INDUSTRIAL TECHNOLOGY

HEARING

BEFORE THE

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NINETY-FIFTH CONGRESS

SECOND SESSION

ON

GOVERNMENTAL POLICY AND INNOVATION IN THE SEMICONDUCTOR AND COMPUTER INDUSTRIES

TOGETHER WITH

A SUMMARY OF PREVIOUS HEARINGS ON INDUSTRIAL TECHNOLOGY

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INDUSTRIAL TECHNOLOGY

MONDAY, OCTOBER 30, 1978

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
San Francisco, Calif.

The committee met, pursuant to call, at 10 o'clock a.m. in the Ceremonial Courtroom, in the Federal Building, Hon. Howard W. Cannon (chairman of the committee) presiding.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The hearings will come to order.

Today the Senate Commerce, Science, and Transportation Committee continues an inquiry that we began earlier this year into industrial technology and its bearing on the health of our economy.

No one paid much attention to innovation when the American economy was booming. Now it is being recognized that the marketing of new products and services and the application of new industrial processes based on advances in knowledge are critical to our domestic economic welfare and our international trade position.

One study attributed one-fourth to one-third of American and Western European economic growth in the 1950's and 1960's to technological change. Another study concluded that innovation has been responsible for about 40 percent of the increase in American productivity.

Clearly we must look to innovation to help accelerate employment, revive productivity growth, control prices, reverse our staggering trade deficit, and bolster the value of the dollar. But when we look more closely at the innovation process, the signs are not encouraging.

In relation to GNP, the U.S. investment in research and development declined 27 percent between 1964 and 1976 in contrast to increases of more than 40 percent in Germany and 30 percent in Japan.

Largely because of reductions in defense and space research and development, Federal expenditures have dropped more than 16 percent in constant dollars in the last decade.

At the same time there has been an astonishing drop in the creation of small high technology companies which have been responsible for introducing a disproportionate share of new products and manufacturing processes.

Several years ago several hundred venture companies entered the market with new issue underwritings each year; in 1977 there were 46.

Although these statistics may not signal our eventual loss of technological leadership, witnesses in 3 days of hearings before the Senate Science, Technology, and Space Subcommittee did agree that a variety of factors have conspired to discourage the high risk ventures that may lead to innovation.

Industry is shifting investment from basic research to product development in the hope of short-term returns, to the detriment of technological advances that could lead to such revolutionary innovations as we have experienced in the past generation.

We have arrived at an unfortunate state of affairs where entrepreneurs and investors are reluctant to launch new enterprises.

The record of the U.S. semiconductor and computer industries stands in sharp contrast to these trends. Just 30 years ago discoveries in solid state physics culminated in development of the transistor. National defense and space programs provided the first markets for increasingly sophisticated devices.

The Government supplied capital to build production capacity and, in the years following sputnik, pumped nearly a billion dollars into research and development.

Industry more than matched these investments in order to exploit expanding commercial markets.

The "electronics revolution" has been led by a group of entrepreneurs combining a passion for technology with acute business instincts.

Especially here in California a succession of companies have been founded to advance the state of the art and to perfect existing products.

These entrepreneurs, in the broadest sense of that term, have capitalized in the "learning curve" of expanding production and lowering prices and have moved aggressively into foreign markets.

As a result, they have led the American semiconductor and computer industries to positions of technological pre-eminence and world market dominance.

Neither the generation of new ideas nor the perception of new opportunities shows any signs of stopping. Yet the semiconductor and computer industries are not immune to the challenges facing American industry as a whole.

Other countries have recognized the strategic importance of these technologies and are actively supporting their development at a time when Government assistance in the United States has declined.

The drying up of venture capital, coupled with higher initial investment requirements, has deterred and is continuing to deter would-be entrepreneurs from striking out on their own. Basic research funds, the U.S. world market share, and our favorable trade balance in components and computers all have declined in recent years.

The future of semiconductors and computers has a direct bearing on communications, the space program, transportation, and other matters in our committee's jurisdiction. More importantly, it has profound implications for our economic future.

It is hoped that this hearing and others to follow will result in a better understanding of the problems facing American industry and foster a closer working relationship in a common effort to preserve and expand our country's well deserved preeminence as the leader in technological innovation.

Today we want to examine the reasons for these industries' success, their ability to remain competitive, and the conditions that govern the creation and growth of high technology firms.

We will hear first from a panel of witnesses including George Heilmeier, of Texas Instruments; Wilfred Corrigan, of Fairchild; Alvin Harman, of the Rand Corp.; and Erich Bloch, of IBM.

Gentlemen, your statements will be entered in full in the record. We would appreciate it if you would limit your summary remarks to 10 minutes each so we will have time for questions and discussion after we have heard all of these introductory statements.

We will proceed with Mr. Corrigan and follow with Dr. Harman and Dr. Heilmeier and Mr. Bloch.

Mr. Corrigan.

STATEMENT OF WILFRED CORRIGAN, CHAIRMAN AND PRESIDENT, FAIRCHILD CAMERA INSTRUMENT CORP.

Mr. CORRIGAN. Thank you, Senator.

The first issue that we have to address is, one, key factors in the success of the U.S. semiconductor industry.

There is no disputing the world leadership position established by the U.S. semiconductor industry over the three decades since Bill Shockley's invention of the transistor at Bell Telephone laboratories in 1947, or the enormous amount of innovation and technical progress achieved in the course of this 30-year period.

In 1977 the U.S. semiconductor industry supplied more than 60 percent of the $6.4 billion world semiconductor market.

From the first commercial single transistors in the early 1950's, the industry has progressed rapidly to the integrated circuit, the medium scale integrated circuit, and large scale integration levels, and is now crossing the threshold of the very large scale integration era.

With VLSI, 100,000 or more electronic components can be fabricated in a single silicon "chip" measuring a fraction of an inch square.

As the technology has advanced in three decades, the cost per electronic function has decreased by a factor of 100,000 and the performance has increase by a factor of 10,000.

This is a battle we are and have been winning.

The critical elements in this success story were the ample availability of private venture capital in the 1950's and the 1960's, as the industry evolved, and the early grasp of the significance of semiconductor technology by American scientists and entrepreneurs.

These factors combined with a rapid and widespread diffusion of technical knowledge to foster spinoffs and new ventures which captured world leadership for the United States.

One major aspect of semiconductor technology is the "learning curve" concept, in which manufacturing costs go down as unit volume and production experience increase.

This has resulted in rapid price declines throughout the history of the industry, making us inherently an inflation fighter.

The early stages of the semiconductor industry were bolstered by large infusions of government R. & D. funding. From 1958 through 1974 various branches of the U.S. Government pumped $930 million into research in the semiconductor industry.

During the same period, private industry supported another $1.2 billion R. & D. effort, bringing the total investment over the $3 billion level in pure research and advanced development.

In the 1950's the Government was the largest customer for semiconductors, understandably since the first commercial silicon transistors sold at prices of $50 to $150 apiece, and only certain military applications could justify their use at this price.

But as costs and prices came down with developing volume, a very large merchant market developed, dominated first by the computer manufacturers through the 1960's and shifting toward general industrial equipment and systems in the 1970's and toward the consumer electronics market in the late 1970's.

Until recently the industry also had traditionally been labor intensive with a relatively low entry cost. The ability to utilize low-cost offshore assembly under such tariff provisions as 806–30 and 807 was essential to the ability of the emerging industry to meet its R. & D. and profitability requirements.

Now, some changes over the past decade. In view of the overwhelming success of the U.S. semiconductor industry, where today we have 60 percent of the world market, why are we here discussing the threat of the deterioration of innovative technology and the erosion of the industry's capacity to withstand foreign competition? What has changed in the last few years?

First of all, as we enter the VLSI era, we are rapidly becoming a capital intensive rather than a labor intensive industry. The cost of equipping a new semiconductor factory has escalated by a factor of at least 20 over the costs of two decades ago.

The first epitaxial furnaces we built in 1961 cost about $4,000. Today a single such unit costs $180,000.

Mask aliners used in the 1960's cost about $2,000 each. Today a single projection aliner, which is essential to VLSI technology, costs $200,000 and is moving toward $250,000 with the automatic alinement features we must have to keep the technology progressing.

The overall industry R. & D. requirement—and by R. & D. I am defining this as advanced R. & D., not normal sustaining and extrapolative engineering—is well in excess of $1 billion, equivalent to the level of combined government and industry funding in the 1958 through 1974 timeframe.

To put that in perspective, a complete critically sized wafer fabrication process plant today is in the $15 to $20 million range. Ten years ago we could achieve the same task for as little as $2 million.

The problem this creates in securing sufficient funds to develop and acquire the tools we will need for the coming decade is obvious. Our industry is extremely competitive. Prices always go down, and typically do not command large profit margins.

We are at the point today where our manufacturing process is reaching the limits of tolerance imposed by the wave length of light in the optical lithography system.

For any company facing this task, the investment in the development of new equipment and processes represents several hundred million dollars.

These are things that we must do in the next 5 years to remain viable in the VLSI race.

Other factors also complicate the problem. Just as we are facing the need for another huge R. & D. investment, we are hindered by a scarcity of venture capital, partly because of high individual capital gains taxes, partly because of restrictive depreciation allowances, and partly because, as we become more and more capital intensive, our industry is less and less attractive to venture capital operations faced with the prospect of severely limited return.

This is a ball game today that is limited to the existing participants, to very large companies, and to government.

At the same time, we are facing an extremely unfair situation in trade practices in both Europe and Japan. These are in the form of tariff and nontariff barriers, while uncertain export controls by our own State Department have thwarted some of our efforts to export mature technologies.

Nontariff barriers are perhaps the most serious aspect of the problem. A single example is Japan's national telephone and telegraph monopoly which purchases absoltuely no component not made in Japan.

In the second quarter of 1978, for the first time the semiconductor industry balance of trade with Japan swung negative, and this at a time when business with Japan is booming for the semiconductor industry.

Foreign governments are strongly supporting semiconductor R. & D. in Europe and Japan with massive development programs not only funded but actually orchestrated and directed by the Government.

We have seen steadily increasing foreign equity investments in U.S. companies, undoubtedly aided by the changing value of the dollar.

Much of this scenario is covered in detail in the supporting documents filed with this committee, but the bottom line is that at a time when we are facing perhaps the greatest need for a heavy industry-wide R. & D. effort, while simultaneously encountering the most potent threat from foreign competition ever amassed against the semiconductor industry, we are losing most of the supports that launched our industry to successful world leadership in the past three decades.

In addition to the Japanese Government, notable initiatives have been taken in the past 2 years by the French, the British, the Germans, and the Koreans, a new factor on the scene.

To address ways in which the Federal Government can help: Several expectations for improvement in the world trade situation have not worked out as well as had been hoped for by the semiconductor industry.

For instance, we had high hopes that the MTN and GATT negotiations would serve to alleviate some of the trade difficulties encountered in recent years. But aside from the lowering of the Japanese tariff, not much significant change has yet resulted.

In considering action the U.S. Government can take to help turn the tide, the U.S. semiconductor industry generally recommends that:

One, the International Trade Commission conduct a study of worldwide trade flows and the effects of United States and foreign governmental policies.

Two, the U.S. Government in the MTN in Geneva and congressional ratification hearings negotiate removal of the most onerous barriers; for example, the 17-percent integrated circuit tariff into the European Economic Community and foreign exclusion from Nippon Telephone & Telegraph contracts.

Three, more vigorous prosecution of dumping provisions under U.S. law and GATT by the U.S. Treasury Department where foreign exports to the United States are found to be in violation.

Four, the President approve the 1978 tax law reducing individual capital gains tax exposure from a maximum of 49 percent to a maximum of 25 percent.

Five, special credits for fast writeoff of high technology equipment used in the manufacture of semiconductors.

We are now looking at equipment that probably obsoletes within 3 to 4 years.

Government subsidy of VLSI research by private industry but without restrictive covenants.

And, lastly, a consistent export promotion program by the Government.

In parallel, a more effective effort to induce Japanese imports by U.S. Government pressure. The Trade Facilitization Committee, Trade Study Group, and Export Missions have resulted in no tangible gain for U.S. industry.

Thank you.

The CHAIRMAN. Thank you very much, Mr. Corrigan. I think we will go right through the entire panel and then we will have some questions for all of you.

Dr. Harman.

STATEMENT OF DR. ALVIN J. HARMAN, SENIOR RESEARCH ECONOMIST, THE RAND CORP.

Dr. HARMAN. Thank you. Mr. Chairman, it is an honor and a pleasure to appear before your committee today.

As a research economist who has studied the computer industry over a number of years but has not studied the semiconductor industry intensively, I hope that my comments today will be useful. I would like to emphasize that the views and conclusions expressed by me today should not be interpreted as representing those of the Rand Corp. or any of the agencies sponsoring its research. I will briefly summarize the points about technological innovation and international trade that should be borne in mind when considering Government policy actions.

I would like to discuss four major themes in these areas and then discuss two policy problem areas.

First, I want to point out that Government policies often have costs as well as benefits. A system as long-standing as our patent system can lead to unforeseen and unfortunate outcomes. A case in point that I have mentioned in more detail in my full statement has to do with the ENIAC, one of the first computers—developed just after World War II and patent application filed in 1947. It took our own U.S. Patent Office 17 years to decide to approve that patent, leading to a patent life that lasted into the 1970's; this led to an opportunity—nearly 30 years after the invention—for patent litigation beween Sperry Rand, Honeywell, and others over patent rights.

The second theme I want to discuss has to do with a distinction between technological supremacy and market leadership. The two are not the same.

IBM was not one of the original leaders in the marketplace in the 1950's. It was Remington Rand and General Electric and, in fact, there were dozens of firms during that period actively vying for the market, some more successful, some less successful. IBM started to outsell UNIVAC, which was a name synonymous with "computers" in the 1950's, only by about 1956. Philco was the first to introduce all transistorized computers and RCA was a leader in integrated circuits. Both of them have since left the industry because they could not become continuously profitable.

The third theme I want to discuss has to do with the process of technological innovation. An understanding of several elements of this process is necessary for the effective formulation of policies. First, there are many opportunities for competition among technologies within the development of new products. The vacuum tube gave way to the transistor which gave way to integrated circuits and so on in the course of computer history. These were not matters of historical necessity. These changes occurred because the prices of adapting different technologies changed as the technologies evolved.

A second element of the process of technological innovation is that such innovation depends on good ideas, and good ideas do not necessarily always require large expenditures of resources. I think a case in point is the development of the memories for Dr. Amdahl's line of machines that are fairly well known. These memories were developed with component technology that was off-the-shelf from more than one source at the time he designed them. He did this deliberately, so as to get the best price for his components. His major "good idea" was in the way he packaged the components.

Another element of the process of technological innovation that I would like to emphasize is the role of the user's needs. If product development activities don't satisfy these needs, the firm undertaking the product development is in serious trouble. General Electric, during the 1950's and especially during the 1960's, acquired Italian and French operations to become a part of their own computer operations—Olivetti's data processing division and Machines Bull. It turned out that the line of computers they tried to develop using these subsidiaries was not internally compatible. This led to market failure of a major sort, and one of the major reasons that GE subsequently quit the industry.

Let me turn to the fourth major theme that I wanted to describe: This has to do with international trade patterns.

There is a well established theory of international trade that describes trade patterns as based on the relative availabilities of the factors of production—resources, labor, and capital—in various countries. That theory doesn't describe the kind of trade we are discussing today. The trade patterns for much of the semiconductor and computer industries are determined by technology, and technological leads are intrinsically transitory. In other words, in order for the computer and semiconductor industries to continue to be competitive, firms must continue to advance the technology. As standard components evolve, that is, as the technology diffuses, then the more traditional basis for trade patterns prevail; the labor intensive production techniques for standard electronic components mean that it is in the best interest of our producers and ultimately of the consumers in this country to import those components.

Let me turn now to the two problem areas I mentioned at the outset.

The first is the concern about Japanese competition. I would like to make some general points in this regard. It is certainly true that the Japanese Government has encouraged technology transfer to itself over the last several decades, and that it has significantly supported the R. & D. in the private sector, including electronics R. & D. However, it is important to evaluate these trends and these activities in perspective. The total R. & D. in Japan is roughly a third to a half of our own. Within semiconductors, roughly 30 percent of the Japanese internal market for integrated circuits is imported.

American firms have a right to insist on freer access to Japanese markets. But the Japanese competition within our country is one of the elements that stimulates further technological innovation on the part of our firms, and that kind of stimulation is not to be lightly discouraged.

Finally, let me briefly comment on the more overriding concern about technological innovation in this country. There are a couple of factors that I think deserve serious attention. There is a widespread impression that basic research supported by the private sector has been declining in recent years; I believe that is a correct impression. It has been a legitimate role for Government to play to support basic research, and I think that further Government support is certainly called for.

Government efforts to foster technological innovation more generally are very difficult to devise and implement. Even the example I gave earlier about patents reveals that good policies can have perverse side effects. There is a real need to improve the incentives for firms to bear the risks that are inherent in technological innovation. Very large amounts may be risked on projects that either are not technically feasible, or not commercially feasible to enter the marketplace, or are not as profitable as other alternatives firms might have had for the use of their funds. However, it is very difficult to devise policies that will have the selective effect of encouraging firms to bear risks. The concept of a risk-related capital gains tax is a very attractive one, but devising a policy that will attain such an end is extremely difficult.

Moreover there are a number of influences from Federal sources that impact on technological innovation. In closing I would just like to mention one.

Regulatory initiatives in recent years have had a sound basis from a number of standpoints but they do have costs, many of them borne in terms of technological innovation. The recent initiatives in medical device regulation is a case in point. For electronics firms, medical devices are not a large portion of their market. When the regulatory initiatives increase, it becomes less attractive for firms to pursue this market. It seems to me that for electronics firms that have done so much to reduce the price of calculators and digital watches, it would be a shame if we do not have use of these firms' technological innovations for reducing prices in the health care sector.

Thank you.

The CHAIRMAN. Thank you, Dr. Harman.

[The statement follows:]

STATEMENT OF ALVIN J. HARMAN

TECHNOLOGICAL INNOVATION IN AMERICAN INDUSTRY: SOME OBSERVATIONS ON THE COMPUTER AND SEMICONDUCTOR INDUSTRIES [1]

Mr. Chairman, it is an honor and a pleasure to appear before the Senate Commerce, Science, and Transportation Committee this morning to describe some of the research I have done on techological innovation in the computer industry

[1] This paper was prepared for presentation at the Senate Commerce, Science, and Transportation Committee hearing on government policy and innovation in the semiconductor and computer industries, October 30, 1978. The preparation of this testimony was paid for by The Rand Corporation as part of its program of public service.

and to discuss more generally the government policies encouraging or affecting technological innovation in American industry. In my discussion, I will try to highlight some of the organizing themes under which I believe much of technological innovation and industry's ability to compete internationally in high technology products can be understood. I would like to make it explicit, however, that the views and conclusions expressed by me today should not be interpreted as representing those of the Rand Corporation or any of the agencies sponsoring its research. In preparing my discussion for this morning, I have consulted with a number of my colleagues at Rand and around the country, and have drawn upon my previous research on the computer industry and on the acquisition of major weapon systems by the Department of Defense.[2] Before discussing the several organizing themes I alluded to a moment ago, I would like to provide several thoughts by way of background on the computer industry.

CAPSULE HISTORY OF COMPUTERS

A very quick thirty-year sweep of the computer industry's history reveals a number of facts that I believe have important interpretations:

The ENIAC, one of the first computers, was developed just after World War II; a patent application was filed in June of 1947.[3] Within several years, the small company formed by the two inventors of the ENIAC had developed the first UNIVAC, and had sold it and their company to Remington Rand, which then entered the computer business. However, it was not until February of 1964 that that original patent for the ENIAC was approved, since even the U.S. Patent Office was stunned by the novelty and complexity of the new product. This delay in patent approval undermined the intent of the patent and led to the opportunity for litigation in the early 1970's between Sperry Rand (UNIVAC Division), HONEYWELL and others over patent positions fundamental to participation in the computer industry. It is well-known that the benefits of patenting vary with market structure; the possible costs of such government efforts to encourage invention are less widely appreciated.[4]

In the early years of the computer industry—throughout the 1950's—the principal dimensions of utility of the computer were limited largely to computational speed and storage capacity; the operation of the computer was handled by coding done in machine language (one machine step at a time); by today's standards the machines were not very versatile. During this period, and in general, technological leadership was not the equivalent of market leadership. Remington Rand's UNIVAC Division has established a very solid early position and such companies as General Electric were quite successful in getting early orders, although less successful in becoming profitable. Dozens of firms were newly formed or diversified into the computer industry. And IBM did not become a substantial participant until about the middle of the 1950's. It was Philco that produced the first transistorized computer in 1958, and RCA that offered the first computer with fully integrated circuits. In IBM's design of the 360 line of computers in the early 1960's, it chose a relatively conservative electronic design compared to the state of the art at that time. And the design work for the low performance end of their line was done with the benefit of foreign scientific expertise—at IBM's West German R&D laboratory.

For some time now international markets have been extremely important to the computer industry's development.[5] In the 1960's IBM chose to participate in foreign markets through a combination of exports and direct investment in production capabilities, so that their production and service capabilities could be controlled directly by IBM. Other giants in electronics, such as RCA Corporation chose to participate in foreign markets largely by licensing—a strategy that made them extremely vulnerable to future decisions by their licensees as the technology evolved. I think the importance of foreign markets in high technology industries is dramatized by the little known fact that the profitability of the entire IBM Corporation for the year 1970 was assured by profits from its foreign operations.

Throughout its history, the computer industry has benefitted from government research and development resources and, more importantly, the government mar-

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[2] I am particularly indebted to R. Anderson, W. Alexander, W. Baer, G. Eads, F. M. Fisher, D. Jaffee, E. Mansfield, R. Perry, E. Thomas, J. Utterback and W. Ware for very useful discussions during my preparation of this paper. Of course, I am solely responsible for any remaining errors of fact or interpretation.

[3] For a history of the computer industry, see [Harman, Chapter 2].

[4] See also [Scherer, Chapter 16].

[5] See also [Harman, Chapter 2].

kets for its products.[6] In the early years, these were both substantial relative to total industry activity, yet much of the innovative activity—the exploration for new products and the markets to make them profitable—was supported from private sources. At the present time, government purchases for advanced applications such as those for defense and space are for very unique capabilities (such as in deep space or to withstand nuclear effects). The Defense Department resources for such very specialized products do not significantly enhance industry's ability to pursue its commercial opportunities. There has even been a recent expansion of privately-funded designs for airborne computers.

ORGANIZING THEMES

As a research economist, perhaps one of my contributions to these hearings will be to describe some of the themes related to technological innovation and to international trade that have come out of past research. I will be discussing basically the alternatives and choices and the function of prices, as well as technology, in determining action.

First, let me discuss for a moment technological innovation at the individual product level and at the industry or market level. Throughout the evolution of high technology products, there are quite often opportunities for choice among competing technologies. We can review the history of computers and observe that they have gone through a number of "generations" of component technologies—from vacuum tubes to transistors to intergrated circuits and so on. There is no historical necessity about such an evolution. It arises from the economics of production of products and components in the various technologies. For example, the transistor was discovered at about the same time as the filing of that patent application for the ENIAC. But it took a decade before it was sufficiently refined and commercially producible to be competitive with vacuum tubes. And the process technology of transistors changed so rapidly that the original innovator—Philco—soon dropped out of the industry.[7] Moreover, I might note that a large portion of ground-based Soviet electronics still is based on the vacuum tube, and they are probably better producers of vacuum tubes than we are. If the example sounded more "modern," someone would probably be urging import restrictions on Soviet vacuum tubes so as to foster the redevelopment of vacuum tube production in this country.

