obviously, DSB's desire to keep these firms solely domestic owned/located is not being met. Perhaps unnecessary limitations are being placed on the defense establishment by restricting vital component suppliers to being domestically owned/located.

Another factor to consider is the differences in technical edge required between the commodity market chip and the specialty market chip. While the commodity market chips do have a greater proportion of total market output, the specialty chips, in fact, require technical superiority in their design and production. Clearly, the technical edge resides in the specialty chip market. Therefore, if DOD derives its technical edge from these specialty chips, the concern of losing U.S. ability to design, using these same chips, is unwarranted. Specialty chip leadership, residing in the U.S., seems to certainly lessen this aspect of the DSB national security concerns.

D. ALTERNATIVES ASSUMING NATIONAL SECURITY RISK EXISTS

Several alternatives to SEMATECH, which may be less expensive, yet continue to guarantee DOD's requirements for semiconductors, are also possible. They may be less glamorous, but equally as effective.

1. Strategic Stockpiling

The Defense Science Board itself suggested one possible scenario would be the strategic stockpiling of semiconductors in the unlikely event of interruption. If legitimate concerns arise concerning a possible prolonged interruption, domestic captive producers (IBM, AT&T) could be designated as back-up suppliers during a national emergency.

2. Diversity of Foreign Sources

The very fact that numerous countries now produce commodity chips itself is a safeguard, so to speak. It is highly unlikely that the U.S. would go to war simultaneously with Japan, Korea, Taiwan or Europe. In addition, there are prospects of further commodity chip production in countries such as Brazil. If the U.S. continued to cultivate relationships with a diversity of foreign suppliers, a total cutoff of commodity chips to DOD during war, or simultaneous political disagreement with several of theses nations, would, in all likelihood, never occur.

3. Buy American

Another alternative suggested by historical precedence might be the Buy American campaign of earlier years. While this might have its attractions to labor unions, domestic industries, Congress, etc., it is actually better for DOD to seek the best, most cost effective, technology wherever it can be found. If this happens to be a foreign-owned firm, then so be it. This is especially true in light of recent U.S. experiences with the steel and auto industry where protected industries failed to upgrade their own technology significantly. A requirement to buy only American made products may, in fact, jeopardize the DOD premise of technological superiority in countering an opponent's numerical advantage. Additionally, Buy American policies tend to drive defense costs up and reduce overall foreign military sales. This exacerbates both government and trade deficits. Therefore, while Buy American is an alternative, it can lead to other problems. In reality, DOD should remain free to scan the entire international market, for both best technology, and best economy.

4. International Agreements

Even while SEMATECH is ongoing, member firms continue, in their best interest it must be said, to foster joint ventures with major foreign peers. Examples include: the Motorola and Toshiba pact; the National Semiconductor and NMB Semiconductor (Japanese) agreement to design, make and sell semiconductors in Japan; and the Honeywell, NEC and Compagnie des Machines Bull of France supercomputer cooperation pact. Advanced Micro Devices also has agreements with both Sony (marketing and technology) and West Germany's Siemens Corporation (sourcing).

What these pacts provide is a type of synergism and symbiosis. In particular, the 1986 Semiconductor Protection Act provided even more impetus for U.S./foreign cooperation. The pact encouraged more and more Japanese companies to locate plants in the U.S. to avoid tariffs to their U.S. customers, while joint ventures in Japan allow U.S. firms to gain access to valuable manufacturing technology. In addition, it is unlikely that Japan will move to restrict these arrangements themselves or to restrict export of crucial components made either jointly or solely by domestic firms. Japan relies extensively on U.S. military protection because of its constitutional restrictions on military spending. The U.S. is also the source of most leading-edge chip and software technology. Therefore, it can be considered to be in Japan's self-interest to provide the most reliable components to the U.S. commercial and military markets. Does this mean they always will? Perhaps not, but the risk they would incur makes the alternative unlikely at best. One-on-one international cooperative ventures, therefore, provide stability in and of themselves to the semiconductor industry and tend to ensure a steady flow of chips for domestic requirements.