Another element of product development that cannot be emphasized strongly enough is the importance of ideas to the success of technological innovations. And exploration of good ideas—the difficult process of resolving uncertainties to achieve a successful new product—cannot be described simply by the dollars expended. Some of the concepts for the new design of a piece of computer hardware may rely on readily available electronic components or technologies. In fact, Amdahl has pointed out that the memories for his new line of hardware used components that were "off-the-shelf" from more than one source. So he sought good performance by packing the components efficiently, while maintaining competitive sources of supply.

The process of developing a new and technologically sophisticated product involves the requirement of flexibility to cope with unforeseen stumbling blocks, and the awareness of customers needs so that the product will find a market. The discipline of competition in the marketplace allows users to choose the product with the best combination of performance and price. So throughout product development activities, and especially during product testing, design oversights can be caught and corrected before much larger resources are committed to production. When testing is slighted, or undertaken in a timing undesirable from the standpoint of catching design oversights before large scale production, the developer for the commercial marketplace is courting financial disaster. The GE failure to develop an integrated line of computers from their acquired French and Italian operations is a good example.[8] But this has also been a problem in government procurement; difficulties with some of the major weapon system programs by the Department of Defense, such as the F-111, can be traced to inadequate and untimely feedback of test results to the design effort.[9]

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[6] For a review of the literature on the influence of defense needs on civilian electronics industry, see [Utterback and Murray].
[7] For further discussion, see [Braun and MacDonald, pp. 142–143].
[8] See [Harman, pp. 24–25].
[9] For further discussion, see [Perry, *et al.*].

Related to this, in that test and evaluation must be done in the context of knowing what the new product is supposed to be able to do, is the critical importance of understanding the ultimate users needs. Some of the failures of small or widely diversified firms in the computer industry in the early years occurred because insufficient attention was given to the ultimate market.

In short, competition enters the process of technological innovation in several ways—in the options for the firms development team to choose their component sources, in the ideas that may lead to enhanced product capabilities at an attractive price, in the testing of those ideas (as embodied in hardware) to confirm their attractiveness, and ultimately in the marketplace. Thus, in a world of changing technology the firm operates in a dynamic environment and must invest in changes in product quality or production process, with the risk that some leads it pursues will not pay off. It is well-known that firms in the computer industry have invested heavily in R&D [10] and the even larger commitments to undertake the series of steps necessary to bring a new product to market.

Let me now turn to international competition. Standard theory of international trade explains trade patterns according to a nation's comparative advantage based on the resources, labor, and capital to produce the product efficiently. One of the important modifications to this theory that has been developed in the last two decades describes international trade based on technology itself. One such theory involves the concept of a product life cycle, in which the essence is that the ability to produce certain products changes over time.[11] In the early phases, relatively few firms have the required production know-how. As technology diffuses, trade patterns are influenced more strongly by the traditional factors determining comparative advantage. Thus, for example, standard electronic components that involve labor intensive production will be cheapest to U.S. producers and final consumers if imported from countries where labor is relatively cheaper than in the U.S.

Leaving the individual product perspective, a firm can maintain its export advantage by continuing to evolve its product line in advance of its competitors. This can only be continued, of course, as long as the sources of technological innovation leading to newer products are sustained. That is, products will have periods of rapid growth and development, followed by periods of consolidation. "Consolidation" may not mean a slowing of technological advances that could enhance the performance (or quality) of a product; but the new technologies may not provide capabilities that are sufficiently valued by the users to merit the price that would have to be charged for them.

Thus, technologically determined trade patterns are intrinsically temporary, but they may last for a long time. The United States has held its advantage in computers, fostered by a continuing stream of advances in technology, and is still unchallenged internationally at the upper end of the computer lines, with no less than four U.S. firms competing for customers. Moreover, some recent developments, such as network-oriented computers, have been made possible in part by the new capabilities provided by the semiconductor industry. Such developments suggest a continuing vitality to the American computer industry. And international activities affect more than our Balance of Payments. Participation in international markets provides opportunities for access to a wider spectrum of new ideas from "the customer" so necessary to further product developments. And the flow of ideas is not always one way (as the example of IBM's 360/20, mentioned earlier, demonstrates).

A POLICY-ANALYTIC FRAMEWORK

At this point, I would like to consider two specific current issues—the semiconductor industry's concern over Japanese competition, and the more general federal concern over the possible slowing of technological innovation in the United States. However, in this limited space I can only make a few comments on each, followed by what I hope will be some useful ideas for how to structure the consideration of policy options affecting technological innovation.

In the last two decades, there has been considerable transfer of technology from the United States to Japan; this has been induced in part by specific Japanese government policy.[12] By 1974, there was fairly specific recognition by the Japanese that they could not rely primarily on the import of foreign technology any longer, and they have chosen to focus public support of R&D in selected areas,

[10] It appears that there has been a reduction in basic research in recent years, however.
[11] See, for example, [Vernon].
[12] For details on the 1960s, see [Harman, Chapter 2].

one of which is electronics.[13] By 1976, they were still paying roughly five times as much for the imports of foreign technology in the electrical machinery sector as they were receiving from technology exports in that sector. That is, roughly $190 million was paid out—payments mainly to U.S. firms. But consider these matters in perspective. Total R&D expenditures by the Japanese are between a third and a half of our own.[14] Public funding in Japan supports roughly a quarter of this total—a larger portion than is the case in this country. And there is indirect support in forms such as tax and trade policies that are very different to measure (as are our own). Still, Japan imports roughly 30 percent of its domestic use of integrated circuits, and the total value of these imports has been growing rapidly in recent years to a total of about $250 million by 1976. These imports are largely "fairly new types and types in which Japanese manufacturers lack competitive power. . . ."[15] This is just what our theories of technology-based trade would have predicted.

In short, Japanese policy has emphasized the acquisition of technology from abroad, but this has not prevented earnings for U.S. firms in payments for both licenses and products. U.S. firms still lead in technology, and there is room for further advances.[16] Japanese policies do not seem to have been discriminatory with respect to the United States, but there is certainly room for reduction in trade restrictions, and this would be highly desirable. I would also like to emphasize that Japanese producers have been quite innovative with the resources they have available, even if these may be less than are available in the U.S. It may be unpopular to point out, but Japanese color television sets have provided U.S. consumers with a greater range of choice of quality and prices. And, as indicated above, competition at many levels (even from foreign sources) fosters further technological innovation, which I a convinced U.S. firms are capable of achieving. I do not know of instances in which restrictive trade policies have achieved this goal.

But I do not want to leave the impression that I see no problems—either for the computer and semiconductor industries or for America's technological innovation more generally. There is a fairly widespread impression (that I believe is correct) that privately-funded basic research activities have been significantly curtailed. Financial backing for such activities has been considered a legitimate role of government, both theoretically and historically. In the process of greater government support in this area in the future, it may be desirable to consider ways of encouraging links between appropriate personnel in industry and in the universities for some of this basic research support. Perhaps some of the ideas generated by such federal support might find their way to the marketplace more quickly than by other mechanisms of information transfer.

The broader objective of government encouragement of technological innovation is certainly desirable, but much more difficult. The more directed the R&D toward a final product, the greater is the need to appreciate the buyers' requirements. And federal agencies are understandably quite remote from "the marketplace" for most products. Federal "demonstration projects" have often been expensive and had quite mixed success as measured by diffusion of a technology or system to widespread use.[17]

As exemplified by both the computer and semiconductor industries, one of fundamental requirements for technological innovation is the willingness to bear risk. Firms do this when they commit scarce resources to a project that may have only a slim chance of a potentially large payoff.[18] Conceptually, it is not difficult to suggest policy remedies—a risk-related capital gains tax would be an example. In practice, it is fiendishly difficult to fully implement a practical policy change that does not end up like the ENIAC patent I mentioned at the outset.

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13 This discussion relies heavily on materials from the Nomura Research Institute, Kamakura, Japan. See especially [NRI, 1977]. See also [McGaffigan and Langer].

14 I am making these observations in very rough terms because of the numerous difficulties in calculating the conversion of what Japanese yen for R&D could buy in United States terms.

15 See [NEI, p. 6].

16 See [Sitherland, et al.].

17 For further discussion, see [Baer, et al.].

18 Mansfield and his colleagues have carefully documented instances in which the combined chance of achieving a technical success that is commercially attractive and that actually succeeds in producing an economic return greater than the firm's alternative uses of its funds are about one chance in eight. See [Mansfield, et al., p. 209].

In closing, I want to very quickly point out that there are a great many actions taken by numerous federal agencies that affect technological innovation in the private sector. I have listed some of the important ones in the adjoining figure (along with a few examples or comments). Much of the figure is self-explanatory, so let me merely make a few observations about it. What I have categorized as the "positive impacts" are generally well understood, and I have already commented on the need for basic research support, and the reduced impact of procurement activities on technological innovation in computers—a situation that is also true for the semiconductor industry.

POLICY-ANALYTIC FRAMEWORK FOR VIEWING GOVERNMENT IMPACTS ON TECHNICAL INNOVATIONS

Positive impacts

Direct support of R&D: basic (NSF, NIH); outcome oriented (DoD, NASA, Agriculture); diffusion oriented (e.g., ETIP).

Indirect encouragement of R&D: technical information dissemination; patent rights—hardware, software; and Government procurement activities.

Government support of education; scientific fields.

Uncertain impacts

Regulatory policies: antitrust actions; environmental health and safety regulations; and uncertainty over next regulatory areas and actions.

Fiscal and monetary policy: policies affecting financial markets; and tax treatments—capital gains.

International economic policies; trade policies; treatment of multinationals.

One of the greatest areas of recent difficulties has come from regulatory policies.[19] The very legitimate social goals of these regulatory policies also have costs, some of which arise from their impacts on technological innovation.[20] A brief example would be the regulation of medical devices, and its likely impact on electronics industry producers who may be less willing to develop medical electronics applications because the market (for the electronics firms) is relatively small. Given the way modern electronics has brought down the price of such products as calculators and digital watches, it would be a shame if such benefits could not be achieved in the health care industry.

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[19] See also [Eads].

[20] Sometimes the particular implementation of a regulatory policy can have an even greater perverse impact than if the policy had been handled differently.

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[The following information was subsequently received for the record.]

RAND CORP.,
Santa Monica, Calif., November 30, 1978.

Hon. HOWARD W. CANNON,
Chairman, Committee on Commerce, Science, and Transportation, U.S. Senate, Russell Senate Office Building, Washington, D.C.

DEAR SENATOR CANNON: In response to your letter of November 14, 1978, I have prepared a brief set of additional comments for the record. In the enclosure, I have recommended a very specific form of additional study of tax policy options to encourage technological innovation, so that when we can evaluate the impacts of the Revenue Act of 1978, better understanding of further options will be available. My other comment—about difficulties of communication about technological innovation—stems from my experiences in dealing with government personnel over the last ten years, and *not* from my activities related to this testimony. In fact, I have found your staff support for the hearings—Steve Merrill and Barbara Bruns—extremely knowledgeable and helpful. But it takes thousands of people to create and implement new policy initiatives; my research experience has convinced me that gaps in real understanding of policy objectives and the world that government policies affect are important impediments to the effective implementation of policies. I have attempted to make this point in the enclosure.

Also, I am in the process of circulating my October 30 testimony to a number of my professional and business colleagues, with a request for ideas about other specific policy options. I hope to collect and distill their comments and my further thoughts into a compact, policy-focused summary of the issues, and would welcome the opportunity to share this further policy research with you. I plan to keep your staff informed of my progress.

Sincerely,

ALVIN J. HARMAN.

ADDITIONAL COMMENTS TO TESTIMONY BY DR. ALVIN JAY HARMAN, SENIOR RESEARCH ECONOMIST, THE RAND CORP.[1]

The two panels of discussion of the topic of Innovation in the Semiconductor and Computer Industries, and the informal discussions that ensued after the formal hearings ended, produced some common views. I would like to comment on one view—regarding federal tax policy—and then make a more general comment about the process of policy formulation to help encourage technological innovation in industry.

Toward the end of my prepared written testimony, I indicated the need for a "risk-related capital gains tax." This general recommendation stems from my

[1] As with my previous testimony, the views and conclusions expressed by me should not be interpreted as representing those of The Rand Corporation or any of the agencies sponsoring its research.

conclusion that the federal government should increase its efforts to create an environment more conducive to technological innovation. During the second panel of these hearings, Mr. Perkins pointed out the change in our tax laws that has removed one such tax provision from existence—namely the "qualified stock option." At various points in Dr. Heilmeier's testimony, he also emphasized the need to reduce taxes on industry. I interpret this to mean highly innovative industry, such as his own firm. The fact that he and his firm would benefit from this change in the tax laws is important for the committee to recognize, but the wisdom of easing the tax burden on technologically innovative firms so as to encourage their further success (with consequent benefits for employment and our balance of payments) should not be overlooked. In other words, sometimes enlightened self interest is still good advice.

But it is not sufficient to conclude that some change in tax policy is warranted. The multitude of tax policies that could be changed—investment tax credits, favored tax status for R. & D., multiple depreciation of investments to introduce new technologies, reinstatement of the qualified stock option, etc.—deserve serious (which is not to say "lengthy") study.[2] I would recommend that the Office of Technology Assessment be requested to undertake a study of various explicit tax proposals—to evaluate their strengths and weaknesses, with particular emphasis on their impacts on technological innovation in identifiable sectors of the economy (e.g., electronics) and on firms of various sizes.[3] If such a study were completed next year, the results would be well timed for evaluation in the context of early indicators of the impacts of the Revenue Act of 1978. Building on the results of such a study, further public testimony or some other activities may be desirable to assist in reaching sufficient consensus for policy action.

My more general comment has to do with problems of *communication* about public policy needs. There are many facets to an understanding of the causes and remedies of a slackening in technological innovation and international competitiveness. These facets extend from international economic policies and government policies toward industry, to industrial market structure and performance, firms' organizations and functional activities, and even to the individual's motivations to invent, risk, and take personal responsibility for his/her work. It is not easy for the Congress, the rest of the federal government, or the public at large to understand the world of firms and managers engaged in the process we call "technological innovation." In my complete written statement, I urged government recognition of the need to encourage the "bearing of risks." During the course of the testimony, Mr. Corrigan gave us a number of examples of his concerns for the risks his firm has to face vis-a-vis foreign competition. Dr. Amdahl described some of the extreme difficulties and frustrations he and his firm experienced before becoming a profitable enterprise. But such uncertainties always seem easier to cope with in retrospect.

I believe that the institutions that each of us operates within (e.g., in our professional jobs) have a large influence on our perceptions of the world. Some legislators, government executives, and especially staffs and other civil servants in a federal structure that changes slowly, as its founders intended, are undoubtedly perplexed by that part of the nation that flourishes on a diet of rapid change—where new products can become totally obsolete within five years, staff turnover is routinely high, and job insecurity even extends (at unpredictable intervals) to top corporate executives.

In short, I believe that technological innovation often provides our society with useful new products and capabilities, and our economy with employment and an improved competitive position in world markets. When individuals (in management, in labs, in production, in sales, etc.) must operate in a world fraught with risk and uncertainty to achieve such innovation—and especially when they must rely on their creative ideas to ensure the success of their enterprises—they must be allowed generous compensation for the activities that bring their ideas to fruition.

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[2] A large number of witnesses testifying last spring before the Subcommittee on Science, Technology, and Space of this Committee also suggested a variety of tax incentives to stimulate private sector R.&D. A summary of their recommendations is contained in the analysis of these hearings by M. E. Mogee, "Industrial Innovation and its Relation to the U.S. Domestic Economy and International Trade Competitiveness," Congressional Research Service, Library of Congress, October 13, 1978, pp. CRS–44 to CRS–46.

[3] Since this recommendation could be construed to be in my self interest—as a Research economist—I would like to state, for the record, that I will *not* request or accept funding from OTA or any other source for the study I am recommending herein.

The CHAIRMAN. Dr. Heilmeier.

STATEMENT OF DR. GEORGE H. HEILMEIER, VICE PRESIDENT, CORPORATE RESEARCH, DEVELOPMENT AND ENGINEERING, TEXAS INSTRUMENTS, INC.

Dr. HEILMEIER. Mr. Chairman, I am pleased to have the opportunity to testify this morning. I commend the commitee for its timely interest in a problem so basic and fundamental to our national well-being.

In my brief remarks this morning I would like to focus on the confluence of events that sparked the growth of the semiconductor industry and explore what must be done if we are to discover and nurture other dynamic growth industries in the future.

Let's begin by examining why the industry grew, and here I am going to be drawing on some of the remarks made by Mr. Corrigan.

I believe it was a synergistic confluence of four aspects; ideas, people, market, and entrepreneurial opportunities. We can begin by examining the ideas.

The industry really grew out of some new physics and new chemistry and that spawned new devices. In turn, the new devices spawned new applications as well as impacting older applications.

In addition, there was an open environment fostered by seminars conducted by Bell Telephone Laboratories and Western Electric which provided an environment for the dissemination of new information.

The second factor in the industry's growth, in my opinion, was people. There was a supply of scientists and engineers educated in the sophisticated technical environment that was a legacy of World War II that were available to spawn a new industry. There was an excitement; the excitement of something new really attracted the very best people. Historically the best students in any university are attracted to the cutting edge of science and technology. There was also a mobility of people that aided in the diffusion of ideas and knowhow.

The third factor, in my opinion, was the markets themselves. Usually a new development has market impact in one or perhaps two of the following areas: Cost, performance, reliability, new functional capability or a direct replacement for an accepted application. The semiconductor industry was unique in that it impacted all of the above.

Still another aspect of the market was the existence of what I will call a carriage trade customer in the form of the Department of Defense (DOD).

The DOD desperately needed the capability that semiconductors could provide and they helped to nucleate and expand the market for such devices. As that volume increased, prices decreased. This is the very essence of the learning curve that Mr. Corrigan referred to earlier. Lower prices opened up other markets and increased volume even further, generating the investment capital to provide for an active R. & D. program which spawned even more innovations.

The fourth factor in the growth of the semiconductor industry was entrepreneurial opportunity. Established industries back in those days viewed the new technology of semiconductors as a threat rather than an opportunity. Vacuum tube companies did not become the leaders in the semiconductor technology.

At that time, the climate was right for expansion. Interest rates were low, taxes were lower. There was a favorable treatment of capital gains and the industry itself really did represent the personification of the American dream in that hard work and the guts to take risks was rewarded.

And people in those days really did work hard at it.

Now, what about the lessons learned? There is a great deal of discussion these days about innovation.

Innovation really has become a good word because it is a synonym for success. I doubt that any of us have ever heard of a bad innovation. If something isn't successful, we simply just don't call it an innovation. What we're really asking is not how we can foster innovation but how we can generate more successful new industries.

To create successful new industries we need a conducive economic environment and that means readily available investment capital and the certainty that hard work and the willingness to accept risk will lead to personal gain.

In this respect, in my opinion, the capital gain reforms of the post 1969 period are among the worst offenders, because they cut in half the potential rewards for high risk entrepreneurial investments. Back in 1969 the Treasury Department estimated that reform would add approximately $1 billion to revenues in 1970 and $3.2 billion annually by 1975. Instead 1969 revenues of $7.1 billion fell to an average of $4 billion in the next 4 years. This has probably also cost the Treasury countless billions of lost revenues and the economy hundreds of billions of lost output.

Historically the golden ages of the Roman Empire, the British Empire, the brightest years of our own economy after World War II, and the German and Japanese recoveries after World War II all have one thing in common. Taxes were low and so were the trade barriers.

So if we want to encourage innovation in the formation of growth industries, we need, first, tax structures which encourage investment.

Second, we need fair and equal access to foreign markets.

Third, we need an end to foreign trade barriers which force us to concentrate on selling products to the U.S. market while selling technology for them to develop their own markets abroad. This eventually results in confrontation with foreign competition and raises cries for protectionism.

Finally, we need protection of private property pertaining to innovation. Current de facto R. & D. procurement practice in the DOE, for example, results in Government control of patents and licenses. Such practice is a definite barrier to commercial innovation.

New industries and economic growth are spawned by the new products R. & D. can generate. I favor incentives for companies to invest in R. & D. and lower tax rates to provide readily available capital in the private sector to provide for and encourage expansion.

Unfortunately there are those in Government who are bent on a different course. They want more Government sponsored R. & D. to be sure, and they treat this as a goal. They tend to be input oriented instead of recognizing that more R. & D. is not a goal, but a way of traveling.

It is really the products generated by R. & D. that create jobs and the growth that we seek. It takes readily available capital and entrepreneurial incentives in the form of lower taxes to make that possible.

More Government funds for R. & D., in my opinion, also imply Government control. It means bureaucratic consensus and inertia in the selection of R. & D. programs instead of entrepreneurial insight and marketing.

The DOD has been successful with its R. & D. because it uses the products of its R. & D. It is, in its own way, market oriented. Few Government technical establishments, in my opinion, have this incentive or final exam for the work they support.

Let me summarize by saying we don't need R. & D. for R. & D.'s sake. Our economy needs outputs of such activity to support economic growth and development.

This requires a conducive economic environment and that implies lower taxes, readily available investment capital, and open access to world markets and, finally, the rewards for taking the risk.

Perhaps in a sense what I am asking is that the Government do less so that we in the private sector can do more.

Thank you.

The CHAIRMAN. Thank you, Dr. Heilmeier.

I may say that I have been recently engaged in trying to get the Government out of the hair of private industry, which is what you are suggesting, with my aviation regulatory reform bill which was signed into law Tuesday of last week.

I certainly agree with you that we need to get the heavy hand of Government out of business' pocket, so to speak.

[The statement follows:]

STATEMENT OF GEORGE H. HEILMEIER, VICE PRESIDENT CORPORATE RESEARCH, DEVELOPMENT AND ENGINEERING, TEXAS INSTRUMENTS INC.

GOVERNMENT POLICY AND INNOVATION, A VIEW FROM THE SEMICONDUCTOR INDUSTRY

Introduction

I am pleased to have the opportunity to testify and commend the committee for its timely interest in a problem so basic and fundamental to our national well-being.

I have a somewhat unique perspective in that I worked in industry prior to a 7-year sojourn in government during which I served as the Assistant Director of Defense Research and Engineering and Director of the Defense Advanced Research Projects Agency. I am now Vice President of Research, Development and Engineering at Texas Instruments.

In my brief remarks, I would like to focus on the confluence of events that sparked the growth of the semiconductor industry and explore what must be done if we are to discover and nurture other dynamic growth industries in the future.

Over the past 10 years or so, there have been a number of reports on the U.S. semiconductor industry, attempting to understand the reasons for its innovative vigor. Often, these studies were commissioned to develop particular issues as support for development of public policy:

1. Several of the European governments have made studies, some under auspices of OECD, to prove the value of government subsidies to innovation.

2. Studies of Japan's recent dynamic growth often have a section devoted to the sale and transfer of U.S. semiconductor technology and its consequent impact.

3. Studies of multinational operations have case studies of the transfer of semiconductor technology to developing countries, noting both impact on the receiving country as well as U.S. domestic economy.

4 The Defense Department has commissioned studies to highlight their contributions to both semiconductor and integrated circuit technologies and, recently,

5. Studies of the semiconductor industry have been used to note a slowdown in U.S. technology leadership versus Japan, Germany, and other industrialized nations.

While individual aspects of each study may be valid, the conclusions should not be generalized as a basis for policy for all industry. The semiconductor industry provides a good insight into the requirements of technology-intensive and high-growth industries. This segment of American industry is of great importance and the focus of these hearings. Yet, conclusions regarding this industry may not be appropriate for capital-intensive industries, or industries in a more mature phase of growth.

It is important that this distinction in characteristics and consequent needs of various segments of American industry is recognized before public policy or regulations impacting American technology and innovation are made.

Unfortunately, this distinction between technology-intensive industrial segments and the remainder of American industry has not been recognized by various departments and agencies of the U.S. government when they solicit industry's viewpoints on proposed regulations. Since the purpose of the proposed regulations are not technology-oriented, and the number of responses favors larger, mature industries, the real issues of technology impact are neither recognized nor assessed.

Semiconductor industry—Why did it grow?

The rapid development of the U.S. semiconductor industry has been due to a synergistic confluence of: ideas, people, markets, and enterpreneurial opportunities.

I will briefly discuss each of these factors.

A strong impetus to innovative vigor was the fact that semiconductor technology and the industry it spawned really were new fields of endeavor, unfettered by prior biases, practices, and traditions of established technologies and industries:

It was the first major application of solid state physics.

The materials, silicon and germanium had not previously been produced.

The manufacturing techniques, from crystal growing to packaging, were new.

It spawned new applications, as well as impacting the old.

Of particular significance was the openness and sharing of timely research and development results through seminars, and reports in technical journals. A large measure of credit for this relatively open environment was due to the Bell Telephone Laboratories, and the open licensing program undertaken by the Western Electric Company in 1952.

The early development of semiconductor technology occurred during a period of strong public awareness and support for science and technology following World War II, which carried through the mid-1960's. As a consequence, the availability of good scientists and engineers who were highly motivated to pursue careers in this field was excellent. Historically, the best students are attracted to the cutting edge of science and technology, and this was true in this case. The combination of intense individual motivation to develop a specific segment of this technology, together with the formation of many new companies, created a mobility among personnel in this field that further aided the diffusion of ideas and know-how.

This same environment impacted the managers of these young firms, providing an opportunity, seized by the more successful firms, to plow new ground in the development of business strategies, such as an early emphasis on worldwide markets, and rapid price declines based on cost reductions, which are predictable by experience curve theory.

Usually, a new development has market impact in one or perhaps two of the following areas: performance, reliability, cost, and ease of application or use, as compared to prior art.

Semiconductor technology is one of those exceptional developments that has impacted all four. Initially, it offered performance advances, and then improved reliability was demonstrated.

In the mid-1960's distinct cost advantages were realized by the application of plastic encapsulated integrated circuits, and with today's large functional capabilities represented by calculator parts, microprocessors, memories, etc., it has become easier to apply electronics by those who are not necessarily skilled in the art.

The existence of a Defense systems market in the 1950's, increasingly dependent upon electronics, provided an early market for semiconductor devices at prices well above the economics of industrial and consumer equipments. This was a unique market opportunity for US semiconductor firms, and accelerated production experience and market development by at least 2 to 5 years as compared to the markets available in other countries.

Of equal significance was the synergistic relationship between the semiconductor and computer industries over the past 20 years. Computer technology had advanced to commercial products in the mid-1950's but the size and cost of these equipments were sorely limited by vacuum tube technology. It was initially transistors, and then integrated circuits, that made possible the order of magnitude reduction in computer costs, while exponentially increasing performance. This, in turn, created the largest market for semiconductor products from the early 1960's to the present time. Again, it was a market largely indigenous to the United States.

As volume increased, prices decreased. This is the very essence of the learning curve and, since semiconductor manufacturing costs are highly leveraged by technology, each technology improvement created dramatic cost reductions. Lower prices opened up new markets and increased volume even further, generating the funds for both active R&D programs and large investments in manufacturing equipment that were required not only for capacity expansion but also due to technical obsolescence, as each new major innovation entered the marketplace.

One of the notable characteristics of the US semiconductor industry has been its high entrepreneurial content. In the early 1950's, the established producers of active electronic components were the vacuum tube manufacturers. Vacuum tube manufacturing technology was largely influenced by economics of scale and capital intensity in the early 1950's. These companies judged semiconductor manufacturing technology as being dominated by similar factors which would allow them to control its manufacturing development. Since semiconductors were viewed as a threat to their established products rather than opportunity, they did not aggressively pursue the development of these products. Therefore, the early leaders in the semiconductor industries were young companies.

Semiconductor manufacturing technology is as strongly influenced by technology growth as it is by economics of scale. Therefore, with each major technology turnover, an opportunity was created for new venture firms to seize the initiative from those firms that became entrenched with the technology of the prior generation. These major technology turnovers have occurred every 5–7 years, and some number of new firms have appeared at each instance. Texas Instruments has been able to remain competitive over a 20-year span.

Throughout this period, the cost of timely entry into each new generation of technology by either an established firm or a new company was moderate: Equity could readily be obtained and the rewards for success were high due to a favorable capital gains tax environment. It was the personification of the "American dream"—hard work and the guts to take risks were rewarded—and people did work hard.

Current outlook

Over the past five years, some elements of this environment have changed. Two changes that have had notable impact are:

First, the focus of semiconductor applications today is for the consumer and general industrial markets. These markets are equally strong in Japan and Western Europe, and not unique to the U.S. experience. Thus, their producers of semiconductors, which are usually units of very large electrical firms, are exerting more competitive pressures with timely new products. Also, along with recognition of this oportunity, there is increased pressure for their governments to subsidize native companies through grants or trade barriers. Secondly, here in the U.S. equity has become less available and capital gains advantages have been greatly restricted. As a consequence, there has been a smaller number of new firms entering the U.S. semiconductor industry, and these firms have received equity principally from either foreign sources or venture arms of large oil companies.

The technology rate of advancement will continue unabated, entering, I believe, one of its most profound periods of impact and opportunity in the so-called VLSI era. The U.S. semiconductor industry has the innovative capability to gain its share of this opportunity but we are no longer alone. We must not allow our ability to compete to be unduly fettered by government regulations, tax statutes, and other policies that place us at disadvantage to foreign producers. The principal elements of concern are those that impact innovation: tax statutes, trade barriers, regulatory delays and interference, and protection of private property.

Lessons learned

There is considerable discussion about innovation, which is widely used as a synonym for success. Has anyone ever heard of a "bad" innovation? If something isn't successful, we don't call it an innovation. So the issue is really, how can we generate more succesful new industries?

First, though, it is important to note several definitions. Too often, R&D invention, and innovation are used almost interchangeably.

R&D may be either the advancement of knowledge, which is science-oriented, or the application of knowledge to specific product or processes development, which is technology-oriented. R&D is often the front end of the innovation process, but, by itself, it does constitute innovation.

Invention is an advancement in the art made in the laboratory. While a patent may be granted, invention is of little value until it is practiced in the marketplace.

On the other hand, an innovation implies a novel advancement in the marketplace, as recognized by its adoption by customers. An innovation requires a large investment in engineering, market development, and manufacturing facilities. Often these "downstream" expenses are 10–20 times larger than the R&D expenses. Of great importance is the timeliness of this investment, so that the market introduction may truly be an innovation.

To create successful new industries, we need a conducive economic environment. That means readily available investment capital and the certainty that hard work and the willingness to accept risks will lead to personal gain.

In this respect, tax statutes have had major impact on both the timeliness of investments for innovations and the subsequent rewards for those who have made the necessary risks.

The capital gain reforms of post 1969 are among the worst offenders for they cut in half the potential rewards from high risk entrepreneurial investments. Treasury estimated that reform would add $1.1 billion to revenues in 1970 and $3.2 billion annually by 1975. Instead, 1969 revenues of $7.1 billion fell to an average of $4.1 billion in the next four years. This one change has cost the Treasury some $10 billion of lost revenue, and the economy hundreds of billions in lost output.

Even more ominous is the fact that the more revolutionary innovations are brought to market by small, high-risk enterprises. These organizations are influenced by the tax environment.

Other tax stautes and regulations, such as the recent Sec. 1.861–8, are a disincentive to the performance of R&D in the United States, and it has the adverse effect of encouraging U.S. firms to transfer more R&D to foreign countries. § 861 requires an apportionment of U.S. R&D expenditures against a U.S. firm's foreign source income. Since the U.S. firm will not receive a foreign tax credit for the apportioned research and development expense, this change will result in U.S. firms not receiving full U.S. tax credits for research and development expenses.

The significance of § 861 and the capital gain tax is not whether it is right or wrong from a tax policy point of view. Rather, the significance is that government agencies have no way of reviewing their regulations in the light of their impact on the development of U.S. technology and innovation. In fact, the question of a regulation's impact on innovation is not even a consideration during the drafting of such regulations. Without an overall technology and innovation policy focused on specific issues, government agencies are unable to evaluate whether technology disincentives are offset by other public policy considerations.

We know that capital formation manifested as new engineering and manufacturing equipment can accelerate innovations, but the government agencies have no way of comparing the values of innovation against the costs of tax disincentives.

A second factor is a strong need for fair and equal access to foreign markets. Too often, our trade policies have been dominated by a "protectionism" climate fostered by segments of mature industries This is a harmful and disastrous policy to pursue as it leads only to retaliation and a disruption of wide segments of trade. In those instances where a U.S. firm has made an innovation, it is important that it quickly gain marketshare in the world markets. To pursue a strategy of concentrating on domestic marekts, while selling technology to foreign firms for their markets is a delusion that eventually leads to confrontation with foreign competition in the U.S. market, amid cries for "protectionism." Again, the most effective strategy is participation in world markets, and this requires fair and equal access to these markets.

A third factor of importance is the protection of private property pertaining to the innovation, so that the owners can obtain a return on their investment and not have it "pirated" from them during its early market development. The patent laws have traditionally recognized private ownership of technology and provide a basis for owners to obtain a return on their investment. Within the past decade, there has been a strong trend among governments, both U.S. and foreign, to override private ownership on issues of national policy. As protection of private investment in technology is eroded, less incentive remains to undertake the risk of applying technology to new products and markets. Yet, these same governments demand that private industry assume the initiative and undertake the risks of applying the very technology that has been usurped by the government. For example, current R&D procurement clauses that give the government ownership or control of patents and subsequent licensing have been enacted by the Congress for Departments of Energy, Transportation, and NASA. It is my contention that these clauses are definite barriers to commercial innovation.

Lately, there is an increased interest in technology assessment. There is a trend, however, among the regulatory agencies in the direction of excessive delays in approving new products; premature standardization; and legislation of solutions rather than prioritization of problems. Fortunately, these regulatory agencies have had minimal impact on the U.S. semiconductor industry in the past. However, the future is not promising and, I fear, the timeliness of some new innovations will be lost to American companies due to interference by regulatory agencies.

Before closing, it is important to address one point regarding government incentives for innovations. There are those in the government who are strongly advocating more government sponsored R&D, and treat this as the only goal. They tend to be input-oriented instead of recognizing that more R&D is not a goal, but a way of traveling. It is the products generated by R&D that create the jobs and growth that we seek. This requires incentives for companies to invest in R&D and lower tax rates to provide for and encourage expansion by the private sector.

More government funds for R&D also imply government interference. It means bureaucratic consensus and inertia in the selection of R&D programs instead of entrepreneurial insight and market-driven exploration of new areas. The Department of Defense has been more successful with its R&D because it uses the products of its research. It is user oriented. Few government technical establishments have this incentive or "final exam."

We do not need R&D for R&D's sake alone. Our economy needs the outputs of such activity to support economic growth and development.

In Summary

We don't need R&D for R&D's sake alone. Our economy needs the outputs of such activity to support economic growth and development.

This requires a conducive economic environment and that implies lower taxes, readily available investment capital, and rewards for the entrepreneur.

Perhaps in a sense we are asking the government to do less so that we can do more.

I am grateful for the opportunity to speak and would be happy to respond to any questions the committee may have.

The CHAIRMAN. Mr. Bloch.

STATEMENT OF ERICH BLOCH, VICE PRESIDENT, DATA SYSTEMS DIVISION, IBM CORP.

Mr. BLOCH. Thank you, Senator. It is indeed a pleasure and an honor to participate in this morning's discussion and hearing.

For all of the 25 years of my professional career I have been involved in the development of semiconductors and computers.

It is from this perspective that I want to discuss the question of innovation in these two areas: The past and present, and future challenges that we are facing.

Several analysts have noted that, starting about 1955, industrialized nations have entered a new economic era, one which can be characterized as the information era.

Today the largest sector of our economy generates, uses, and disseminates information. This includes not only manufacturing of and suppliers to the semiconductor and data processing industry but also the entire field of communications as well as others in the public and private sectors who create, provide, and use information.

Because our present economic era is dominated by this sector, I think it is important to review some of the contributions that semiconductors have made to this particular environment. I will be using IBM technologies and products as examples although a similar story could be told from the perspective of many other semiconductor companies.

IBM's large semiconductors first used in 1964 put a single computer circuit in one small package.

In 1970 four or five circuits were put into the same package.

Last week, IBM announced a new technology that puts 704 circuits in a package that is only slightly larger.

Because we can put so many more circuits into the same area of silicon, the cost of each circuit is decreasing and its speed is increasing. It is faster than yesterday's circuits and tomorrow's will be even faster.

Similar advances have been made in computer memory. Earlier this month, IBM announced a semiconductor technology that stores 64,000 bits of information on a tiny chip of silicon whereas in 1970 a simliar chip contained only 512 bits of storage.

This kind of advance has enabled us to reduce memory devices by a factor of more than 50 in 8 years.

With these kinds of advances being made at the semiconductor level, system designers have been equally innovative in providing increasing function in the hardware and operating systems for modern computers. This has led to more innovative computers and more innovative applications.

Because of competition all who make semiconductors and computers must commit ever-increasing amounts of money to research and development.

For example, in 1971 IBM spent $540 million on R. & D. Last year the figure was over a billion.

The U.S. economic system has benefited immensely from this kind of technological progress. In the early 1950's there were but a mere handful of computer installations in this country. Today there are more than 300,000.

In 1977 total computer spending was about $195 per capita as against $100 in the 1970 and $195 at today's spending is only a few dollars less than the per capita spending on automobiles.

At the same time the computing costs have decreased significantly. In 1952 it cost $1.25 for 100,000 multiplications. In 1964 it cost 12 cents and today it costs about a penney, and this means enormous savings for our customers.

The equivalent of a computing system that filled a large room and demanded a multimillion-dollar price tag in the early 1950's today costs but a few thousand dollars and occupies the space of an ordinary desk.

While these price reductions are impressive, advances and functions are at least as significant because innovation in this area leads to productivity enhancements in other industries and other areas of endeavors.

While the computer's development would be impossible without the progress made in semiconductors, the reverse is also true. Computer systems play important roles in designing semiconductors and controlling their manufacturing lines and processes and in testing them.

I have described the developments and state of semiconductors and computers. Two important questions can and should be asked:

First, will the progress and innovation slow down? Second, are there signs of leveling off in opportunities and new applications in these two important areas?

My answer to this question is decidedly "no." If anything, progress and innovation occur at an increasing pace; and the reason for that is quite fundamental. The limits imposed by laws of physics are orders of magnitudes away from impeding developments. Important work and progress going on are not only confined to products but to processes, to tools, and to materials. Let's look at this evidence.

First let me talk about semiconductors. We have seen integration levels—that's the number of circuits or bits we can put on the silicon chip—we have seen these levels double every few years. This is reflected in lower costs and increased productivity.

As processes, design approaches, and tools used in the development and manufacture of semiconductors become better understood, new approaches are being pursued.

A supporting industry has grown up around the semiconductor manufacture. It supplies tools and materials at an increasing rate and at reasonable prices. This makes the entry of new producers feasible and increases the competition.

As costs continue to decrease, new uses have and will emerge and become economically feasible, thus increasing the demand and volume of semiconductors again. This volume increase will lower costs even further, as was discussed already twice this morning, as learning economies and economies of scale occur.

New uses for semiconductors are being found constantly. Already we have seen the electronic watches that are cheaper, more effective, and provide more functions than the mechanical timepieces. Electronic hand calculators make mechanical desk-top ones obsolute, and we see microprocessors being used in more and more household appliances, and many control functions in cars will be executed by semiconductor components.

In an analogous way, similar evidence suggests an equally productive future for computers. We see competition increasing as new companies enter the field. These new entries are greatly helped by progress and general availability of semiconductor products. We can see a broadening in performance and function as computers are designed and produced to fit many different applications.

We can expect computer applications that will reach into every office of every enterprise. Such applications will become a prerequisite to the day-to-day operations of manufacturing lines, plants, distribution centers, and what have you.

As in semiconductors, the growth in applications will be further helped by decreasing costs, and this we expect will continue a productive spiral of higher demand, leading to lower costs and leading to still higher demands.

I don't think there can be any doubt at this time that the United States is still a leader in both semiconductors and computers. This is obvious and well recognized. Let me address myself to the key reasons for this U.S. preeminence.

First, when semiconductors and data processing were in their start-up phases, a wealth of theoretical knowledge was available for immediate use. Solid state physics and numerical mathematics were disciplines ripe for industrial uses.

Second, excellent working relationships between the university, Government, and industrial communities developed during World War II and they were sustained by large endeavors such as the space program.

Third, the American technical community was a mobile one, both geographically and technically. It readily embraced and mastered new skills required, unimpeded by old methods.

Fourth, these fields have emphasized technical education and the rapid publication of technical innovations.

Finally, the U.S. Government and its major suppliers have been leading users of semiconductor and computer technology.

Over time, that last role has diminished. In addition, U.S. preeminence in these fields is being challenged.

Compared to the 1960's, the technical base underlying semiconductors and data processing has stabilized and matured. Entry of new companies is facilitated.

In semiconductors, this base and this potential represents a well-defined target for exploration and new development. The knowledge base has been diffused worldwide. New entries into the industry might be more costly, as has been mentioned this morning already, but it is certainly less risky.

In data processing, the universal use of established computer language make computer applications more portable from machine to machine. Also, the longevity and establishment of computer families by major manufacturers allows for entry of companies that produce compatible equipment—input/output equipment, memory products, and even central processing units. This applies to domestic and foreign makers of equipment as well.

The successes and the critical importance of semiconductors and data processing to any nation's economy has been recognized by the national governments of France, the United Kingdom, Germany, Brazil, Japan, and others.

Let me take Japan as a case in point. The Japanese Government has identified the establishment of a strong data processing industry as a national goal. It is well understood by Japan that to accomplish this goal, leadership in the semiconductor area is prerequisite. Through combined Government and industry funding, an advanced laboratory has been established. All companies with a stake in the development of Japan's data processing effort participate in this central laboratory.

Japanese companies have invested in U.S. semiconductor and computer companies. Such ventures aid them in their development, marketing, and manufacturing of their own products.

This sophisticated effort is not aimed only at domestic needs. It is also aimed at the export markets for semiconductors as well as computers.

Japanese competition is noteworthy. Their technical publications and educational facilities are impressive. So is their inventiveness and technical productivity.

Let me turn now to requirements.

Successful innovation implies rapid changes to products, tools, technologies, procedures, and processes. To counter foreign threats and to stimulate innovation in this country, we must create an environment which encourages the production of change and improvement. Here in general terms are some of these requirements:

First, industry cannot take advantage of new and innovative processes and ideas without continual replacement and improvement of existing plants and equipment. This must be recognized and facilitated to assure future growth.

Second, the continuous influx of trained and well-educated people who can develop new ideas is very crucial. The education system, as well as the support of the education system, should be evaluated to insure the continued availability of this talent.

Third, semiconductor and computer companies must take a global view. Government regulations on technology transfer should consider this.

Fourth, barriers to free trade should be minimized. For example, today more than 40 countries impose tariff rates on imported computer products which are at least double that of the U.S. rate.

And, last, the Government can contribute to the strengthening of semiconductors and data processing by being a well-informed and sophisticated user of computers. This would spur new endeavors, new applications, and new developments.

In conclusion, in an information age, the computer represents an essential tool for coping with the complexity of modern society.

In a highly competitive environment, the U.S. semiconductor and data processing industry has made great progress in the past 30 years. If we address the challenges, the promise for the remainder of the century would be equally bright.

Thank you.

[The statement follows:]

STATEMENT OF ERICH BLOCH, VICE PRESIDENT, DATA SYSTEMS DIVISION, IMB CORP.

1. BACKGROUND

My name is Erich Bloch; I am Vice President of IBM's Data Systems Division and General Manager of the East Fishkill facility. The East Fishkill facility is responsible for the development and manufacturing of logic and memory semiconductors and packaging. Our developments and products find their use in all of IBM systems and products.

Throughout my 25-year professional life, I have had the good fortune to be involved with the development of semiconductors and data processing.

It is from this perspective that I want to discuss the question of innovation in semiconductors and data processing: the present and future and the internal challenges we face.

2. THE INFORMATION ECONOMY

Several analysts have pointed out that, starting roughly in 1955, the industrialized nations have entered a new era characterized as the Information Economy.

Today, the largest sector of the economy is involved in the generation, usage, and dissemination of information.

This information era covers not only manufacturing of and suppliers to the semiconductor and data processing industry, but also the entire field of communications, including newspaper publishing, telephone and TV to name the most obvious areas, as well as others in the public and private sectors who create, provide, and use information.

An example of the value we place on information is that total data processing and communication spending per capita was about $195 in 1977—approximately the same as the per capita spending to buy and depreciate automobiles ($215).

3. SEMICONDUCTORS AND DATA PROCESSING HISTORY

In reviewing some of the key events in semiconductor history and their contributions to today's environment I will be using announced IBM technologies as examples. A similar story could be told from the perspective of many other semiconductor companies.

IBM's semiconductor electronic circuits, announced in 1964, put a single computer circuit in one small package. Last week, IBM announced a new high-performance technology that puts 704 circuits in a package that is only slightly larger.

Because we can put many more circuits into the same area of silicon, the cost of each circuit is decreasing and, at the same time, its speed is increasing.

Comparable advances have been made in computer memory. Earlier this month, IBM announced a semiconductor technology that stores 64,000 bits of information on a tiny chip of silicon, whereas in 1970 a similar chip contained only 512 bits of storage. During the same time period, the price of memory has decreased by a factor of more than 50.

With these advances being made at the semiconductor level, system designers have been able to provide ever-increasing function in the hardware and operating systems for modern computers. This has led to more innovative computer systems, with more innovative applications.

In the early fifties, there were but a mere handful of computer installations in the United States; today, there are more than 300,000. During this time, the cost of computing has shown significant decreases from year to year. For example, in 1952 it cost $1.26 per 100,000 multiplications. In 1964 it cost 12 cents and today it costs about a penny—representing enormous cost savings to our customers.

Memory costs also have gone down. In 1973, it cost the user $315,000 per megabyte of memory. Today, the same amount of memory can be purchased for $20,000.

The equivalent of a computing system that filled a large room and demanded a multimillion dollar price tag in the early fifties today costs but a few thousand dollars and occupies the space of an ordinary desk.

While this price reduction in the cost of computing is impressive, equally or more important are the advances in functions and capabilities that have been made. These new functions, in turn, provide new capabilities and productivity enhancements to whatever tasks they are applied.

While the development in data processing would be impossible without the progress in semiconductors, the reverse also is true. To design a complex, competitive semiconductor product and to control its manufacturing processes and its testing without the aid of computer systems is at best difficult.

This inerdependence between semiconductors and computers, at many levels, means that their futures are interwoven.

This progress is being made throughout both of these highly-competitive areas, and has been fueled by increasing amounts of money dedicated to research and development by the many firms in the United States and abroad. For example, in 1971 IBM spent $540 million on R&D; last year the figure was $1.14 billion.

4. FUTURE OF INNOVATION

Having described in general terms the development and present state of semiconductors and data processing, it is important to discuss the question: Will this progress and innovation slow down and are there signs of leveling off in opportunities and new applications?

We believe that the innovation and progress in these two industries will continue in the future, if anything, at an increasing pace.

The limits imposed by laws of physics are orders of magnitude away from imposing a limit on further developments.

Innovation in both semiconductors and data processing is not just the innovation of products in response to user needs, but equally important, includes the innovation in processes and tools.