5. Captive Producers

As mentioned earlier, the domestic, captive market segment is quite sizable. IBM and AT&T could easily provide all the DOD requirements for commodity chips if needed in an emergency. So long as captive producers exist, and there is no reason to believe that IBM will rely on outside sources for its chips, DOD currently has in place a domestically owned and domestically located supplier.

6. Advanced Chip Programs

DOD could sponsor specific firms to develop and produce both specialty and commodity chips for its own use.

While DOD itself is not an economic factor to the total semiconductor industry, it certainly could be to individual firms, if the majority of their contracts were to be government oriented.

The point behind listing these possible alternatives is to show that alternatives do exist. SEMATECH does not have to be the only means of ensuring a continual flow of defense-critical semiconductors. The argument that because foreign-owned semiconductor firms currently dominate the commodity chip merchant market, then national security must be imperiled, is much too narrow-minded and simplistic in today's interconnected and interdependent world.

E. VIABILITY OF THE ORGANIZATION

The question of SEMATECH's organizational form brings short-run and long-run questions to mind. Unlike previous R&D consortia, such as MCC, where not all member firms have equal access to ongoing R&D, SEMATECH is structured under the premise that all members be allowed and encouraged to participate in all research. Since SEMATECH is under a 6-year federally subsidized mandate, its plan of action, so to speak, is scrutinized yearly by DARPA. This supposedly ensures a continual focus on the goal of developing technology to mass produce a 64MB DRAM by 1992. In the short-run, therefore, SEMATECH's financial viability is somewhat guaranteed. It cannot be totally guaranteed, of course, because Congress could cut federal funding or member firms could leave. Although to prevent this, member firms must commit to a four-year financial period.

SEMATECH's short-run goals, however, are somewhat more uncertain. This is due to two uncertainties: technical and market. Technical uncertainty deals with the probability of developing whatever technology SEMATECH envisions. There is always a risk involved in R&D; however, with the numbers of talented scientists from each member firm there is at least a reasonable percentage of success here. Market uncertainty, though, can be quite a different factor, especially in an area where others seem to have comparative advantages. Therefore, it is by no means assured that SEMATECH's emphasis on re-taking the DRAM production lead from the Japanese will be successful in light of the Japanese comparative advantage.

In the long run, the critical question is what happens after direct federal involvement ends? What are the procedures for choosing R&D projects? Interviews with SEMATECH representatives indicate that much the same produces that are in place currently will be continued.

That is, periodic strategy sessions are held with representatives from each firm and long-term decisions are made via group consensus. Small firm and large alike are given equal billing in this forum. Without the focusing attention of the initial 64MB DRAM goal, problems may indeed arise between firms whose long-term vision and on-going internal R&D Programs do not match. This could bode poorly for future viability. Japan's MITI, while not always successful, provides funding efforts focused on a specific goal. Once this specific goal is achieved, the MITI-sponsored cooperative pact is disbanded. The member firms do not continue on their own initiative.

SEMATECH expects to remain a productive entity in spite of the potential problems described. Realistic? Probably not, but that is a risk the individual firms will need to assess when conflicts arise. By this time, the Federal side of SEMATECH will presumably be over.

F. CONCLUSION

In the final analysis, is SEMATECH the best way for the U.S. taxpayer to spend $100 million/year for six years? For the following reasons, gleaned for the arguments for and against SEMATECH as already stated, there is reason for skepticism.

- Does Japanese superiority in DRAM production pose a national security risk? No evidence, historical or otherwise, indicates that our strongest allies will restrict militarily-important industrial components. Besides, there are mechanisms available to ensure adequate short-term, and probably long-term, supplies in case of a crisis (via captive producers, for instance);

- Are SEMATECH's goals properly focused? While the 64MB DRAM certainly has numerous potential payoffs, it is competing directly with Japan in an area where Japan seems to have developed a comparative advantage through its years of experience in this field. Federal funding might be better directed toward quantum-leap technology, in areas where no particular nation has yet achieved superiority, in order to receive adequate payback for its investment;

- Is DOD the appropriate sponsor for SEMATECH? DOD has no inherent responsibility for the commercial viability of the semiconductor industry. As it currently stands, the $100 million annual federal support comes solely from the DOD budget, ultimately at the expense of other projects. Because of its commercial focus, SEMATECH might more naturally be sponsored by a commercially oriented agency such as the Department of Commerce. Furthermore, SEMATECH should not preclude investment by DOD in more directly beneficial areas;