With regard to semiconductors:

The integration level of circuits doubles every couple of years. While this parameter is not the only one by which to judge innovation and progress, it is one of the more important ones. This rate of change is reflected in the cost of the product as well as in productivity increases in the industry.

As processes, design approaches, and tools used in the development and manufacture of semiconductors are better understood, new approaches are being pursued resulting in keen technological competition.

An entire industry supporting semiconductors has emerged to supply tools and materials at an increasing rate at reasonable cost, thus making the entry of new producers possible.

As costs decrease, new applications will emerge and become economically feasible thereby increasing the demand and volume of semiconductors. This volume increase will lower the cost further as learning and economies of scale occur:

the electronic watch is cheaper, more accurate and offers more function than the mechanical timepiece;

the electronic hand calculator has already obsoleted the mechanical desk top calculator;

microprocessors will find their use in household appliances, entertainment products, and the like;

many control functions in the automobile will be executed by the microprocessor and other semiconductor components.

Analogous developments in data processing:

Rate of progress is increasing, as is the competition through new entries into this field. These new entries are greatly helped by the progress and general availability of semiconductor products.

The spectrum in performance and function is broadening as computers are designed and produced to fit many different tasks.

The applications being designed make computers a prerequisite to the day-to-day operation of an office, a manufacturing line, a plant, and distribution center. Eventually, these applications will even reach into the home.

As data processing costs decrease, new applications will be available for computerization. This, in turn, will increase the demand for the product and because of this higher demand still lower costs will result.

5. PREEMINENCE OF U.S. SEMICONDUCTORS AND DATA PROCESSING

While the success and rapid growth of these industries are well recognized, the underlying causes of this unique preeminence are not as obvious. The following factors were key contributors:

A wealth of theoretical knowledge was available for immediate application. Solid state physics and numerical mathematics were mature disciplines ripe for industrial use.

An excellent working relationship between the university, government, and industrial communities had been developed during World War II. This relationship was sustained by some large endeavors in the public sector, such as the space program.

The U.S. technical community was a mobile one—both geographically and technically—readily embracing and mastering these new technical skills, unimpeded by old ways and methods.

The companies in the semiconductor and data processing fields have emphasized technical education on a large scale and the rapid publication and use of technical innovations.

Military and space agencies of the U.S. government and their major suppliers have always been leading users of semiconductor and computer technology.

Examples in the semiconductor industry of government stimulus are the procurement of transistors and integrated circuits for the Minuteman programs, the development of military specifications, the insistence on reliability across the industry as well as the establishment of second sources for major components.

During the early development of data processing, the AEC, DOD, and the space programs periodically funded the development of new machines and were the receivers of the first models (Illiac I & II, Whirlwind, Sage, LARC, Stretch, Cray I, Illiac IV).

Over time, the government's role in stimulating basic development has lessened. The government today is increasingly a user of off-the-shelf technology. There are signs of new awareness of the need for government stimulus—today's hearing being an example of this renewed interest.

6. CHALLENGES TO U.S. PREEMINENCE

The competitive and technical environments are shifting. Many countries have recognized the strategic importance of semiconductors and data processing. As the technical base underlying these two areas has solidified, the entry of new companies is facilitated.

In semiconductors, the emergence and dominant role of the silicon planar process and its large potential for future improvements represent a well-defined target. The knowledge base has been increased; this base has been diffused worldwide, making new entry less risky.

In data processing, the universal use of high-level programming languages makes computer applications more portable from machine to machine. Also, the longevity and establishment of computer families by major manufacturers ease the entry of competitive companies that produce compatible input/output and memory products and even compatible central processing units (CPUs).

The successes and the critical importance of these two areas to any nation's economy has been recognized by many governments, notably France, the United Kingdom, Germany, Brazil and Japan.

A number of methods have been used by these governments to foster growth of national semiconductor and data processing. Japan is one case in point:

The Japanese government has identified the establishment of a strong computer industry as a national goal. It is well understood by Japan that to accomplish this data processing goal, leadership in semiconductor capability is a prerequisite.

Government-initiated reorganizations have consolidated the Japanese computer effort. Through combined government and industry funding a Very Large Scale Integration laboratory has been established with the participation of all companies that have a stake in the development of the computer industry.

Japanese companies have invested in U.S. semiconductor and computer companies. Such ventures can assist them in the development, manufacturing, and marketing of Japanese products.

This sophisticated effort is aimed not only at domestic needs but also at establishing semiconductors and computers as leading exports.

Japanese competition is noteworthy. Their technical publications and education facilities are impressive so is their inventiveness and technical productivity.

At the same time, there are signs in the United States of reduced interest or accomplishments in these areas. For instance, in 1965 about 20 percent of U.S. Patents were issued to non-U.S. nationals. But by 1977 that figure had increased to 37 percent.

Also, the number of active U.S. scientists and engineers has declined or at best stablized since 1971, and there has been a shift away from the hard sciences and engineering disciplines.

7. REQUIREMENTS

Successful innovation implies rapid changes to products, tools, technologies, procedures, and processes. To encourage innovation, we must create an environment which encourages the introduction of changes and improvements.

Industry cannot take advantage of new and innovative processes and ideas without continual replacement and improvement of existing plants and equipment. This must be recognized to assure future growth.

The continuous influx of trained people who can develop new ideas is crucial. The education system, as well as the support to the education system, should be evaluated to insure the continued availability of this talent.

Companies in the semiconductor and computer field must take a global view. Government regulation of technology transfer should take this into account.

Barriers to free trade should be minimized. For example, today more than 40 countries impose tariff rates on imported computer products which are at least double the U.S. rate.

The Government can contribute further by becoming a well-informed and sophisticated user of computers. This would spur new endeavors and new applications and developments.

In an information age, the computer represents an essential tool for coping with the complexities of modern society.

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In a highly competitive environment, the semiconductors and data processing industry has made great progress in the past 30 years. Despite the challenges, the promise for the remainder of the century is bright.

The Chairman. Because the sound system is not working very well, perhaps it would be better if everyone pulled his microphone a little closer.

You gentlemen all suggest, and most analysts seem to agree, that military and space programs were critical to the development of the semiconductor and computer industries in the 1950's and 1960's. They provided large amounts of capital for production equipment and an assured demand for new high-priced products. Without this support, it is doubtful that the industries could have increased production and reduced prices sufficiently to greatly expand commercial markets.

In the early 1970's, the Government's share of the semiconductor market dropped to about 15 percent. An OMB-sponsored study group is preparing a report that is highly critical of the Government's obsolete data processing equipment and procurement policies, and Mr. Bloch seems to agree that the Government is no longer a sophisticated buyer of computers.

Let me ask you this. Is the Government market, contrary to these indications, still functioning effectively to advance technology?

Dr. Harman. I will make a brief comment, since I'm the least technically sophisticated of the members of the panel, being an economist.

The Chairman. All right.

Dr. Harman. I think there are a couple of dimensions that should be emphasized. DOD need for electronics are sometimes very specialized; for example, the electronic components that can withstand nuclear effects. This type of buying, and the R. & D. that goes into making the products before they can be bought, is important for the Government, but it doesn't really, as I understand it, enhance the capability of industry to produce products for the private sector. So, in that sense, there may be sophisticated buying but a very specialized sort.

The Chairman. Mr. Bloch.

Mr. Bloch. Let me just comment on a very personal note on that.

First of all, I think the Government has been too much an off-the-shelf user of these components or, primarily of components, where some stimulation by some very specialized kind of requirements could have given the whole industry an important input and impetus.

Second, my point before was the Government also has to be a sophisticated user of technology, I think that this is important. It was such a user in the past—it is not so today and should become an innovator again in the future.

The Chairman. I also sit on the other side of the table, on the Armed Services Committee, where the objective has been to try to encourage the Government to buy more off-the-shelf items. You are suggesting that this policy is really hindering advancement of technology. Would you suggest, then, that we try to change our procurement practices in some way? What kind of approach do you think we ought to take here?

Dr. Heilmeier. I think that where the DOD can buy equipment off the shelf, they should do so; but I think what you are implying is that the DOD should not seek new technology for new technology's sake. Where it is important for the accomplishment of their mission, they can and do sponsor very creative and innovative efforts; but

I think over the past several years, as we have all begun to take a closer look at military expenditures, I think it is in the best national interest that the DOD not be in a position where technology is something which is pursued for technology's sake.

The CHAIRMAN. Of course, one of the problems that we have had is that you can't see and feel the results of R. & D. Having come from ARPA you are well aware, I'm sure, of the problems we had in trying to get adequate funding for R. & D. programs. If it's something that's a little exotic, it is difficult with an appropriations committee or an authorization committee to try to get dollars to do something we know not what.

Mr. Bloch.

Mr. BLOCH. I think, it's a balance of things that matters. It can't be all one way or the other way, and I think one has to find that middle road that stimulates the development of new components or new systems, while at the same time taking full advantage in a sophisticated way of what is available in the marketplace.

The CHAIRMAN. What are other governments doing now to advance the state of the art in the absence of military and space programs? Even though we have had and do have the largest military and space programs, it seems that some of these governments are doing more to advance the state of the art.

Mr. Corrigan.

Mr. CORRIGAN. Senator, I would almost go back to your earlier question. The mechanism perhaps, the only mechanism available to the Government to foster R. & D. spending is perhaps in its procurement practices. The U.S. Government has not so far followed any of the practices that the foreign governments have followed, and it was mentioned earlier by several speakers, the unifying effect, whether it was with the universities, industry, and the Government, of a national goal like the space program, or like the major thrust in defense after World War II, where we differ perhaps today from some of the other governments is the fact that the computer industry and the semiconductor industry have been established as national goals by several countries across the world, beginning with the Japanese; and with the Japanese, you have a much more cohesive relationship, very similar to what we had in the 1950's and early 1960's where our national goal was perhaps expressed in the space program and the defense programs, but the national goals of the Japanese is economic in nature.

They have tended to go the direct subsidy route, investing conservatively $500 million and perhaps as much as $1 billion in direct funding of their semiconductor and computer thrust.

What the British Government has done is a little more creative, perhaps. There you have a socialist government acting as a private venture capitalist to directly extract American technology which is somewhat unique; and I am sure we will have some political problems as they move down the road on that, but investing in the range of £50 to £100 million directly into supporting the semiconductor industry, and even start-up ventures.

The French Government has no less than three separate thrusts, with three separate agencies of the government vying to invest money in the semiconductor industry.

The Germans have taken perhaps a more practical approach where they have encouraged their major industries to take positions in American companies, notably Siemens and Bausch have been two major German companies who have taken positions in American companies, and that is with the encouragement of the government.

The Korean Government, and the Japanese look on the Koreans perhaps as the next major threat, has defined as a national goal creating a viable semiconductor industry; and this thrust today is not in the computer area but it's in the consumer area, and that is to support their thrust into the TV market, what the Japanese did to the West market over the past 10 years.

So we have some very direct investments of all the major industrialized countries, clearly from the perception that unless they have a secure position in the computer area in the next 10 years, they will not be a major factor in the 21st century.

The CHAIRMAN. Several of you referred to very large-scale integrated circuits as the next generation of semiconductor technology. We know the Japanese Government and industry, as you have mentioned, are investing upward of $250 million in a 4-year coordinated effort to develop VLSI circuits.

Are there any other countries engaged in efforts to surpass existing technology?

Mr. CORRIGAN. I think, in general, the Japanese effort is a little unique; and maybe because of that, it's going to be most effective in the long pull, that they are past the stage of attempting to acquire technology from the Americans, and they have decided they are going to develop an indigenous technology base and the capability that was mentioned earlier to develop and build the leading edge technologies, and they have invested directly.

I believe the other governments are still in the acquisition stage where they are attempting, directly and indirectly, to acquire American technology and perhaps Japanese technology over the next several years; but the Japanese are unique in that they are attempting to attack the problem frontally by creating their own technology and their own ability to create further technology.

The CHAIRMAN. Mr. Bloch pointed out that IBM's R. & D. budget for last year was $1.14 billion, and Texas Instruments spends about $100 million per year. Now, I am wondering how the Japanese VLSI effort of $250 million over 4 years split between five companies can really pose a serious threat to our technological lead, or does it?

Mr. CORRIGAN. Because very simply the $250 million is nonsense, that the $250 million is just the simple tip of the iceberg; and it's rather looking at Japanese social security and measuring it against ours when, in reality, the social security problems are laid out to the major aspect in exchange for other services rendered to the government. In the same way, the $250 million that's published as being the program is just the tip of the iceberg. The real program is perhaps 10 times that.

Dr. HEILMEIER. I think another aspect of that, Senator, is that the Japanese effort is focused on VLSI technology, whereas the R. & D. numbers that you quoted for IBM and for Texas Instruments are spread across a broad range of technologies.

The CHAIRMAN. Mr. Bloch.

Mr. BLOCH. I agree with that comment that was just made. I would like to point out one thing.

This word "VLSI" is a very nebulous kind of a word. It is a moving target. Today it's 1,000 circuits on the chip. Next year it's 10,000. The year after it might be 20,000. So there is a lot of potential left in this technology, this very broad and pervasive technology called semiconductor VLSI. In the next 5 to 10 years, it will make continuous progress, fundamental progress, that will lead to many new innovations and applications.

The CHAIRMAN. Is Dr. Harman right when he suggests that industry has shifted away from basic research?

Mr. HEILMEIER. I think that he is right, Senator Cannon. I think that in the 1960's, American industry was primarily input oriented insofar as its R. & D. policies were concerned; and then due to changing economic conditions and other pressures, it became output oriented in the late 1960's, and that has continued through the 1970's as well. I think that basic research which was formerly done in industry in the period of 1950 through 1965 perhaps no longer is done due to pressures of profitability and economic cycles which we all face.

Mr. BLOCH. I too, would like to comment on this question.

I think there has probably been a shift away from what was called basic research. How much of a shift, I'm not sure. The pressures which were mentioned before are causing this shift toward more output-oriented present day kind of developments.

On the other hand, let me also say there is a very fine line between basic research and development, and one should not underestimate that in an area like semiconductors and computers.

The CHAIRMAN. How much are Texas Instruments, Fairchild, and IBM devoting to development of VLSI?

Mr. CORRIGAN. That's a difficult question. I would take a stab at it. I would guess perhaps 2 percent of sales; and in the Fairchild case, that would be at about $5 million a year, 2 percent of $5 million a year, that you could relate perhaps directly to VLSI research.

The CHAIRMAN. It would be more than the Japanese are devoting unless, as has been suggested, the figures cited are really just the tip of the iceberg and there are many, many other ways in which the effort is going forward.

Mr. CORRIGAN. I'm not so sure, Senator. You see, the other factor that you have—and maybe it's the Japanese solution, and I can't quite visualize the same relationships existing between the industry, the universities, and the Government in the United States—but it is extremely focused so you have tremendous cohesion between the moneys invested in computer development and semiconductor development and in the peripheral equipment development, and all of this is orchestrated by the central government, which is difficult for us to visualize, but that's done very successfully, and I think it is part of the general culture in Japan. So not only do you have many more dollars invested than is published, but I think it is much more focused and much better used than our somewhat diffused system.

The CHAIRMAN. Dr. Harman.

Dr. HARMAN. I would like to comment on several of these questions and in fact, to follow up on something that Dr. Heilmeier said about bureaucratically controlled R. & D.

The fact that foreign governments are investing in new technologies is worth recognizing and taking into consideration, but that does not necessarily mean that good ideas and good products will result. The case of President De Gaulle's Plan Calcul is a very good one. Compagnie des Machines Bull was protected by the French Government, but 66 percent controlling interest was eventually sold to GE. That was the wrong company for France to select—GE ultimately failed in the computer business. So there are very difficult challenges for the firms of many different countries to face with new technology; some firms will be successful and some not. The level of resources committed to support technological innovation is one measure of the seriousness with which various countries and the companies in them are pursuing the technology, but it is not necessarily a good measure of who will be successful.

The CHAIRMAN. Some people in the U.S. industry have reservations about the announcement of DOD and ARPA that they plan to spend approximately $150 million over a 6-year period to advance the development of high speed circuits. What is the relationship between VHSI and VLSI technology?

Dr. HEILMEIER. I think that the way in which the DOD program has been cast, there is very little difference between what they call VHSI and what we call VLSI.

The CHAIRMAN. Are the DOD programs likely to have commercial payoff even though they are geared to defense needs, or will they divert resources from projects that could better meet market demand?

Dr. HEILMEIER. No, I think there very definitely will be spinoffs from a successful DOD VLSI program, no question about it.

Mr. CORRIGAN. Senator, I think each of us, obviously being involved with individual companies, when we comment on a program like the DOD program which has to be focused more on the needs of national defense—I personally think it's a good program—but obviously companies which are not involved in very high speed circuits, and very high speed as opposed to very complex, usually are bi-polar in nature and extrapolations of bi-polar technologies. You will get some division in the industry with those companies that don't do any work in this area, will feel that it is probably not the best way to certainly attack the commercial needs of how do we compete on a world basis, because in some ways the DOD advances in technology are not necessarily in line with exactly what is needed in the commercial market.

The CHAIRMAN. Will the Government funds displace private R. & D. spending in these areas or do you think that those efforts will go forward as well?

Mr. CORRIGAN. I think those efforts will go forward. If you look at the basic developments in the West technology, which really has been similar technology for developing VLSI, the companies that are most successful in that area have virtually no Government support whatsoever and where the basic memory work was done in companies that were not involved with the Government.

The CHAIRMAN. Mr. Bloch.

Mr. BLOCH. The program is a new one and has not yet fully emerged. At this point it's very difficult to judge it, but I think that in principle it's a good thing to have such a program. I think it will supplement what goes on in the industry and not replace that effort. I only hope that it be focused correctly and not used to fund many small specialized efforts that are not pulled together into a workable, understandable worthwhile goal and stand-alone endeavour.

The CHAIRMAN. Do you think that the Government should avoid duplication of effort, or should it really support competing efforts?

Dr. HEILMEIER. I think the history of innovation in this country and other countries as well has shown that competition is a healthy thing; that is, competition in ideas as opposed to duplication of ideas.

The CHAIRMAN. You will recall that in some of the military and space programs the Government supported parallel efforts to try to achieve a particular purpose. I well remember when the objective was made by President Kennedy to place a man on the Moon. One of the questions that we ran into constantly was what is all of this spending really getting for us. We are investing these tremendous amounts in order to put a man on the Moon and bring him back, and then what have we got? I believe it was during Jim Webb's term as Administrator of NASA that they compiled and published some of the commercial spinoffs and the benefits to mankind, to show what had been really achieved as a result of some of these tremendous R. & D. efforts and expenditures of dollars. It was staggering. I suppose you couldn't calculate the value of some of those achievements to mankind.

Mr. CORRIGAN. I think I can give you a case in point, Senator, and that was in 1960, I remember very well working on the Germanian MESA transistor technology for Minuteman I, and running down the same line, we were using the identical technology to sell to IBM for some of the IBM computers. This was a case where the fundamental technology for Minuteman was feeding into the computer industry.

The CHAIRMAN. Mr. Corrigan, you made eight recommendations for Government action. Five of the eight deal with matters of international trade and seem specifically concerned with Japan. How do these relate to our central question today, which is the capacity for innovation of the semiconductor and computer industries?

Mr. CORRIGAN. Basically, the two are related. Without commercial success, an industry-funded R. & D. program is not feasible. Obviously industry, without direct Government support, has to generate those profit margins that enable that R. & D. to be addressed, and we see as our major competitor today the Japanese industry that has very direct government funding. It has prohibited areas which prevent the U.S. industry from effectively selling into Japan and does not have the same needs for profit margin which private U.S. companies have. So that if you address the one you also address the other, but, obviously with higher profit margins due to more effective penetration into national trade, the U.S. industry will be able to pour back more into R. & D.

The CHAIRMAN. Several of you have referred to increasing foreign direct investments in U.S. semiconductor and computer companies. We have been able to document 18 cases of substantial German, Japanese, Canadian, and British equity purchases in the past 5 years, 8 in the past year alone. You have explained the economic conditions that encouraged such investments, but you have not said a great deal about the motivation. Do these represent efforts to gain immediate access to U.S. technology, to establish a U.S. marketing base, or simply make a profit?

Mr. CORRIGAN. I would say the last is the least of the considerations. I think it's a matter of buying position at a critical time. It's a matter of accessing the technology relatively directly. In short, profit motivations are really not involved.

Mr. MERRILL. I am Steve Merrill of the committee staff.

In the previous hearings before this committee and again today, we have been told that very often the conditions for innovation are not recognized, let alone considered, by the Government when new regulations are proposed or changes are made in the tax code or other policies are adopted. As Dr. Heilmeier pointed out, it is not simply a matter of educating Government officials, because often their mandates and responsibilities are not directly to promote innovation. Moreover some of the solutions that have been suggested, such as requiring innovation impact statements on new regulations, seem to entail more bureauracy rather than less. For example, it seems clear that they would impose more paperwork and reporting requirements on small businesses. Therefore, something more fundamental seems to be needed, but there have not been many suggestions.

Could you suggest any changes in either the organization of the Government or its procedures that would result in a better balancing of innovation with other social needs and policy objectives?

Mr. CORRIGAN. I think that would be a very presumptuous thing for me to address. I think I will pass that to somebody else.

Dr. HARMAN. It looks like I'm elected, so I'll take a crack at that one.

As I said, I think in greater detail and hopefully greater clarity in my written prepared testimony, this is a very difficult problem area. It seems to me that one step in the direction of the solution you are looking for is a more concerted analysis of possible regulatory or other changes before they are enacted. The formation of the Congressional Budget Office and OTA are steps in that direction, although I don't think that they provide sufficient focus on some of the issues of the impact of nontechnology based policy or legislative initiatives on technological innovation. It seems to me that more thorough analysis needs to be directed to that purpose. I don't really want to address whether that should be institutionalized in any broader sense.

Dr. HEILMEIER. I take perhaps a very simplistic view of the situation, Senator, but it seems to me that more Government studies and more Government analysis and perhaps more Government regulations isn't really going to address this problem well at all. It seems to me that the best way to do it is to go back and look at those periods in our history, and indeed the history of other countries, where innovation in industry did flourish and ask why it flourished; and while I don't profess to be an economist, I think there is good correlation between the tax structure and progress, industrial progress. It seems to me that we can throw a lot of extraneous factors into the hopper, and we can do a great deal of analysis of the situation, but I don't believe that the sophistication of our conclusions are going to be any more than there is a definite impact that the tax structure has and we ought to go about fixing that.

The CHAIRMAN. What about the tax bill that Congress passed just a couple of weeks ago? As a matter of fact the President hasn't signed the tax bill as yet, I guess, but he has said he will. I am referring to making the investment tax credit permanent and reducing somewhat the capital gains tax.

Dr. HEILMEIER. I think that is a good first step. I think we have got several other steps to make as well.

The CHAIRMAN. You think that that will be helpful, though, to some degree?

Dr. HEILMEIER. Very much so.

The CHAIRMAN. Thank you very much, gentlemen. We certainly appreciate your being here and giving us the benefit of your views.

Our next panel of witnesses will discuss the importance of new firms in sustaining innovation and problems in their creation and growth.

We will hear from Dr. Gene Amdahl of Amdahl Computers; Mr. Tom Perkins of Kleiner and Perkins, a venture capital organization; and Mr. Zeev Drori of Monolithic Memories, in that order.

Dr. Amdahl.

STATEMENT OF DR. GENE AMDAHL, CHAIRMAN OF THE BOARD, AMDAHL CORP.

Dr. AMDAHL. Good morning, Mr. Chairman.

I represent a company that has had a rather unusual history, and I think perhaps some of the aspects of this company are worth looking at just as an item to study.

It is somewhat of a recordbreaking company in that it has had a record venture investment before its first revenues. This venture investment was some $47½ million, all raised during a period when venture capital was almost impossible to acquire.

The company went almost 5 years in a stage of R. & D. before its first revenues. After having achieved its first revenues, the company became immediately profitable with a positive cashflow, and its revenues have approximately doubled annually. The revenues are now at a running rate well above $300 million a year. Our profitability is also excellent in that it's between the 25 and 30 percent pretax area.

We now employ over 2,600 people, and exports represent about one-third of our revenue.

Amdahl Corp. is based on innovation. We have the most advanced high-performance technology in the computer field which, together with its product design, yielded unusual capabilities in terms of high performance, high reliability, and moderate cost.

All these things are the consequence of the desire to go out and innovate and to produce the best that could be done.

Amdahl Corp. also has a foreign investment. More than half of the $47½ million came from Japan and from Europe. Some $28 million came from those sources.

The ownership of the company is about 27 percent foreign and 73 percent United States.

Amdahl Corp. had to raise its financing during the most depressed capital markets in the history of our economy. At the time the raising of financing first began, which was in 1970, Amdahl Corp. found almost no sources of capital that were currently considering investments above approximately $100,000. The principal reasons for the great lack of capital at that time appeared to be principally due to the increased capital gains taxes, with two lesser but still serious considerations, one was the rather restrictive transfer capabilities for the securities held under rule 144, and the other was the prudent man rule which applied to the large funds which were managed as trusts.

All three of these things very seriously reduced the capital market for venture companies. In particular, the capital gains tax affected the availability of funds in a second manner as well, because the ability to have an orderly stock market was almost impossible in the face of the high tax rates.

I don't know that one really wants to talk about an orderly capital market because it was never orderly even before the high capital gains tax, but it was more exuberant, and the exuberance was missing ever since the enactment of the higher capital gains tax in 1968.

There was one other complicating factor for the particular field into which I went, and that complicating factor was a fear generated in the investment community that action by IBM who was the dominant force in that industry would be able to force us out of any successful market activity at any time they would so choose.

This fear kept out even most of the investors that were otherwise willing to put in as much as a $100,000. However, the fact that we were able to go out and get capital from companies outside of the United States made it possible to bring along concurrently a number of U.S. investors.

The first financing we got was some $2 million which all came from the Heizer Corp., a venture capital corporation in Chicago.

A search for some 6 months after that in the U.S. capital market showed no promise whatsoever of any funds at all. At that time I turned to Japan. I turned to a company by the name of Fujitsu which was the leading computer company in Japan, and for the investment of some $5 million and the joint development program initiated together with them, we were able to conclude essentially the financing which turned out to be also a key relationship to a succeeding financing from that same company.

In return for the investments and for the financing in the joint development, Fujitsu received equity commensurate with the amount invested at that stage in the company, and also it received via the joint development activities rights to utilize the technology so developed in the domestic Japanese computer market and in markets nonexclusively outside of the United States and Japan.

Fujitsu's activities at this time are still principally in domestic markets of Japan. We have seen some competitive activity as they have extended their marketing somewhat outside of the Japanese marketplace, and some of the marketing activities that they are engaged in outside of Japan are in the form of OEM agreements with companies such as Siemens in Germany.

The other investor was a German company by the name of Nixdorf who invested some $6 million. This occurred after, approximately 1 year after, the investment of Fujitsu of $5 million. These investments from Nixdorf in Germany were able to trigger the investment by a number of U.S. companies, that is investment groups, and we raised some $8 million from U.S. sources at the time we received the $6 million from Germany. At that same time, Fujitsu also repeated their investment of $6 million.

Later in 1973 when we were trying to raise the last of the capital we felt we needed, we were attempting to go out for a public offering. We were unable initially to find an underwriter who was willing to undertake an offering in such severe a marketplace, that is stock marketplace. We finally ended up with a sudden break occurring about the middle, actually about August 1973, in which there was a successful public offering for a small venture company. At that time we got a firm based in San Francisco to support us as an investment banker, and we went ahead and prepared a filing for a public offering.

We were able to complete our filing for a public offering in November of 1973, early November, and that filing stayed in the Securities and Exchange Commission until well into December before it was first looked at. But it happened by virtue of that one successful offering there had been a landslide of submissions for public offerings—and we, unfortunately, were not at the leading edge of that landslide.

In December we began a European tour prior to a U.S. tour to stimulate interest in the offering. We arrived for the first of two meetings in Europe, the first one to be held in London. We arrived at the appointed meeting place for this luncheon, and people came late. They came about an hour late with very long faces, and it turned out that that morning on the London Stock Exchange they had the largest drop in the stock market since 1929; and the last of our hopes were dashed at that point.

In 1974, we turned once more to our largest investors, the Heizer Corp. and to Fujitsu, who together were able to provide the amount of capital needed to complete the development and initial marketing of our product.

As I indicated, we got our first revenues in the fourth quarter of 1975. From that point, our financing problems ceased because we had positive cashflow from that point.

So that is the story of how the capital markets operated in the time when we were attempting to begin.

I think if the capital markets had been operating properly, Amdahl Corp. probably would have been able to shorten its R. & D. period by more than 20 percent to something less than 4 years.

The amount that would have been able to be raised, I believe, would have been adequate to have permitted the company to have even gotten a more rapid and more significant start in the marketplace.

I think since it was requested in my invitation letter that I should also mention something about why I left IBM to form Amdahl Corp. I left IBM in late 1970, I had been a fellow at IBM, which was one of a relatively small number of people in that category, about two dozen of us, I believe, at the time that I left.

At IBM I had been the head of architecture for system 360: and after being appointed a fellow, I had moved to the west coast and I had ultimately become director of advanced computer systems in Menlo Park. In that activity, IBM was attempting to develop higher levels of integration, at that time in the range called medium scale integration, and to develop a high performance computer in such technology.

We were not successful in doing so because of the price tags that were to be attached to a product having that performance level. We were unable to obtain a large enough market at those prices to obtain the revenues necessary to offset the costs of development and manufacturing.

It may seem strange that I make the statement that way, but IBM had a line of computer products that were compatible one with another that formed the system 360 line of computers. This set of computers was compatible one with another, and so the performance and price of one entry in that line affected the price for the performance of any other entry also in that line. That meant that if you offered a more capable machine that the price which should be placed on that computer should be related to its performance in order not to disturb the product line economics.

Because of this, an exceptionally high capability computer would be priced out of the marketplace regardless, basically, of what its cost might be.

I attempted to change some of these policies in IBM. I asked for and received an audience from the three top men in the company at that time: Mr. Learson, Mr. Cary, and Mr. Opel. I presented a case for the change of six policies within the company. I presented, first of all, the case as to what effect they had in the advancement of the computer art in the world then the effect of the change. The response that I got from those three executives was that they agreed with the effect of those six policies, and their final statement to me was that, in spite of this, they felt it was not in the best interest of the IBM Co. to change a single one of those policies.

It took me some time to fully understand what my alternatives were, but ultimately I decided the only way in which I could perform the kinds of activities that I was interested in was to leave IBM and proceed to advance the state of the art in computing as I thought it should be. It was somewhat unique relative to other entrepreneurial activities in that there was no technology in IBM at that time that could be transported out of the company to assist in such an undertaking. So all of the technology that is employed in the Amdahl computers was developed at Amdahl with venture capital money, and all product designs also were undertaken at Amdahl again by those same capital venture funds.

Because of this experience, and discussions with many other entrepreneurs, I believe that much of the innovation in terms of bringing new technology into products occurs in the new venture company. I believe that most of the entrepreneurs are in the same situation I was in, one of frustration for achieving something that you have a vital interest in achieving. Whether it be for pride or whether it be for patriotism, I don't know, but it is something that motivates an entrepreneur very, very strongly.

Most companies that become established do develop vested interests in their product and/or marketplace positions and tend to suppress the introduction of new technology beyond just that level necessary to sustain the position that they attain in that marketplace.

Now, in terms of bringing such innovation to the benefit of our economy, I believe that we must go farther in the relief of the capital gains taxes, because I believe that the only viable source of money for new venture companies is from the venture capital area, and there is very high risk associated, and I think high rewards must accompany that high risk or the money will not be made available; and it should not apply just to the venture capital either in terms of the capital gains because the venture capitalist must ultimately turn his investment back into some other liquid form via the stock market. So I believe all the stock transactions have to ultimately have the same relief in the capital gains.

I do think, however, that this is not something that can be done too immediately since there is a reduction already in the works; but I would propose that there is something else that could be done that could help industry across the board; and I think it is essentially in the form of a governmental support of R. & D. but not in the direct form. I would look on it sort of an equivalent of an investment tax credit to be given for doing R. & D. in the corporation where the amount that one is allowed to write off as expense is not the expended dollars in R. & D. but 1.x times the expended dollars where x should become appreciably close to 1.

I think if this is done we could expect immediately that with the same amount of capital available in a company for R. & D., one would find that you could do about 50 percent more R. & D. under this circumstance.

The advantage of doing the R. & D. support in this manner is that it allows the direction of that R. & D. to be directly related to the introduction of the results into the marketplace and so stimulate the economy rather directly, both in terms of the desirability of our products here in the United States, and also the desirability of our products in the world market.

I believe as a consequence one would create quite a few more jobs because the resulting innovation would stimulate and expand the marketplace.

Now, I don't suggest that this be kept only to the high technology companies. I think it should be extended to all corporate undertakings in the United States, because I believe that one of its great advantages would be the increase in productivity that such innovation would introduce even in well-established low-technology undertakings.

That is the last of my prepared remarks, and I would seriously suggest the investment tax credit for the R. & D.

The CHAIRMAN. Thank you very much, Dr. Amdahl.

Mr. Perkins.

STATEMENT OF THOMAS PERKINS, GENERAL PARTNER OF KLEINER & PERKINS

Mr. PERKINS. Thank you for letting me have the opportunity to speak on Government policy for the semiconductor and computer industries.

A word or two on background. I am a general partner in Kleiner & Perkins, a venture capital organization specializing in high technology new enterprises.

As Kleiner & Perkins, we have invested in many opportunities and have a dozen firms in our portfolio. We take particular pride in two companies in which we provided all of the initial capital and associates on our staff became the operating management.

These "spinout" firms have done very well and have received considerable favorable publicity recently. One is Genentech, a pioneer in molecular genetics—or recombinant genetic engineering—which has been the first and only entity to successfully produce a useful product using this new technology; our achievement of human insulin produced by *E. coli* bacteria has received worldwide acclaim and holds the promise of saving millions of lives.

The other pure startup company from our shop is Tandem Computers, Inc., which began life with a radically new technology in the dark days of 1974 and has grown extremely rapidly to a current annualized volume of $30 million, with a net profit margin after tax of 10 percent. Tandem went public last December through a well-received underwriting.

Prior to our partnership, my associate, Eugene Kleiner, was one of the founders of Fairchild Semiconductor, the progenitor of virtually all the other bay area semiconductor firms. I was the founding manager of the Hewlett-Packard Co.'s computer division which is now the world's second largest minicomputer manufacturer. In view of this dual background, I hope I will be able to address today's issues from both the venture capitalist's and the entrepreneur's perspective.

In preparing these remarks, I reviewed testimony I gave in April 1976, on a similar topic before the U.S. Department of Commerce. I am now struck by the very gloomy tone of that presentation. While many of the problems I was concerned with—as continuing inflation which would lead to inroads of foreign capital—have, in fact, intensified the favorable change in attitude of the Congress and certain key regulatory agencies was totally unforeseen.

I am delighted that the tax problems which have been so very heavy and detrimental to venture capital formation and investment have been understood. The tax bill currently on the President's desk is a major step by the Congress toward improving the health of our high-technology industries. Similarly gratifying have been the recent moves by the SEC in response to requests to liberalize rule 144, improving liquidity for long-held venture investments.

This change in attitude is extremely encouraging, for if those in control want to understand, the problems will indeed be solved.

Perhaps the greatest problem or question is: Why is it easier to obtain growth equity capital from foreign sources than from American venture investors? The answer, in my opinion, is that we have so cheapened American values that our technologies are the greatest bargain in the world. There is no fundamental shortage of capital for investment from American sources, although there are impediments in the path which we need to look at, but the deficit-fueled rate of inflation has so depressed stock prices— I understand the market is down 15 again this morning—and the adverse trade balance so impoverished the dollar that the foreign buyer has an enormous advantage and incentive. When one further realizes the capital gains on American profits are taxed at zero percent for most foreign investors, both here and in their home countries, the motive is complete and compelling.

I recognize the latent oversimplification of this summary and the difficulty in changing the situation. Yet, clearly, the U.S. Congress is the only path to the solution. No amount of voluntary or involuntary wage and price programs can control inflation caused by continued deficit stimulation through huge Federal deficit budgets. Only Congress can control and curtail spending. Similarly, only Congress can enact legislation to improve the export balance and the dollar. Our average portfolio company exports about 40 percent. This ratio could be further improved if the benefits of the Domestic International Sales Corporation (DISC) tax treatment were to be enhanced not attenuated.

At Kleiner & Perkins, we are intimately aware of the thrust of the foreign investor. Recently 60 percent control of one of our portfolio high-technology ventures—in the pollution control equipment field—was obtained by a German conglomerate which outbid all domestic offers.

Turning more specifically to the problems of starting a new high-technology company, I will draw from the experience of Tandem Computers. Two elements were obviously required: venture money and enterpreneurial management. In 1974 we were unable to obtain funds from a single other venture investor. We had to assume all the risks ourselves. Assuming that the new tax bill is signed, I believe today we would have an easier time in raising capital—the risk/reward ratio will have obviously been improved.

On the other hand, the problem of hiring and retaining enterpreneurial managers has radically increased since 1974. In today's environment I am not sure that we would be able to accomplish the task. The major change is the demise via the 1976 Tax Reform Act of the qualified stock option. Tandem required a large number of computer software and hardware experts. This talent was recruited from several large companies with the qualified stock option tool then available. As you may recall, the old option plan treated profits on exercised options as a capital gain.

Now the only tool we have to pry talent away from the large secure companies is the nonqualified option, and this just doesn't work very well. As you may know, under the revised tax law—which is unaffected by the pending changes in capital gains rate—the enterpreneur has an immediate tax to pay when he exercises his option, assuming he has a paper gain. He has gained no real profit. No cash has been received by him. On the contrary, he has had to fork over cash to buy the stock.

Nevertheless, he owes the IRS a payment for the paper profit. This tax liability usually forces him to do exactly that which is directly against his best interest and that of the venture, namely, to sell a big chunk of his ownership to pay the taxes.

But here is the real zinger. If he is an officer of the venture and it is a public company, the SEC's "Catch-22" about simultaneous buy/sell transactions will require him to wait 6 months before he is able to sell even a single share. If the price of the stock has collapsed in the interim, eliminating all profit, he nevertheless is stuck with the full tax. Curiously, his employer gets to write off the tax against earnings and the net revenue to the IRS is essentially zero. I am personally acquainted with three officers of a bay area growth company who have been carrying a bank debt since 1976 of roughly $80,000 each to pay taxes from this "Catch-22" on profits they have never received.

Would you leave the womb of the large corporation to play the venture game against punitive tax risks like these? The qualified stock option must be restored. There is no equity or even any sense in the present situation where taxes are paid on ephemeral or nonexistent profits.

There is a spectrum of potential investors in America ranging from the small "pilot light" partnerships like ourselves at one extreme through the huge banks and pension funds at the other. Our role is to get the venture started, eliminate most of the front-end risk, and then secure ongoing equity from the larger institutions at the other end of the spectrum. Ideally, we should then be able to recoup our capital and reinvest in new situations. If our velocity of capital turnover could be increased, our leverage—and that of our many competitors—would be increased tremendously. But, both tax policy and SEC regulations lock us into the venture for many, many years and materially slow the rate of capital turnover.

Two proposals have been proffered by the National Venture Capital Association. The first to the SEC would lift all trading restrictions for stock held in public companies for the noncontrolling venture capital investor 5 years after the company's first S–1 registration. The SEC has the proposal under consideration and will be seeking comments from industry and Capitol Hill. We urge your favorable comment.

The second idea is that of a tax "rollover" similar to that available to the real estate industry. The rollover is simply a tax deferral on profit generated from the sale of securities in a small business—as defined by the Small Business Administration—if the profit is reinvested in another small business. The enactment of this simple idea would materially speed the velocity of capital turnover and hence the generation of new enterprises which are so valuable to the overall economy.

Much has been written about the regulatory morass which businesses seem to be increasingly facing. The bureaucratic dynamic which Professor Parkinson described so humorously long ago isn't very funny any more. Again only Congress, with control of the purse strings, can begin to cut back on the inexorable growth. There is an excessive emphasis on protection of the public from the private sector, which has gone so far that the dividing line between the sectors is disappearing and everybody is being inconvenienced. Being involved in a dozen companies in several dozen markets, our ventures have at one time or another been entangled in the redtape of virtually every agency.

There is a cost to regulation which is necessarily passed along to the consumer in higher prices. This is not an inconsiderable factor in the current inflation. For example, a laser manufacturing company of which I am a director has had to add safety shutters and key locks to all its products, not just the big potentially dangerous ones but all of them, even the little ones incapable of doing any possible harm. This necessitated a price increase of several percent. This ruling has been forced upon an industry which has not had a single accident in its history.

The FDA is notorious in this regard. So much so that it is inconceivable that a new venture could be started to market a new drug. The cost of approval is now several million dollars over several years, leaving innovation in pharmaceuticals strictly in the hands of the giant established firms. Clearly, the public must be protected from health hazards and quack products. Yet, the present regulatory burden encourages additional concentration at the expense of competition. The human insulin breakthrough to which I referred has been licensed to one of the giant firms as there was no practical way for our small company to finance the product all the way through FDA approval.

At this time there is, in my opinion, an adequate pool of venture capital available to finance the relatively small stream of worthwhile ideas being generated. But this pool could rapidly become insufficient if the entrepreneurs come forward in larger numbers in the future as a result of improving economic conditions. Certain major sectors are blocked from participating in higher risk start-up venture pools of the type we operate. The recent ERISA Act tends to prohibit a pension fund from investing with any group which takes high risks. The interpretation of this act requires clarification, so that a small portion of such funds may be employed at the high risk/high reward end of the spectrum.

Similarly, the Investment Act of 1940 prohibits the general public's participation in any investment fund where the fund's managers have a financial stake in the outcome. As virtually all venture capital funds operate on such an incentive basis, by "protecting" the public investor, he is, in fact, prohibited from meaningful participation, and ventures are denied a major potential source of capital.

In 1976, I was concerned that the accelerating nature of many of the problems I have outlined would lead to what I called the "Penn-Centralizing" of today's high-technology industries. Now, particularly in view of congressional leaders' interest in listening to the problems of our industry, I am much more hopeful.

Thank you for letting me present these ideas.

The CHAIRMAN. Thank you, Mr. Perkins.

Mr. Drori.

STATEMENT OF ZEEV DRORI, PRESIDENT, MONOLITHIC MEMORIES, INC.

Mr. DRORI. I probably have somewhat different a background than the rest of the speakers. I came to the United States 16 years ago from Israel with great anticipation. When I came here, I did not speak the language and had to attend a university and simultaneously learn English and support myself. For me, this country represents the epitome of the free enterprise. I was under the domain of socialistic government and came here with great expectations.

After finishing school, I went to work for IBM, started as a junior engineer, and in rapid order have gone from a junior engineer to an engineering manager of the semiconductor operation for the semiconductor memories in the IBM plant in Vermont. This was in the late 1960's, and I have discovered there is a great opportunity in the future in the development of semiconductor memories. I have decided to capitalize on it.

I moved to California, and in the early 1970's decided to raise capital for a new startup. Needless to say, America was experiencing a recession in the early 1970's, and it took a lot of effort, yet I have raised the $2.5 million required. This amount was sufficient for the startup of a semiconductor memory company. I will dwell more about the company later on but I would like to submit here in this forum

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a five-point proposal with some specific options, at least in my mind, that will encourage the development of new corporations, will develop high-technology companies, and will promote new ventures.

There is a delicate balance between young and small companies and big government. This balance, if properly maintained, will establish a climate that will nuture the growth of new ventures. It will encourage the development of new industries, in particular, science-based or high-technology industry. My experience is within the semiconductor industry, and I think it would be instructive to take a look at this industry.

Twenty-five years ago this industry was virtually nonexistent. Today it employs 125,000 people within the confines of the United States alone, it manufactures to the tune of over $3 billion per annum, and it would not be an overstatement if I claim that this industry is the backbone of the entire electronic industry, be it the computer or the home appliance, the sophisticated military satellite, or simple transistor radio. One cannot find a better example of how entrepreneurs and their ideas and dedication brought about employment of millions of Americans, improved the standard of living for millions of peoples and nations, and rewarded the investors and the individuals who brought their knowledge and efforts to fruition.

Again it would be fair to say that the technological revolution of the 20th century was brought about through the development of the semiconductor.

In contrast, take a look at the United States balance of payment deficit and recognize the position the United States is in vis-a-vis other nations and what the electronics industry can contribute to the United States. Our industry supports substantial employment in the United States, as well as easing the pain of a large trade deficit. We are a net exporter. We employ a broad spectrum of people, whether they are engineers, scientists, or technicians. Our industry is a nonpollutant industry, extremely modern. Working conditions are superb by any standard, and the employee benefits are second to none.

The average price of the semiconductor declines by about 20 percent per annum. This is in spite of ever increasing cost of power, labor, land, water, and raw material. I challenge any industry of any sort within the United States to demonstrate similar performance.

I will give you an example of our own. In 1971 we introduced a product which was called 1K PROM. I will not burden you with the technical implication of the part. Let's take a look at the financial side of it. When we introduced the part in 1971, each unit sold for $120 each. In 1978, the same part costs 80 cents, substantially lower than the 20 percent per annum stated above. This is not a peculiar example. I will hasten to say that this is the norm in the semiconductor industry. In fact in our own company's history there is not one single part where the price went up. Without exception, all prices declined by an average of 20 percent per year.

A few words about our company. Today we employ approximately 2,000 people, of which 900 are employed in California and about 1,100 overseas, mainly in Malasia. Forty percent of our sales are exported to Europe and Japan, and our results for fiscal year 1978 were $32.5 million in sales.

I submit that the economic climate today is no longer the same as it was in the late 1960's and early 1970's. Today it would be very difficult for a new startup to establish itself. Specifically, when Monolithic Memories started, our entire capitalization was $2.5 million. This $2.5 million was sufficient to build facilities, purchase sophisticated equipment, engage scientists and engineers in research and development, and bring products to the market. Today the cost of a similar venture would be a minimum of $20 million, and this is a conservative estimate.

I will give you some specific examples, one of which Mr. Corrigan has brought before, and I am delighted to see that we have the same figures. If we take the Mask Aligner, which cost 10 years ago a few thousand dollars (about $5,000 or $6,000) the same equipment cost today $250,000; and 2 years hence, it is going to cost over a half a million dollars. Mind you, that you need 8 to 10 aliners to have a meaningful production capability.

Another example is test equipment. Eight years ago typical test equipment cost $40,000. Yet today the minimum that one pays is a quarter of a million dollars and it will go upwards of $600,000 to $700,000. We do not need fewer testers. In fact, we need more.

Today's requirements are of substantial sums of money. The venture capitalist was given no incentive to risk his money on a new venture. In addition to the large sum required for high technology startup, some vacuum was generated in the business environment. The big corporations are moving in into this vacuum, and I'm afraid, from my own perception, that the larger corporations are going to devour the smaller, independent semiconductor companies.