- Is SEMATECH directed at the proper market segment? American industrial strength, historically, has been especially viable in the entrepreneurial setting. The U.S. does not need to worry about the relatively low-tech DRAM and the dominance by foreign firms in this field. The fact that other countries are able to produce commodity chips at a comparative advantage to the U.S. simply indicates DRAMs are in the mature, standardized product life cycle stage. This is a normal and expected evolution of all products. [Ref. 26:p. 201]

- Federal funding might be better used to combat the dearth in scientific and other technical majors in the educational system. Ultimately, these graduates will continue to expand the horizon of the scientific world through commercial entrepreneurial and leading edge firms. The small start-up semiconductor firms who specialize in customized chips have the highest profit margin and are the most successful section of the entire world-wide semiconductor industry. Creativity and innovation is what needs to be subsidized, not mass production of already established techniques;

- SEMATECH's long-term viability is uncertain. After attainment of successful 64MB DRAM production, it may become difficult to find agreement between the large and small member firms. Their respective focus may be on different segments of the semiconductor industry. In addition, many member firms may have strong internal R&D capabilities. This increases the problem of setting long-term goals because member firms will want consortium projects to complement, not duplicate, their on-going internal projects. Furthermore, firms with the strongest internal R&D capabilities may be hesitant to share their talents with those firms that have weaker (or no) internal programs.

- The U.S. may have to accept the internationalization of high technology as a given. America is no longer living in a world where her preeminence is guaranteed. Cooperation among technologically advanced nations may have to be more pronounced. Protectionism will only tend to inhibit the mutual benefits of utilizing each other's specific skills toward producing a common product; a product which neither one might be able to manufacture on its own.

G. PERCEPTIONS

While the semiconductor industry in the U.S. has its ups and downs, it essentially is no different than any other industry. Some segments of it are stronger than others. SEMATECH concentrates on one such segment: the low-profit, high-volume commodity chip production market. Can and should we save this segment, or should we concentrate on segments where we have a comparative advantage? More fundamentally, is the threat real or perceived? Is the situation the semiconductor industry finds itself in a natural trade pattern in the product life cycle? SEMATECH was proposed, after all, as the best solution to counter this perceived Japanese threat to the U.S. semiconductor industry.

SEMATECH's short-run viability depends on whether the U.S. can and should salvage a market segment where Japan and others (Korea, Taiwan, etc) appear to have developed a comparative advantage. SEMATECH's long-run viability depends on its ability to coordinate the diverse interests of its members. The national security benefit depends on the importance of retaining a domestic merchant capability in low-profit, high-volume commodity chips and on SEMATECH as the best alternative for maintaining this capability.

Encouraging a free and open market for entrepreneurs, our real strength, and funding education programs to replenish the scientific community would seem to go much further, in the long run, in ensuring America's high technology leadership throughout the world.

VII. SUGGESTIONS FOR FURTHER STUDY

There are a number of areas for in-depth study related to the issues raised in this thesis. While certainly not all inclusive, the following questions may be of particular interest for continued research:

- What are the relationships between the smaller member firms of SEMATECH and their larger peers?
- What are the prospects for SEMATECH long-term viability?
- To what extent does DOD relay on low-profit, high-volume commodity chips in its weapons systems?
- What is the link between nationals security and the domestic industrial base? To what extent will technical leadership or mobilization affect this link?
- If it is determined that DOD should relay more on the allied defense base, then which products and which countries should be permitted entry into the U.S. defense market?
- Which products should retain a domestic production capability and how should this be accomplished?
- What past experience does the U.S. have with the other protectionist policies as they relate to defense products (i.e., antidumping, Buy American, etc)?
- What circumstances (industry structure, R&D level) appear most conducive to utilizing a consortium as opposed to another organizational form?

- What is the appropriate type of consortium for meeting these circumstances (i.e., university oriented, centralized, independent, etc)?

- How is technology transferred most effectively? How is technology prevented from being transferred when desired?

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