The future looks even more ominous when you are looking at foreign governments and foreign corporations. My position there is not a mere phobia. In fact, the statistics show that in the last 3 years foreign corporations have acquired substantial interests or complete control of five semiconductor corporations. All of them are located in the San Francisco Peninsula area. The significance of this poistion is that the foreign corporations, with their governments' encouragement, will utilize it to bolster their knowledge and production of semiconductors, thereby causing not only the reduction of exports from the United States to these foreign countries, but, in fact, will reverse the direction of product and revenue flow.

Foreign governments encourage their corporations to invest in technology and in American corporations. This is true for most foreign corporations, be it Japanese, German, Dutch, or whatever.

I believe that the United States must act now in establishing the proper environment that will encourage the development of high-technology and science-based industry such as the semiconductor industry.

What are then the five specific points that I propose that will bring some ease of pain for our present predicament and dilemma?

One, the Government must encourage investment for new enterprises which are high technology in nature. The Europeans have recognized it and are successful in pursuing this objective. My proposition goes much further than presently envisioned. I propose that no capital gain will be paid by an individual investor if he has invested in a high-technology company, provided that he keeps his investment for 3 to 5 years. By a crisp and concise definition of a science-based industry and drawing a distinction between an individual investor and a large corporation, as well as the establishment of the 5-year period, I believe it will attract substantial resources. The prospect of paying no income tax will tap virtually unlimited sources of funds.

Second, any science-based industry that invests at least 8 percent in R. & D. should pay a reduced income tax. I propose that the company that meets the above criteria will pay no more than 25 percent until they reach a size where their revenue exceeds $20 million per year. This provision is recommended so that new ventures will be able to develop and succeed. We need to sow. We need to cultivate and we need to harvest. In the absence of any one of these elements, we will not suceed.

The third component is to encourage corporations to export. Of course, the counter argument will be that DISC provides for this already. What I propose is going further. I propose that the company that exports will pay less income tax on the revenue derived from these exportations.

Fourth, simplify export licensing and cut the redtape associated with the export of product overseas. On this subject alone, I am sure, Senator, that you hear a lot. I can convey to you an example that I experienced. After working for months to get an export license to get a German company, we received an order for $600,000. The order was a composition of three shipments, each one $200,000. We shipped the first portion without any difficulties. A few months later, we shipped a second shipment and just before the shipment of the third portion the Commerce Department suspended the export license for the third portion. The explanation was that they had some suspicion that ultimately the designated user is somebody in the Eastern bloc. Now, the word here is "suspicion" and not evidence. To further aggravate the situation, ultimately the shipment of the third portion was achieved. However, not by us, but by some other corporation.

The Japanese are not impeded by our regulations, and they can export to the Eastern bloc at will. I am not going to belabor this point, I just intended to illustrate how Government sometimes can hinder exportation.

The fifth point, I would like to recommend the equalization of tariff barriers between the United States and foreign countries. I don't mean containment. I mean equalization. Again probably an anecdote will illustrate this issue. Five years ago now I met with a colleague in France, and he commented to me about the trade imbalance between the United States and Japan. He has mentioned to me that he believes the United States will be in deep trouble where the Europeans are not going to be. So I asked him, "How is that?" He said, "Simply, the Americans are very slow to act where we have years of experience with prejudice." What he was saying, in effect, that the American will try to be overly fair while the European will contain any Japanese assault on their own economy through imposing restrictions on Japanese imports that will be no less restrictive than whatever the Japanese Government established in its own land. In summary, I believe if you would review these points you will find that they are constructive. I don't propose anything which will inhibit. On the contrary I propose elements that will enhance the development of young corporations that will allow them a more free and more equitable trade.

The CHAIRMAN. Thank you very much, Mr. Drori. You have made some very interesting suggestions.

Mr. Drori, both you and Mr. Corrigan cited the rapidly escalating cost of semiconductor production equipment which has increased the initial investment required to launch a new firm by a factor of 10 or more. How much of this increase is accounted for by inflation and how much by advances in technology?

Mr. DRORI. It would be presumptuous of me right now to break these components, although I believe that by far the majority is the technology costs and not inflation. We are dealing today with much more sophisticated equipment, which has much more capability and a higher level of inherent complexity. Should you ask yourself, why does the industry pay such enormous sums for this expensive equipment, there is only one answer for it: productivity. We invest in this equipment because they will enhance the productivity and, therefore, will reduce the cost of our component.

In terms of the inflation, I don't believe that inflation is a significant factor in the total sum of the startup cost.

The CHAIRMAN. Would this indicate that there will likely be fewer opportunities for new entries regardless of capital market conditions?

Mr. DRORI. Beyond any shadow of a doubt.

The CHAIRMAN. Dr. Amdahl and Mr. Perkins, would you comment on whether or not that is also the case in the computers?

Dr. AMDAHL. I don't believe it is yet the case in computers. I think, in fact, the costs in computers have been reduced largely because a major portion of the development activity is actually being undertaken by the semiconductor companies in the area of VLSI.

The CHAIRMAN. Mr. Perkins.

Mr. PERKINS. I think that the money is available for virtually any enterprise that can show a growth in ultimate profits regardless of the amount of money required, so that the threshold has increased, I would say, to go into any high-technology business; but also the growth in profit potential can be also higher. So I think that the very fact that the cost of entry has gone up does not prohibit the formation of the enterprises. I think a lot of other things could, but not just the cost.

The CHAIRMAN. In light of the present conditions do you think that the future is very bright for these industries in which new, small firms with leading edge technologies have traditionally played an important role?

Mr. PERKINS. Yes; I think that there is no shortage of ideas. Some of these are spining out of the larger organizations, some from universities, some from governmental laboratories; and oddly enough I don't think there is a shortage of venture capital. There are huge pools of capital available in the country to be invested; but what is missing is the incentives to private capital and also the incentives for entrepreneurs to take the risks to go into the ventures.

Dr. AMDAHL. I would like to add one thing onto that, and that is for many of the companies, when they reach a certain size, they need to expand, and that requires, in general, a larger amount of capital than the company required in its venture state. At the present time it is not clear that with the badly functioning stock market that the additional capital is all that likely to be available, and this puts fear, I believe, in the mind of the venture capitalist, particularly if the undertaking is one in which over the long run, large amounts of capital investment are going to be required for further development of the investment.

Mr. PERKINS. I think that's exactly it.

The CHAIRMAN. Dr. Amdahl, I understand that your partnership with the Japanese company has been a very successful one, and I listened with great interest to your story. Were you not able to obtain the initial financing in this country because of the scarcity or cost of risk capital, lack of confidence in your ideas, or other factors? What was the basic obstacle?

Dr. AMDAHL. It was mostly the two things I mentioned. One is the reduction in the amount of venture capital that was being available. For example, at the time that I was seeking funding for the first investment in Amdahl Corp. in 1970, there were three other young companies seeking financing. Not one of those other three companies was able to acquire any further investment money at all, and all of the money that went into large computer entrepreneurial activity at that time went into Amdahl Corp.

The CHAIRMAN. Competing companies?

Dr. AMDAHL. They were in large computers. They were not necessarily directly in competition with us, but in a sense they were. Definitely they were in competition for funds.

The CHAIRMAN. Would you comment on the concern expressed by many that the technology you shared with Fujitsu in return for its investment in your firm has enabled Fujitsu to be a more aggressive competitor with other U.S. companies, both in the United States and abroad?

Dr. AMDAHL. There may be some more competitive activity in Japan itself; but if you look anywhere outside of Japan, I don't think you will find any of the Fujitsu computers utilizing that technology placed in any location in competition with anybody.

The CHAIRMAN. Do you think the U.S. Government should be concerned with the potentially adverse effects of such technology transfers on U.S. domestic and worldwide competitiveness?

Dr. AMDAHL. I would like to back up, if I may, before I answer the second question.

I would like to add one thing, and that is that that technology would not have been available to anybody in the world, the United States or anybody else, without the invested moneys from Fujitsu. To that extent, one has to view the use of the Japanese money in the Amdahl Corp. as almost the equivalent of technology transferred from Japan to the United States.

The CHAIRMAN. That's a very interesting point.

Dr. AMDAHL. As a matter of fact, it was studied this way by the Department of Commerce 2 years ago, and that was their conclusion in their report.

The CHAIRMAN. So it was not a pure technology transfer because the technology itself had not then been developed. Is that what you are saying?

Dr. AMDAHL. That's correct.

[The following information was subsequently received for the record.]

AMDAHL CORP.,
Sunnyvale, Calif., November 3, 1978.

Senator HOWARD W. CANNON,
The Capitol Building,
Washington, D.C.

DEAR SENATOR CANNON: At the Committee hearing at the Federal Court in San Francisco this Monday you asked me how much the Amdahl technology (that we have given Fujitsu rights to outside of the U.S.) had been utilized by Fujitsu in competition with us or with other computer manufacturers. My response to you at the hearing was that I did not know the figures for Japan, but that to the best of my knowledge they were not particularly large and that outside of Japan that there had been very little such equipment sold by Fujitsu.

To clarify that more fully I requested from Fujitsu the information regarding the number and kinds of M–Series (the machines that enjoy the Amdahl technology) that had been sold outside of Japan. They have provided me with that information. There are two M–190s in Spain (these machines were Fujitsu's contribution to a joint venture in Spain), and there is one M–160 in Australia and two M–160s in Korea. To place an economic value on these sales, I will compare them as well as possible to Amdahl Corporation's computer product offerings. An M–190 is almost identical to an Amdahl 470V/6 which retails in a nominal configuration at $2.4 million. The M–160 is much smaller, and we have no equivalent machine in the Amdahl product line; but our estimates for the prevailing machine price in that performance range are that the probable price would be about $400,000. The two M–190s and the three M–160s then would represent a total market value of $6 million. In my opinion this cannot in any sense of the word be considered as even noticeable competitive activity.

To place in context the relative significance of the relationship established between Fujitsu and Amdahl Corporation which resulted in the development of the technology and the Amdahl product, Amdahl will by the end of 1978 have shipped computers into the U.S. and other parts of the world a cumulative total total of $600 million, or 100 times greater than Fujitsu's international sales resulting from that joint activity.

I think without question the Commerce Department's conclusion is indeed correct—that the Fujitsu investment in Amdahl Corporation was more appropriately to be considered as a technology transfer from Japan to the U.S. rather than vice versa.

Very truly yours,

GENE M. AMDAHL,
Chairman of the Board of Directors.

The CHAIRMAN. Mr. Perkins, you very ably pointed out the problems created by the demise of the qualified stock option plan. I would be interested in your evaluation and that of the other panel members of the ranking the industry would accord this as a disincentive to the recruitment of talented people and the growth of new high-technology firms.

Mr. PERKINS. First of all, I, having hired people from Amdahl and IBM and Texas Instruments, we might find a difference in view on this subject, my being concerned primarily with the very small companies that need to get people from the larger ones, and I do suspect that the larger corporations are less concerned about the demise of the qualified stock option that I am because it's a tool we need; but without the qualified stock option, you have a very, very difficult time in starting a venture.

To give you an example, if a bright individual walks into the office with an idea that we decide to finance, and let's just say it takes $1 million, and we'll take half of the company and he will take half of the company—we invest $1 million. He suddenly has stock in a company worth $2 million by simple arithmetic. He owns half of it, and we put

$1 million in cash in it. So the IRS will come to him immediately for a tax to be paid by him on this sudden windfall profit that he has achieved; but obviously he hasn't achieved anything. He just sold us something but the ways around that are very, very difficult and quite awkward. There is no good alternative. Without the qualified option, it is very, very difficult to attract the staff that it will need to build that venture.

The CHAIRMAN. Do you have any alternatives to suggest should the Congress not choose to reinstate the qualified stock option plan?

Mr. PERKINS. I think the reason the qualified option was killed was that it gave favorable, more favorable treatment of capital gains that were considered really not a gain but an income payment to the individual. So I would say that the principal problem we have with the absence of the qualified stock option is the taxes required to be paid when there is no profit. I think, just in general, a tax should never be paid until there is a true profit. So if the law could be changed so that on options taxes are paid when indeed there is a realized profit, in other words, a sale of the stock for a profit, regardless of the rate on the tax, that would help us tremendously.

The CHAIRMAN. Was that provision shifting forward the imposition of the tax changed by law or by an IRS ruling?

Mr. PERKINS. That is a change in the law and the IRS is just following it through.

The CHAIRMAN. Dr. Amdahl, what in your opinion motivated or encouraged the Japanese and the German companies to invest in your company?

Dr. AMDAHL. It's a curious thing. Outside of the United States, there were, to my knowledge, only two profitable computer companies in existence at that time. One was Fujitsu in Japan and the other one was Nixdorf in Germany, and both of those companies saw the financial wisdom of such an investment. I think it was the same insight that had given them the insight that made them profitable.

I must say that I used the same description of the potential to other computer companies in the United States, other computer companies in Europe, and to the venture capital community throughout the world.

The CHAIRMAN. Dr. Amdahl suggested an investment tax credit—like treatment of R. & D. expenses; Mr. Drori proposed a rollover provision for individual investment in science-based companies, and Mr. Perkins supported the latter for small business generally. How far should the tax code go in favoring high-technology enterprise?

Dr. AMDAHL. I propose that the R. & D. investment tax credit not be limited to high-technology companies. My reason for this is that I believe that throughout the U.S. industry we have had a dearth of innovation relative to the other industrialized countries of the world. We have not maintained a proper pace in productivity. I think in enlightened self-interest our Government, our economy, has to view innovation as the only bright hope we have for producing a better quality of life for every man on Earth.

The CHAIRMAN. But innovation goes beyond R. & D., although it is inclusive of R. & D., wouldn't you say?

Dr. AMDAHL. Yes; I think it could go beyond it, even capital investments to introduce innovation into production processes.

Mr. PERKINS. I think obviously the Government has to have income to distribute to the present array of programs, but there have been a number of studies made that show how very productive private capital is. For example, venture capital can create a job for a one-time investment of approximately $14,000 per job, whereas the Government requires something like $30,000 per year per job. Similarly, each dollar of venture capital invested will in the future generate approximately 30 cents per year to the Federal, State, and local tax authorities. It's obviously a marvelous thing to encourage, so that the lower the tax rate can go the greater investment there will be, and I think the benefits will accrue very rapidly in both employment and ultimately tax revenue back to the Government.

The CHAIRMAN. Of course, that was one of the problems that we ran into in Congress, when the present capital gains figure was arrived at in the late 1960's with the argument that this change would result in more revenues. I think one of the gentlemen on the previous panel pointed out that just the opposite was true. The revenues went down rather than increasing, and that was a big factor in our recent consideration of the latest tax bill, to make some changes in the capital gains law so that it would encourage more investment, and would really result in more revenue to the Federal Government.

Mr. DRORI. I think it is interesting to note that in some European countries, though basically socialistic such as Germany or France, one does not pay capital gain at all; yet we are in a capitalistic country that imposed a tax on capital gain and therefore penalized and curtailed investment.

I believe the Government should review its tax investment credit policy for the possibility of expending it to R. & D. costs. With the increase in R. & D. activity more jobs will evolve from the R. & D. efforts and ultimately a stronger economy.

The CHAIRMAN. Gentlemen, thank you very much. We appreciate your being here.

That concludes the hearings for today.

[Whereupon, at 12:45 o'clock p.m., the hearing stands adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

Semiconductor Industry Association—Statement of Concern on Matters Relating to International Business and Trade

(Prepared by Trade Policy Committee, Semiconductor Industry Association)

STATEMENT OF CONCERN SUMMARY

The Semiconductor Industry Association and its member companies wish to alert the U.S. semiconductor and electronics industry and the responsible branches and commissions of the U.S. Government to the issues and potential threat of protectionism and anti-competitive practices now confronting this critical, high technology industry.

Protectionism and anti-competitive activities are as old as international trade, but new approaches have evolved in Western Europe and Japan which neither U.S. industry nor government are adequately prepared to meet and counter.

This Statement of Concern develops the case that the U.S. semiconductor industry, even though the strongest and most innovative in the world, is not immune to severe damage from foreign competition backed by concentrated and governmentally coordinated effort.

The study demonstrates the importance of the semiconductor industry to U.S. industrial leadership and world markets and, by examining the experience of other major industries, identifies the anti-competitive practices which could threaten U.S. semiconductor technology and markets. The protectionist practices of Western Europe are documented, but the study concentrates on Japan, the country of our greatest and most immediate concern, because of its target industry strategy. This government coordinated program for achieving market dominance divides the research, product development and market tasks among companies through a system of goals, incentives and subsidies. These practices place U.S. industries at a distinct competitive disadvantage because they are well beyond the resources of individual companies and existing governmental remedies.

The Semiconductor Industry Association endorses free and open competition in international trade, but we believe our trading partners must abide by the same competitive rules. Today the rules and practices of world trade are not reciprocal or equal and failure to correct this imbalance will ultimately lead to a protectionist reaction.

Therefore, recommendations by SIA cover actions for industry and government, to assure a fair competitive environment and a strong industry. Regaining clear technological leadership through increased R. & D. is considered the most crucial job for industry, while reduction of trade barriers, enforcement of antitrust laws and tax law changes are the essential government actions required.

IMPORTANCE OF SEMICONDUCTORS AND SEMICONDUCTOR ECONOMICS

A semiconductor is an electronic component normally made on a thin wafer of silicon that is cut into many small chips. These chips can be designed to perform many functions.[1]

In a February 20, 1978 article on semiconductors titled "The Age of Miracle Chips," Time magazine states the following:

"The miracle chip represents a quantum leap in the technology of mankind, a development that over the past few years had acquired the force and significance associated with the development of hand tools or the discovery of the steam engine. Just as the Industrial Revolution took over an immense range of tasks from men's muscles and enormously expanded productivity, so the microcomputer is rapidly assuming huge burdens of drudgery from the human brain

[1] A function would include electronic operations such as an amplifier, memory bit, or logic gate.

and thereby expanding the mind's capacities in ways that man has only begun to grasp."

American scientists' and entrepreneurs' early grasp of the profound significance of semiconductor technology has built for the U.S. a world leadership position in semiconductors and electronics. In 1977, the U.S. semiconductor industry supplied over 60 percent of the $6.4 billion world market.[2] The same year, the industry's domestic growth rate was three times the real GNP, providing employment for 125,000 workers in the U.S. The industry has a favorable balance of trade and has consistently reduced prices, helping to make electronic equipment a major noninflationary sector of the U.S. economy.

The first commercial silicon transistors were produced during the early 1950's and sold at prices of $50 to $150 apiece. At these high prices, only certain military applications could justify their use, but as volume developed prices came down. Manufacturers of computer and electronic equipment were attracted to semiconductors because they were smaller, more reliable and generated less heat than vacuum tubes. These transistors (or diodes) are known as discrete devices which perform a single function and for which the cost of interconnecting a number of them into a functioning circuit is very high. To reduce these interconnection costs, the semiconductor industry began to place (i.e., integrate) more and more discrete functions onto a single chip of silicon, leading to the birth of the integrated circuit. The first low-density integrated circuits were superseded by medium-scale (MSI) and later by large-scale (LSI) integrated circuits. Today, the industry is developing very-large-scale (VLSI) integrated circuits which contain as many as 100,000 discrete components on a single chip of silicon.

As the technology has advanced, the cost per function has decreased and the performance increased. Since the early 1950's the average cost per function decreased 100,000 times, while performance has increased 10,000 times.

What does this tremendous advance in technology and concomitant reduction in cost per function mean to the United States? In the same way that an increase in the price of steel has a highly inflationary impact as it is passed through every facet of the economy, the constant reductions in the cost per function of semiconductors have a highly anti-inflationary impact. The cost and performance of electronic equipment made with semiconductors has improved dramatically and provided unique benefits to the U.S. and world economies.

The semiconductor has made possible these advances:

Computer technology.—Today, the multibillion computer industry touches every facet of our lives and plays a vital role in our national business and financial systems.

Telecommunications.—Satellites, central office switching and microwave systems have brought every person in the United States faster and better communications at a lower cost.

Process control.—Electronic instrumentation and automation have increased productivity and improved quality in a wide variety of products made in factories throughout the United States.

Consumer electronics.—The quality and reliability of large complex home electronic systems is made possible by semiconductors.

Defense.—High technology defense capability, based on electronics and semiconductors, protects our country from enemy attack.

THE WORLD SEMICONDUCTOR INDUSTRY AND MARKETS

Country after country is recognizing the importance of electronics technology as a vital and basic element to its industrial and military base. The reasons for this are evident: low energy consumption; low raw material content; environmentally clean; high value added; good value-to-weight ratio (low freight costs); provides desirable employment.

The above reasons especially apply to semiconductors. Semiconductors are the heart of computers, communications, and nearly all other electronic equipments which comprise the U.S. electronics industry today. The case for a strong semiconductor industry is so great that many countries have set up such an industry with government assistance, even though they do not have sufficient industrial or economic base to justify an indigenous semiconductor industry.

The U.S. semiconductor industry has earned a position of leadership in the world market through vigorous marketing, technical excellence and innovative low-cost manufacturing. Virtually all of the important inventions in semicon-

[2] SIA Trade Statistics Report 1977.

ductor technology from the development of the transistor in Bell Laboratories through the microprocessor miracle chip have been credited to Americans. U.S. firms have captured 96 percent of the domestic market, 52 percent of the European market and slightly less than 10 percent of the Japanese market.[3]

The U.S. industry is characterized by fast growth, rapidly changing technology, continually declining prices, considerable mobility among professionals, rapid diffusion of technology, and a profusion of new entrepreneurial firms replacing older firms that fail to keep technically up to date. This dynamic environment has made the U.S. industry very competitive and effective in penetrating most world markets. Also, the industries technical and market position has been a source of strength for the U.S. manufacturers of electronic equipment in establishing leadership in worldwide markets.

The importance and value of semiconductor technology is clearly understood by the governments of Western Europe and Japan. Direct subsidies, quotas, high protective tariffs, and nontariff barriers (NTB's) are or have been the general rule as these governments attempt to develop its nascent semiconductor industry by shielding them from foreign competition.

In Western Europe, U.S. exports are threatened by high duties and new protectionist measures. The Common Market duty on semiconductors is 17 percent as compared to the U.S. rate of 6 percent. Rules of origin for semiconductors installed in export equipment, mandatory local sourcing of semiconductors in telecommunications equipment and exclusionary quality assurance provisions are being increasingly used to inhibit imports and encourage local production. Thus, to maintain access to these markets U.S. companies must transfer the technology and produce in Western Europe.

In the United Kingdom the National Enterprise Board, an agency of the Government is reported to have set up a £ 50 million ($98 million) fund to secure semiconductor technology. Inmos Ltd., funded by the NEB with a reported £ 25 million ($49 million) to acquire and transfer technology from the United States to Britain has attempted through a U.S. subsidiary to recruit scientists at very substantial salary levels (reported at two times the going rate). These matters are now before a U.S. district court.[4]

While there has been steady although slow progression toward "liberalization" on the part of Japan since 1974, the former use of quotas and administrative guidance has effectively limited U.S. exports. U.S. industry shipments to Japan were $122 million in 1973 and $168 million in 1977.[5]

Japanese claims of inadequate U.S. marketing efforts ignores the record of nearly two decades of success. New U.S. high technology semiconductor devices have been designed into Japanese equipment through U.S. marketing and application skills since 1960. Virtually every semiconductor product in use today in Japan including: diodes, transistors, bipolar integrated circuits and digital MOS circuits were initially U.S. exports. This demonstrates that there has been continuous and adequate marketing to meet the needs of the Japanese. The failure to continue to buy from the United States cannot be attributed to lack of marketing or knowledge of the applications.

Japanese Government plans may be more helpful in explaining the low 10 percent U.S. share of the Japanese market. In the early 1970's semiconductors were selected as a "target industry" by the Japanese. The steel industry is an early example of a target industry.

STEEL AS A CASE HISTORY

Of the many industries that have been targeted, nowhere are the results of Japan's trade policies and practices more clearly illustrated than in the phenomenal growth of the Japanese steel industry. Steel was recognized as the basic component in the manufacture of capital goods. The Japanese Economic Planning Agency and the Ministry of International Trade and Industry set out in the early 1950's to create a successful and internationally competitive steel industry.

To accomplish this objective, the Japanese economic planners developed a three-point program: First, the steel industry was provided with enormous amounts of capital, primarily in the form of low-cost debt. Second, the Japanese steel industry used this capital to add new large increments to capacity which provided economies of scale and low operating costs. Third, the government and industry

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[3] SIA Estimate Based Upon U.S. Government, MITI and other published sources.
[4] Electronic News, Aug. 14, 1978.
[5] WEMA and SIA Trade Statistics Reports.

worked together to increase domestic and export sales and maintain high operating rates to protect the industry's highly leveraged financial position.

In order to assure high operating rates, the Japanese protected their domestic market from foreign competition and developed a two-tiered pricing strategy which set domestic prices above the average cost of production and which priced exports on a floating variable cost basis. Thus (through widely varying export prices), the Japanese steel industry used foreign markets as a "shock absorber" to maintain domestic production volume and employment throughout economic cycles.[6] As a result, the Japanese steel industry has become highly efficient and has benefited greatly from the added volume from the U.S. market.

Just as a protected home market enabled the Japanese steel industry to price discriminate in their exports, the open U.S. market made it uneconomic for the American Steel industry to meet the lower prices of imported steel.[7] The Japanese industry continued to expand and become more efficient while the American industry using older, less efficient facilities found itself unable, currently or prospectively, to earn adequate profits or return on investment. Lacking adequate financial returns the American industry ceased adding new capacity, thus allowing foreign imports a greater share of the market, and the cost advantages of new modern capacity. As this process continued year after year the U.S. industries, market, financial, cost and employment position declined.

JAPAN'S NEW TARGET INDUSTRY—SEMICONDUCTORS

The foregoing history causes us serious concern, since semiconductors, along with computers and telecommunications, have been selected by the Japanese economic planners as the next "Target industries." The ability of Japan's target industries strategy to penetrate and dominate foreign industries is evident in the steel case and in consumer electronics. The rapid decline of the CB radio industry documents the effectiveness of this strategy in electronics.

The target industry concept exemplifies the process by which the Japanese Government channels and coordinates technological development. Under the direction of Ministry of International Trade and Industry (MITI), the computer industry agreed on a 4-year plan that would achieve the critical first step for computers—leadership in semiconductor memories by the early 1980's.

To develop semiconductor technology an ambitious joint industry-government effort called the VLSI program was initiated. Industry groups contributed manpower, facilities and funding, while loans and guidance were to come from MITI. The Japanese Government budgeted an estimated 30 billion yen ($150 million) in zero interest loans that may be paid back if profits permit.[8]

By contrast, American companies not only have antitrust constraints but have great hurdles to overcome in attracting capital, particularly when the most advanced technology products are involved. Data compiled on major American and Japanese electronics companies shows that the Japanese use twice the level of debt financing, and at the same time secure a substantially lower return on equity. Since debt costs less than equity, Japanese companies are able to survive even when they earn little or no return.[9] For target industries bank loans are assured by the Bank of Japan.

Japanese semiconductor manufacturers tend to look upon significant portions of their labor expense as a fixed cost. This means that the Japanese semiconductor industry must maintain a high operating volume in order to pay for this high debt burden plus the fixed operating cost, regardless of business conditions. It also makes it much more sensitive to a decline in business. The Japanese semiconductor companies are, therefore, under enormous pressure to keep their capacity utilization rates high at all times.

To accomplish these broad objectives for the target semiconductor industry, the Japanese government and industry have followed a program similar to steel.

First, the Japanese have selectively isolated their home market from foreign (U.S.) competition. They have essentially limited imports from nearly all foreign semiconductor competitors except for the very highest technology devices or those devices they themselves do not yet make. Thus, while the Japanese semi-

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[6] That use of the two tier prices and employment by the Japanese exporters was clearly anticompetitive was dramatically proven by their huge price increases of 1973 and 1974 when steel was in short supply in the United States.

[7] Economics of International Steel Trade. Putnam, Hayes & Bartlett Inc., p. IV.

[8] IEEE Spectrum, Sept. 1977, Technological Japan, p. 36.

[9] See Exhibit A.

conductor market has grown from $1.3 billion in 1973 to $1.9 billion in 1977, U.S. exports to Japan have remained relatively constant.

Second, the Japanese recognize the need to compete with high performance quality products, and the VLSI program illustrates the methods used to develop advanced technology. The use of cooperative research may be a real advantage in the Japanese environment, since it could be much more efficient and expeditious.[10]

Third, the highly leveraged financing system has enabled the Japanese semiconductor industry to pursue aggressive expansion of manufacturing capacity. The Japanese government supports this expansion through loans which are easily obtained from commercial banks subsidized by the Bank of Japan.

If the scenario follows that of steel, the drive for access to high volume export markets will become an imperative in order to utilize the excess capacity during down turns in the Japanese market. To rapidly load this capacity export prices must be extremely low and below competition. It is not surprising that this environment encourages the use of incremental pricing in the export market, it is the most economical alternative available.

To meet this competition, U.S. companies will reduce prices to retain their customers, and under these conditions the marginal U.S. producers, the most thinly capitalized—the high technology specialists—will pass through their break-even points and will rapidly slide into financial crisis.

POSSIBLE EFFECTS OF THE JAPANESE TRADE STRATEGY

What will be the effect of the United States economy if the Japanese strategy succeeds?

First, the Japanese strategy will lead to increased layoffs in the U.S. in periods of recession, if the Japanese producers lower their export prices in order to keep their productive facilities operating at a high level of capacity. Thus, the Japanese could attempt to maintain their fixed high level of domestic employment while they, in effect, export their cyclical unemployment to the United States.

Second, Japanese sales of semiconductors, computers and electronic equipment to the U.S. will increase, and our trade deficit with Japan would get worse.[11]

Third, Japanese sales of semiconductors, computers and other electronic equipment to other world markets will replaced U.S. sales to these same markets, and the U.S. electronics trade surplus with other nations would decrease.

Fourth, as Japan develops semiconductors and electronic technology comparable to the U.S., these technologies may be accessible to Eastern Bloc nations. This could lead to a relative decline in the West's high technology defense capability and strategic position, while at the same time making the U.S. defense establishment more dependent upon foreign sources for a share of the more advanced technologies.

TRANSFER OF TECHNOLOGY THROUGH INVESTMENT

The sources of private venture capital in the United States are very narrowly based. Because of the high rate of failures in high technology ventures, the investors' requirements for capital returns are extremely high, that is, 7 to 8 times growth in capital within three years to five years on successful venture. Since capital gains tax incentives have been reduced investors have put their money in less risky but lower return tax sheltered ventures, such as orchards, oil wells, real estate developments, and mobile home parks.

Given the increasingly high entry investment in a high technology venture—up by a factor of 10 from $3 million to $30 million in the past decade—and the debilitating affect of double digit inflation, the supply line of high technology venture capital has bceome increasingly scarce. Contrast the bumper crop of new entrepreneurial ventures in the 1960's (led by firms such as Intel and Mostek) to the 1970's during which few new independent ventures have survived.[12]

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[10] By comparison, the effectiveness of U.S. semiconductor industry research is diluted because it is performed by a large number of companies which are often underwriting parallel research. On the other hand, the U.S. system has the advantage of being more diversified and thus offers more potential for developing optimum solutions. For these and other reasons we do not advocate a Japanese solution for the United States.

[11] It should be noted that substantial quantities of Japanese semiconductor exports are in equipment. In 1977 $75.8 million of semiconductors were exported as components and $206 million of semiconductors were exported in end equipment from Japan, and $93 million for other nations, for a total of $375 million. (See exhibit B.)

[12] Exxon has invested in wholly owned high technology ventures, for example, Zilog.

Despite the drying up of venture capital, there has been no slowing of creative ideas, so firms and individuals have progressively turned to foreign sources of venture capital during the last half of this decade.

A partial list makes the point:

U.S. company	Foreign direct investor (equity, percent)	Year acquired
Signetics	Phillips, 100 percent	1975
Advanced Micro Devices	Bosch, 25 percent	1977
Intersil	Northern Telecom, 21 percent	1977
Siliconix	Lucas Industries, 24 percent	1978
Electronic Arrays	Nippon Electric, 100 percent	1978

Equity participation in these high technology American semiconductor firms has given the Japanese, German, British and Canadian companies potential access to American State-of-the-art technology, at bargain prices, given the depressed value of the U.S. dollar.[13]

RECOMMENDATIONS FOR INDUSTRY AND GOVERNMENT

To meet the challenge of increased foreign competition, the SIA recommends that member companies consider a three-point program.

1. Research and development

Increase spending in R. & D. to improve and maintain technological superiority. In the past the U.S. industries market leadership has been greatly aided by superior technology which partially compensated for unfair trade practices. Since R. & D. expenditures are limited by industry economics, greater efforts are clearly required.

2. Export trade

Expand efforts to export semiconductors, particularly to Japan. The benefits in increased competition in the Japanese market place will reduce their threat in the U.S. market. The Japanese government has made a commitment to increase imports, and this commitment should be tested.

3. Semiconductor Industry Association

Support the SIA program on Trade Policy to the U.S. Government. Continuous efforts to inform government officials of the importance of semiconductors to the nation's economic and industrial strength are necessary to achieve the following program.

U.S. Government action is also needed. Government's role should be to assure fair competition in a strong economic environment.

1. Tax incentives

The U.S. tax system must stimulate the flow of equity capital into high technology ventures and make allowances for the rapid rate of change in high technology. Legislative changes along the lines of the following tax program would assure continuing U.S. technology leadership.

(*a*) Lower capital gains tax rates to the 1969 level.

(*b*) Provide investment tax credits over a 3 to 5 year period (rather than 5 to 7 years) for industries with very high rates of technical change.

(*c*) Provide for faster depreciation for research equipment.

(*d*) Provide tax credits and incentives to increase high technology R. & D.

(*e*) Legislation to broaden the base of venture capital to include pension funds, profit sharing funds, and similar income sources.

2. Trade barriers

Stronger efforts are needed to remove tariffs and nontariff barriers. The GATT Multilateral Trade Negotiations currently in progress in Geneva must, as a minimum, achieve the following:

Reduce EEC duties on semiconductors from the discriminatory 17 percent level to parity with U.S. rates.

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[13] A far more powerful competitive strategy than know how patents or cross license agreements with American firms where technology transfers usually is quasi-obsolete.

New mechanisms must be put in place to provide equal customs valuation and classification, uniformly applied in all developed countries.

Eliminate exclusionary standards and specifications based on national origin.

If the Geneva discussions fail to secure these concessions, we recommend the use of offsetting incentives and reciprocal treatment to restore competitive balance and to lever future concessions. For example:

Forbid the use of Japanese components in U.S. telecomunications as a mirror image of Japanese practice.

Enact new tax incentives for U.S.-firms' overseas market development costs to counteract export subsidies by other governments.

3. Antitrust

A program to enforce antitrust laws against cartels and foreign business combinations as vigorously as such laws are enforced against American firms should be undertaken. However, the Justice Department's record of inaction is not likely to change without congressional stimulus. Therefore, the SIA recommends:

The Senate Subcommittee on Antitrust and Monopoly investigate the Justice Department and its performance in this area, particularly in relation to the television industry, which has been seriously damaged by unfair trade and pricing practices of similarly foreign competitors.

FAIR TRADE, THE BASIS FOR SIA RECOMMENDATIONS

The Semiconductor Industry Association reaffirms its support for fair trade. We believe that world production, employment and wealth will increase if all the nations of the world open their markets to the products of other nations and export their own products at prices which reflect the full cost of production, including reasonable profit. We believe that all nations can effectively compete in such an environment.

We believe that all trading partners should work with equitable rules of trade. If any one nation employs or condones unfair trade practices or unilaterally changes or interrupts rules in order to unfairly promote the competitive position of its own national industries over the industries of its trading partners, then protectionist reaction can be expected.

Both industry and government share responsibilities for world trade. We are confident the semiconductor industry will do its part to compete fairly and effectively in free world markets. We expect the U.S. government to take new initiatives to secure more equitable international rules of trade. These rules must seek to reduce barriers, eliminate unfair trade practices and provide a swift and certain response for those who violate the rules.

Based on its performance record, the U.S. semiconductor industry can meet the challenge if the competitive battle is fair and open. History suggests it will not be easy. We believe industry and government must act now, while the industry is still healthy and strong and has the means to meet the challenge.

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EXHIBIT A

1977 UNITED STATES VERSUS JAPANESE ELECTRONICS COMPANY PERFORMANCE

Company name: Business	Sales 1977 (millions)	Sales 1967 (percent)	Profit levels (after taxes) 1977 (millions)	Profit levels 1976 (percent)	Margins (percent) 1977	Margins (percent) 1976	1977 EPS	Business profitability: NI sales (NAT mgns) (percent)	Sales, dept plus equity (cap. turns)	Dept plus equity/common stock equity (leverage)	Return on common stock equity (percent)	Memo: Debt/debt plus equity ratio (percent)
UNITED STATES												
Gould Inc.: Electric and electronic	$1,619.6	32	$93.6	42	5.8	5.4	$3.72	5.8	1.94	1.37	15.4	27
General Electric: Electrical equipment	17,519.0	12	1,088.2	17	6.2	5.9	4.79	6.2	2.42	1.22	18.3	18
Westinghouse: Electrical equipment	6,137.7	0	271.3	22	4.4	3.6	3.10	4.4	2.27	1.18	11.8	15
Emerson Electric: General electrical and Government contract	1,809.2	20	142.1	22	7.9	7.8	2.47	7.9	2.09	1.12	18.4	11
RCA Corp.: Electrical equipment	5,880.9	10	247.0	39	4.2	3.3	3.23	4.2	2.35	1.75	17.2	43
Raytheon: Electronic and comp. equipment	2,818.3	14	113.2	33	4.0	3.5	3.67	4.0	4.00	1.13	18.1	12
Motorola: Portable Communications Equipment and semicond. devices	1,848.4	23	106.3	24	5.8	5.7	3.50	5.8	1.87	1.25	13.6	20
Texas Instruments: Electronic equipment	2,046.5	23	116.6	20	5.7	5.9	5.11	5.7	2.64	1.04	15.7	4
No. Telecom: Telecom equipment	1,268.7	14	81.8	11	6.4	6.6	3.09	6.4	2.44	1.11	17.3	10
Average		+16			5.6	5.4		5.6	2.45	1.24	16.2	18
JAPAN												
Matsushita Electric Works: Electrical equipment	1,652.9	10	48.6	14	2.9	2.8	.13	2.9	3.32	1.18	11.4	15
Matsushita Electric Industries: Electric appliance	6,450.2	9	218.6	18	3.3	3.2	.22	3.3	3.36	1.00	11.1	0
Mitsubishi Electric: Electrical equipment	3,562.0	14	43.9	14	1.2	1.2	.03	1.2	2.06	3.21	7.9	69
Sanyo Electric: Electric appliance	2,392.6	14	49.1	18	2.1	2.0	.97	2.1	4.45	1.20	11.2	17
Fujitsu: Communications equipment	1,742.0	18	36.9	12	2.0	2.8	.05	2.0	1.72	2.27	7.8	56
Hitachi: Electrical equipment	6,243.6	7	141.4	4	2.2	2.3	.05	2.2	2.08	1.97	8.9	48
Average		+12			2.3	2.4		2.3	2.83	1.80	9.7	34

EXHIBIT B

U.S. IMPORTS FROM JAPAN, SELECTED EQUIPMENTS AND SEMICONDUCTORS

[Units and dollar amounts in millions]

Description	Product code	Units	Amounts	Semiconductor percent	Semiconductor amounts
Solid state calculators	7142005	8.2	$138.1	10.0	$13.8
Cash registers	7142040	.2	82.7	2.5	2.1
Accounting, computing machines	7143000	.02	58.7	8.0	4.7
Office machines	7149160	2.2	204.3	5.0	10.2
TV sets, including combinations	7241000	3.8	550.9	6.0	33.1
Radio, solid state	7242020	7.8	354.9	10.0	35.5
Telephone apparatus and instruments	7249120	NA	39.8	5.0	2.0
Amplifiers, audio	7249230	1.1	50.4	15.0	7.5
TV cameras and parts	7249920	NA	180.8	2.5	4.5
Transceivers	7249925	8.4	463.2	12.0	55.5
Radio telephonic transmission and reception apparatus	7249945	NA	96.8	2.0	1.0
Transistors	7293040	66.4	16.8	----------------	16.8
Semiconductors, all other	7293050	198.7	59.0	----------------	59.0
Automobiles, new	7321020	1.3	4,221.2	.05	2.0
Tape players and combinations	8911105	9.0	367.7	3.6	13.5
Recorders and dictation machines	8911175	2.4	182.2	3.6	6.6
Do	8911180	4.4	111.9	3.6	4.0
Tape recorders, video	8911185	.3	143.1	6.2	9.0

SEMICONDUCTOR INDUSTRY ASSOCIATION ANNUAL FORECAST DINNER, SEPTEMBER 28, 1978: WORLD TRADE AND THE CHALLENGES FACING THE U.S. SEMICONDUCTOR INDUSTRY

(By Robert N. Noyce)

When the 20th century comes to a close, historians may well record it not as the era of the auto, nor that of nuclear energy, nor even that of the computer. The real driving force of a major portion of this century, and the one that was truly revolutionary in its impact on our lives will be perceived as semiconductor electronics—the ability to move electrons through small "chips" of silicon in a way that performs useful functions.

Historians will also record that semiconductor technology and the industry that spawned it was a purely American phenomenon in origin and development. The U.S. semiconductor industry furnishes the technological building blocks for computing, telecommunications, consumer and automotive electronics, to name a few—the end products of the so-called "electronics revolution". Put in financial terms, in 1977, the $6.1 billion worldwide semiconductor market supported $58 billion of end product sales. Of this, American firms have captured 96 percent of the U.S. market, 52 percent of the European and 10 percent of the Japanese market.

But if we are not able to cope with some very serious challenges in the world market these figures may changes drastically, and the U.S. semiconductor industry may end the decade of the 80's as a follower rather than a leader. Indeed, historians may also note that in addition to originating and nurturing a vibrant semiconductor industry, the United States also lost it—the same way we have lost the steel industry and the T.V. market—to foreign competition.

The challenges to the U.S. semiconductor industry come from several directions. One is the clearly stated intention of the Japanese to become the dominant electronics supplier to the world by adding computers, telecommunications and semiconductors to their dominant position in consumer electronics. Another is the mobilization of resources by other foreign competitors, such as the Germans, French, and British, to pre-empt American leadership in semiconductor technology also.

Both of these threats would be of little consequence were it not for the narrowing of our technology lead and a third and more serious threat—from our own Government. The defects—the deliberately legislated defects—of American capital formation and tax policies and the chronic failure of our Government to enforce existing antitrust and antidumping laws in a timely way, when coupled with the efforts of our foreign competitors and their governments' protectionist policies, present, I feel, a serious danger to U.S. leadership in semiconductor technology.

If this trend is not reversed by our Government, I am afraid the result could be the U.S. fading to second class status in technology.

What I've just outlined is, of course, what we in the industry call the "worst case condition". Our economic and political problems are solvable. And a mutually beneficial relationship between the U.S. and our foreign competitors—Japan, in particular—is possible. But it will require a mutual commitment to the understanding of our differences, to the preservation of our individual national styles and traditions, to the development of mutual concern for the problems and limitations of the opposite partners. Openness in research and development can foster benefits in both directions. Inhibition of trade by artificial means would be a catastrophe to all concerned.

What, specifically, is to be done?

For starters, let's look at those first two problems—the protectionist stances of Western Europe and Japan—in a little more detail.

As far as the Japanese are concerned, the U.S. semiconductor industry to date has not been seriously threatened by their competition. But neither were the U.S. steel industry nor the U.S. television industry—until it happened. The time to throw up a block to a karate chop is before it lands, not after. And given the massively monolithic nature of the Japanese governmental-industrial complex, that karate chop can be quite effective, indeed.

In semiconductors, the Japanese operate a nearly closed domestic marketplace, with vertically integrated firms—Nippon, Hitachi, Toshiba, Mitsubishi, Matsushita, Fujitsu and Oki—whose semiconductor divisions produce most of the requirements for Japanese end equipment. These firms are favored and subsidized by MITI, the Ministry of International Trade and Industry.

A "buy Japan" attitude pervades the buyer-supplier relationships, based on centuries of cultural insularity and economic insecurity. In fact, some sections of the economy are so sensitive that procurement is limited to Japanese suppliers by government policy. For example, Nippon Telephone and Telegraph awards no contracts to foreign semiconductor producers. Japanese telecom suppliers, by contrast, have free access to the U.S. market.

The way the Japanese Government channels and coordinates technological development is well illustrated by its VLSI program. Under this program, MITI and the computer industry have agreed to a 4-year plan to achieve technical parity—if not leadership—in semiconductors by the early 1980's. Five multibillion dollar corporations have formed a VLSI cooperative laboratory under MITI sponsorship. They contribute scientists, facilities and funding, while the government, through MITI has budgeted 30 billion yen in grants and loans, and coordinates the program.

But that's not all. Again under MITI, industry research, automation and capacity expansion are directed toward specific objectives cooperatively agreed to. Funding is provided through the banking system at very favorable rates and government loans or grants. As you can well imagine, this process stretches the U.S. competitive and anti-trust concepts beyond recognition. While there is no evidence of a cartel as such, Japanese law and custom sanctions the use of this anti-competitive concept. They call it industry rationalization.

There's more. Historically, the Japanese society allocates a higher percentage of its gross national product to industrial investment and by tradition build excess capacity deliberately to assure themselves they'll be able to produce as much as is necessary to meet future markets. Because of ready availability of capital the parent corporations can finance this capacity primarily through corporate debt, operating at a capital structure of about 80/20 debt to equity ratio. By comparison, U.S. semiconductor companies operate at less than 20 percent debt. This means we operate at a considerable disadvantage depending primarily on equity to finance expansion.

The Japanese staff their factories to achieve a high percentage capacity utilization and consider their employees lifetime wards of the corporation, but these fixed costs—(indeed, all overhead costs)—are covered by artifically high domestic prices in the protected home market. For example, while American consumers were paying $350 for a TV set, the Japanese consumers were paying over $700 for an equivalent set. Japanese producers can then peg export prices nearly as low as they want, since they need only to cover incremental variable costs. It's difficult to argue that they did not know this was illegal dumping, with the recent disclosure of under the table rebates to the purchasers.

This leads to two-tier pricing. During a downturn, the two-tier structure allows the Japanese—motivated by their heavy fixed obligations and guaranteed employment—to flood the export markets with products at bargain prices. If this pattern is repeated in the semiconductor market, during a recessionary period, the U.S. market would be flooded with underpriced Japanese integrated circuits and LSI products.

American companies, having limited access to the Japanese market and faced with falling prices and bookings in the U.S. market and rising inventories, have no choice but to cut production or go bankrupt. The Japanese have, in effect, exported their unemployment to the United States. It is interesting to note that American companies with Japanese facilities layed off a higher percentage of their American employees in the U.S. than they did in Japan during the 1974 recession.

Under these conditions, everyone gets hurt, especially the marginal American producers—the most thinly capitalized, and the dedicated, specialized start-up ventures—who will rapidly slide into a financial crisis as they bring their prices down, passing through their break-even points.

What about the Europeans?

Well, the situation is not quite so serious there, at least not for the present. While maintaining a very high tariff rate of 17 percent on imports of semiconductors into the European Economic Community—the Europeans have systematically taken a series of actions which constitute a formidable threat to foreign imports.

Such nontariff barriers include pressure on users to purchase from domestically owned companies and discriminatory rules of origin under which tariffs can be imposed if foreign semiconductor content in equipment exceeds a ridiculously low 3 percent. There have also been massive grants—perhaps amounting to as much as $200 million—and subsidized loans by the British, Germans and French to their domestic industry.

To offset these barriers, U.S. semiconductor companies have formed subsidiary manufacturing ventures, including wafer fabrication and assembly in EEC countries to augment marketing organizations as well as formed joint ventures with European firms. For the larger corporations these strategies have been successful to date. They've received tax and financial incentives, technology grants and have generally been welcomed by host governments on equal terms with European-based firms. As a consequence they've been successful in maintaining and even increasing market share in Europe.

But while over the short term the individual companies benefit, over the long term the entire semiconductor industry is harmed. For one thing, considerable high technology has been transferred to Europe, as well as high skill centered jobs that would have remained in America. Secondly, the U.S. balance of payments with Western Europe has been impaired by the substitution of domestic production for U.S. exports, and by the heavy flow of direct investments in Europe by American companies, heavier than economically necessary. What makes things even worse is that two-thirds of the American semiconductor industry is hampered from competing effectively in Europe because the firms have chosen not to build uneconomic factories there.

Unfortunately, the current Geneva negotiations aimed at resolving our problems with Europe by reducing tariffs and removing trade and non-trade barriers now appear to have been unsuccessful.

As far as the Japanese are concerned, the most appropriate remedy would be vigilant surveillance by the anti-trust division of the Department of Justice of Japanese pricing activities and the Department of Treasury on Japanese dumping in this country. If its past record of neglect is any indication it's not likely that either Justice or Treasury will take any such action. For example, a dumping complaint on T.V. imports was filed against the Japanese in 1971. But it took 6 years, until 1977 by which time the U.S. industry was destroyed, for the U.S. customs service to verify dumping had occurred and still another year, until March of this year, for a $400 million dumping assessment to be issued. Not surprisingly, no assessment has been paid to date, as the Custom Service has been thwarted by bureaucratic in-fighting among Treasury, Justice, and State Departments.

Therefore we in the semiconductor industry association recommend that the proper Senate committees investigate the Departments of Justice and Treasury in this area, particularly in relation to the television industry which was severely damaged by these pricing practices.

Vigorous enforcement of existing antitrust laws, covering the manufactured products of foreign competitors if imported to the U.S. would go far in stopping collusion by any nation on their export pricing policies. As far as expecting the existing dumping law to be enforced I don't believe there is much hope. (Rather than take your time going into the various ramifications I'll provide a copy of a recent *Harvard Business Review* article on the subject. Just sign up as you leave tonight.)

The most serious problem—the threat from our own Government—will be the hardest to solve. The answer is not the same kind of protectionist policies our competitors are imposing upon us. Nor is it in operating in the non-competitive, two-tier manner of the Japanese even with the approval of the U.S. Government. The answer does lie in our own Government not making it more and more difficult to compete in the world market. At present we're facing not only other Governments' trade barriers to our imports to other countries but also by our own Government to our exports from this country. It is an ironic fact of life that our own Government puts up more barriers to exports than any other advanced country. This trend needs to be reversed.

It is also necessary to increase the amount of capital available through U.S. private equity markets to finance future innovations and growth of semiconductor companies. More accurately, the healthy tax and capital investment climate that existed for the semiconductor companies before 1970 must be recreated.

When one studies the sources of significant technological innovation in the American Semiconductor Industry by the type of firm, the most prolific source of new technologies flow from the dedicated specialized firms. These firms are usually formed to commercially exploit the idea of a single person or small group who typically spin off from one of the established firms to exploit a strategic technology gap. Therefore, even though the captive companies, the diversified producers and the broadline firms do contribute substantially, a disproportionate share comes from the dedicated, specialized firms. They are the source of much of the dynamism that drives the semiconductor industry.

But the new specialized venture companies require private outside capital to get them off the ground. The engineer-founders with the ideas are rarely financially independent at the point of startup.

The sources of private venture capital in the United States are very narrow-based, consisting of wealthy individuals, corporations, insurance companies and bank trust funds. Because of the high risk of new venture, these investors' requirements for capital returns are by necessity very high—seven to eight times growth in capital in 3 to 5 years. As of today there are no longer any special capital gains tax incentives for venture capital investors in the U.S. tax code. This biases investors toward less risky, but lower return tax-sheltered ventures, such as orchards, oil wells, real estate and mobile home parks.

Given the increasingly high entry investment in a high technology venture, and the crippling effect of double digit inflation, the supply line of high technology venture capital has become increasingly scarce. Compounding the problem, venture capital usually dries up during business recessions. Contrast the bumper crop of new companies in the late 1960's with the 1970's, during which few independent ventures of any consequence have survived.

Despite the drying up of venture capital, there's been no slowing of creative ideas, so firms and individuals have progressively turned to foreign sources of venture capital during the last half of this decade. But equity participation in these dedicated specialized American semiconductor firms has given the Japanese, German, British and Canadian companies immediate access to American state-of-the-art technology.

What can be done by our government to increase high technology innovation and eliminate the insufficiency of capital?

An important first step now being taken is the reduction of the capital gains tax to near the 1969 rates. We applaud Congress, the A.E.A. and hopefully, President Carter, for their important actions. Given the higher entry costs and the inflationary environment, no halfway measures are adequate.

Second, legislation needs to be enacted to encourage and broaden the base of venture capital by facilitating such investment by pension funds, profit sharing funds, and similar institutional funds. This will provide a larger base from which capital can flow into emerging companies.

Others have proposed legislation to provide tax credits and incentives to increase high technology R. & D., and for investment in short lived research equipment, and depreciation of this equipment.

These tax changes will help the semiconductor industry to not only meet the enormous challenge of the next generation of VLSI technology but also the challanges facing us in the world market. I'm confident these tax changes will stimulate American industry to perform the creative job which past history shows it is capable of doing. This is a tax program which emphasizes American strengths and builds on them in a way that's compatible with the policies of the world trading system.

A recent study by the AEA of 325 companies accounting for more than $45 billion in revenues in 1976 indicates these changes will have an even more pervasive and profound impact on American society and industry in general resulting in more jobs; increased exports, which would lessen our foreign trade deficit; and increased tax revenues.

Because of the unique ability of long term investment to generate jobs and economic growth, reducing capital gains taxes may not decrease federal tax revenues at all.

In fact data from the AEA study indicate a significant reduction in a capital gains tax rate would actually increase rather than decrease federal tax revenues.

Should such improvements not be forthcoming and existing trends continue, then in a few years we could find a seriously jeopardized semiconductor industry. Should that occur it's clear that this vital industry must be sustained in the U.S. at all costs. This includes, if necessary, an absolute import quota system. But only as a last resort.

To prevent the creation of a situation that would be disastrous to all concerned, semiconductor companies, both individually and through trade associations such as the S.I.A. must act positively and vigorously. First we must support the previously outlined steps to restore balance to our tax and trade system.

Second, we must commit ourselves to reestablishing the technology lead that characterized our industry early in its history. It is that technology lead that has protected us, given us dominance in the world market, provided U.S. industry with the best products and our government with an unsurpassed defense capability. With that technology lead it was a seller's market, with the rest of the world buying. With or without help from our government, with or without barriers to free competition by foreign countries, we must dedicate ourselves to re-establish our technological lead. Over the short term that may require massive and painful investments in research and development.

But over the long term it will mean continued dominance of the worldwide market. We have the capability and the reserves of intellectual and creative strength. What it comes down to is our commitment to leadership—commitment that expresses itself in dollars and not just talk.

Board of Supervisors,
County of Santa Clara,
San Jose, Calif., November 14, 1978.

Hon. Howard W. Cannon,
Rayburn House Office Building,
Washington, D.C.

Dear Senator Cannon: I am pleased that the Senate Commerce Committee Hearing on October 30 was focused on the semi-conductor industry, an industry of great importance to the Nation as a whole, and in particular, to Santa Clara County, where many are based.

The enclosed resolution was passed unanimously by the Board October 30. Also several cities within Santa Clara County plan to press this matter at the National League of Cities Convention November 26.

I have asked to be kept informed of future hearings by your committee in order to be informed about this and other matters brought before you.

Please call on me if I can be of any help to you.

Very sincerely,

Rod Diridon,
Chairperson.

RESOLUTION OF THE COUNTY OF SANTA CLARA, STATE OF CALIFORNIA, IN SUPPORT OF AN ACTION PLAN TO FOSTER A CLIMATE OF FREE COMPETITION WORLDWIDE FOR THE AMERICAN ELECTRONICS INDUSTRY

Whereas, the health of the American high technology electronics industry is crucial to the well-being of the Cities and the County of Santa Clara. Semiconductor technology is the core of the American electronics industry. Of the ten largest integrated circuit semiconductor manufacturing companies in the world, eight are located in Santa Clara County. These companies employ nearly 25,000 persons directly, and account indirectly for the livelihood of an estimated 125,000 additional workers. Their worldwide sales for the year 1977 alone amounted to almost Two Billion Dollars; and

Whereas, a crucial dependence on the electronics industry is a fact of life not only for the County, but also for other regions of life not only for the County, but also for other regions of the United States as well, there being over 1000 high technology electronics companies located in virtually every State in the Union; and

Whereas, the electronics industry in the United Sttaes has flourished from its beginnings following the free enterprise mode, including the financing of its own research and development; and

Whereas, the health of the electronics industry in the United States is threatened by several factors:

a. Certain foreign governments, most notably the Japanese, impose high tariffs and a host of nontariff barriers on imported computers, peripheral computer equipment, and semiconductor products, which discourages the introduction of such products into their domestic markets.

b. Japanese semiconductor firms are acquiring the very latest technology from American research and development by direct purchase of interests in semiconductor firms in this country, while American firms enjoy no such access to Japanese technology.

c. The Japanese Government is subsidizing a research and development program designed to overtake the American lead in semiconductor technology. Direct aid is given in the form of heavy subsidies for research and development, and indirect aid is provided by allowing members of the Japanese semiconductor industry to cooperate in research and in the establishment of market objectives without even the threat of antitrust action.

d. In contrast, the American semiconductor industry receives little or no direct monetary subsidy from the Federal Government; its individual companies, whether great or small, must bear the enormous financial burden of conducting independent and often parallel research and development; and all are subject not only to rigorous antitrust action but also to numerous other regulations that are both expensive and wasteful of resources needed to compete in world markets; and

Whereas, a flourishing American semiconductor industry is vital to the economy of the entire country, both by improving our balance of payments position and by providing the life blood to a multitude of interrelated industries and suppliers and to the millions of American workers employed by them; and

Whereas, an important national priority should be the creation and implementation of an action plan to foster a climate of free competition for the semiconductor industry in the major markets of the world;

Now, therefore, the Board of Supervisors, taking cognizance of the aforestated facts and premises, hereby does resolve as follows:

Section 1. Reduction of Japanese tariffs and nontariff barriers. The United States Government should strengthen its efforts to encourage the Japanese Government further to reduce its tariffs and other trade barriers on computers, on peripheral computer equipment, and on semiconductor devices generally.

Section 2. Tax incentives. To enable the American semiconductor industry to increase exports and to take a more aggressive stance in research and development, the following tax program should be enacted:

a. Provide greater deductions for research and development expenses.
b. Provide greater investment tax credits for research equipment.
c. Provide for faster depreciation for research equipment.
d. Lower capital gains rates to their pre-1969 levels.
e. Provide greater tax deductions for overseas marketing costs.

Section 3. Antitrust actions. A program to enforce the antitrust laws against cartels and foreign business combinations as vigorously as such laws are enforced against American firms should be undertaken by the United States Department of Justice. Where amendments to antitrust laws prove necessary to achieve a climate of free competition for the American semiconductor industry in world markets, such legislation should be enacted.

Passed and adopted by the Board of Supervisors of the County of Santa Clara, State of California, at a regular meeting held on the 30th day of October, 1978, by the following called vote:

Ayes: Sanchez, Cortese, McCorquodale, Steinberg, Diridon.
Noes: None.
Absent: None.

APPROVED:
ROD DIRIDON,
Chairperson, Board of Supervisors.

Attest: County Clerk:

———— ————.

County Clerk.

STATEMENT OF H. WILLIAM TANAKA ON BEHALF OF THE ELECTRONIC INDUSTRIES ASSOCIATION OF JAPAN

I would like to present the following view on recent developments in the computer and semiconductor industries on behalf of the Electronic Industries Association of Japan (EIA–J). I thank the Senate Commerce Committee for affording us the opportunity to do so.

As indicated in the opening remarks made by the Commerce Committee Chairman, Senator Howard Cannon, at the San Francisco hearing, technological innovation has played a significant role in the American economy over the last 30 years. Nowhere has the effect of such change been more in evidence than in the electronics industry. And, as every witness at the San Francisco hearing testified, the technological revolution in the electronics industry has been encouraged and promoted by U.S. Government policies in the areas of procurement and research and development.

This technological revolution in the electronic industries has not been limited to the United States, and, in recent years, governments and industrial enterprises in other countries have begun to perceive the importance of the semiconductor and computer industries to their own economies. This growing understanding has motivated them to fund research and development in an effort to catch up with the United States. This development has injected an element of international competition in what had heretofore been a virtual American monopoly. At times the real issue of technological change has been obscured by a drumfire of unfair competition charges against foreign competition, particularly from Japan. However, the relevant question, as suggested in Senator Cannon's opening statement, is the U.S. leadership in semiconductors and computers threatened?

Since charges against Japanese competition cite examples of what has happened in the consumer electronic products area, a review of the postwar developments in the field of electronics is helpful.

The development of the transistor in 1948 by Bell Laboratories under a U.S. Government grant marks the genesis of the post war growth of the electronic industries. Four years later commercial production of the transistor was launched and with it enormous changes were set in motion.

On the one hand, the transistor brought undreamed of benefits in creation of new markets through miniaturization of end products to serve new consumer uses opening up use of small portable power sources, etc. On the other hand, the mushrooming application of this revolutionary device left in its wake destruction of entire industries, vitiation of highly refined skills, job losses and community dislocations.

The first industry phased into redundancy by the transistor was the thriving receiving tube industry, along with the complementary component segments of the electronics industry. End product manufacturers victimized by the technological predation of transistors were tube-type radios, tape records, hi-fi equipment, electro-mechanical calculators, spring operated scales, mechanical watches, and the list goes on. In the process, the traditional producers often lost their leadership to more innovative domestic and foreign competition. For example, technological leadership in the components businesses has shifted from General Electric, Westinghouse, Raytheon, Sylvania, Tung-Sol, and others to Texas Instruments, Motorola, Fairchild Camera, Intel and others who were not even in the components business 25 years ago.

In the case of watches, the leaders in the revolution which completely remade the industry almost overnight were high technology American companies with no experience in making and merchandising watches, such as Texas Instruments, Fairchild Camera, National Semiconductor, Litronix, Intel and Pulsar. The immediate success of digital watches resulted in a sharp reduction in price. The traditional watch industry was relegated to the jewelry business as digital watches quickly moved toward mass production and mass merchandising and displaced Swiss watches.

The story of the digital watch is one in which innovative U.S. producers displaced imported products. However, what is the impact when domestically produced goods are consigned to redundancy by technological predation?

The vacuum tube industry provides an excellent illustration. Instead of implementing strategies designed to keep pace with the innovation, certain receiving tube manufacturers elected to seek protection of their dwindling market by filing dumping complaints on two separate occasions, 1960 and 1968. Meanwhile, the technological erosion of the receiving tube market by transistorization of consumer electronic products, including radios, television receivers, continued as a number of receiving tube manufacturers closed down their facilties and/or shifted to offshore sourcing. Since the fundamental cause of the industry's problem was the technological displacement of vacuum tubes, any relief from import competition would only have served to encourage postponing further the critical decision to diversify out of receiving tube production and production of end products using receiving tubes.

What these experiences teach us is simple. Corporate managers must not only keep in stride with the pace of technological innovation, but must stay ahead of their competition by longer range research and development and, particularly, product planning. But its implementation involves substantial risks and complex decisions balancing competing priorities within financial, legal and available skill-level constraints.

It is difficult to conceive of an executive of a major vacuum tube manufacturer making a decision in the middle 1950's to spin off a profitable but labor-intensive vacuum tube division and/or to commit substantial resources to the manufacture of transistors. If the vacuum tube facilities were reasonably modern and fully or largely amortized, a decision to spin off the facilities would have been even more difficult. However, these are decisional risks which must be assumed by corporate managers, if they are to stay in step with the tempo of innovation and ahead of competition, both domestic and foreign.

Import market share in a number of consumer electronic product lines has reached significant levels in the last 20 years, including transistor radios, smaller screen monochrome and color TV sets, high fidelity monaural and stereo components, tape recorders, CB radios and home video tape equipment. In the case of each of these products, the notion prevails that imports destroyed or are potentially destructive of the domestic industry producing the competing product. However, a closer look will show that it has been the dynamics of innovation, rather than import competition *per se* which has brought about the significant change in the conditions of competition in the market place.

Technological innovation has resulted in a better product at a lower price. With each new discovery have come additional convenience features which automatically appeal to the consumer. Technological innovation results in cost efficiences for the producer whose energy, material and labor costs are reduced. Once scale and learning economics are achieved, these cost efficiencies are translated into lower prices for the consumer. Technological innovation is therefore inherently counter-inflationary. Rapid and quantum reduction in prices of products of innovative industries manifest this effect. The secondary counter-inflationary effect is the accompanying reduction in repair and maintenance costs incident to the use of more technology intensive products.

1. PORTABLE RADIOS

Prior to 1956, all portable radios were tube type with a storage battery or dry cell power source. In that year, personal, pocket-size, transistorized portable radios weighing an average of 20 ounces and priced at an average of $57 were marketed. No imports were available. By 1959, the Japanese came on the market with miniature portable sets weighing about 10 ounces, less than half of the weight of the smallest U.S. radios, and costing less. The Japanese innovation consisted of sharply reducing the size, weight and ultimately the price of personal portable radios and, in so doing, opening up a new market which had not been serviced by the U.S. industry. The innovation did not, of course, involve the basic transistors but rather the reduction in the sizes of the complementary components such as antennas, battery supplies, loudspeakers and, most importantly, tuning capacitors. It was the transistor combined with the additional innovations that enabled the Japanese to tap in and activate the latent market demand for pocket portable radios. In fact, the U.S. designed product "missed the boat" in that it failed to take full advantage of the design possibilities offered by transistor technology.

2. AUTOMOBILE RADIOS

Here again, up until 1956, only tube type automobile radios were available which required the troublesome vibrator power supply. This component required frequent replacement and had high power consumption characteristics. With the introduction of the germanium output transistors and transistorization of the entire unit, separate transformers and tubes were eliminated resulting in substantial reduction in production costs and size. Vibrator power unit and auto radio transformers manufacturers were put out of business and the tube manufacturers lost their auto radio market.

Here, it was the U.S. manufacturers, not importers, who quickly took advantage of the potential for innovation to achieve cost reduction, low maintenance costs, low power drain, and satisfy smaller space requirements, of auto manufacturers. As a result, the U.S. manufacturers pre-empted the market for transistorized auto radios.

3. SMALL SCREEN BLACK AND WHITE TV SETS

The Japanese industry, by designing and marketing transistorized monochrome television receivers in nine inch, eight inch, five inch, and four inch sizes, beginning about 1963, tapped into a latent market demand for personal portable television receivers. For the first time, the television receiver began to move out of the living room and family room to be used in the bedroom, library and the kitchen. Meanwhile, some domestic producers responded to this move by affixing handles to 19-inch table models weighing 60 pounds or more and advertising them as "portable" units instead of designing and marketing smaller screen solid state monochrome sets. Others began importing solid state smaller screen sets to satisfy this new market demand. Still others came out with smaller screen tube type sets in the 12″ or larger screen sizes. Only one domestic producer came out with a 9″ small screen set for a short period but manufactured largely by use of imported components. Affixing handles on these heavy sets may have passed legal muster under Section 5 of the Federal Trade Commission Act but the novel idea contained nothing which would rise to the dignity of an innovation.

4. COLOR TELEVISION RECEIVERS

The first transistorized console color television was marketed by a U.S. manufacturer in 1968. It was not until 1974 that transistorized color sets became the industry standard. The imports began shifting to hybrid and fully transistorized sets during the latter 1960's and shifted almost entirely to transistorized units from one to two years prior to U.S. producers. Again, the transistorized sets were smaller, light in weight, characterized by low maintenance costs, and consumed less power.

These over-simplified, illustrative examples set forth above suggest that dynamics of innovation rather than import competition is at the heart of product substitution, market discontinuities, and worker displacement.

The lightning speed with which innovation has taken place and the impact in the market place of rendering a product obsolete almost overnight has frequently produced a situation which is aptly characterized as market forfeiture whereby domestic manufacturers have sought to source abroad rather than expend funds to establish production facilities in the U.S. to compete with innovative imported products. This is the easiest course and the most cost effective as the corporate managers were well aware that the life span of the innovative product will be shortened by accelerating rate of technological improvements. Nevertheless, this short term profit oriented response represents a voluntary abdication by the domestic enterprises.

The pocket transistor radio case involves market forfeiture to imports by major U.S. consumer electronic products (but an explosive market growth for transistor battery manufacturers such as Union Carbide, Mallory, etc.). For example, General Electric, for cost and performance considerations, decided not to go into the manufacture of pocket radios for the mass market or import the "guts" of the set and enclose them in American-made cases. Other domestic producers opted to purchase imports under their brands or produce offshore. Some of the problems in manufacturing these radios domestically included the lack of a ready domestic sourcing base for miniature components and the difficulty of mechanizing or automating transistor radio assembly lines except at high cost because of their small size. Here again, in part, to protect the market for tube-type table and portable storage battery models, a petition was filed in 1959 to restrict pocket transistor radio imports.

In view of the generally conservative approach of major U.S. consumer electronic producers against investing in domestic manufacture of transistor radios, it was not likely that a domestic pocket radio industry with sufficient capacity to supply the mass markets would have developed even if effective barriers to imports had been established.

With respect to the CB radio market, all diversified major U.S. producers stayed out of domestic manufacture based on sound financial judgments that the market growth potential was not sufficient to justify domestic investment in manufacturing facilities. Thus, even though CB radios have been authorized since 1958, none of the major consumer electronic manufacturers have ever seriously attempted to enter this market with domestic production. Here again is a clear case of market forfeiture and default of competition by domestic producers which left a market vacuum for imports to occupy.

These cases suggest voluntary market forfeitures as an important factor accounting for substantial import market shares of consumer electronic products. The investment priorities of highly diversified multiproduct manufacturers, being oriented toward major equipment production, and sound strategic planning considerations often dictate market withdrawals or offshore sourcing of shorter life-cycle products. GE is a spectacularly successful firm in this category which has frequently spun off unprofitable product lines.

In the light of the experience of U.S. producers in the consumer electronics market, the question arises as to whether similar patterns of major import shares are likely to develop in the IC and computer market. The indications are that they will not develop with respect to these technology-inensive products, provided U.S. producers continue to maintain their lead in technology and product development by maintaining adequate research and development funding to meet the market demand for innovation.

The U.S. electronic industry has dominated production and international trade not only in manufacturing computers, but also in producing high density, solid state circuitry which continuously results in smaller and more powerful models. The technological and marketing lead that U.S. multinational firms have maintained in ultra-miniature semiconductor circuitry, which is basic to the production of computers, is beyond any serious challenge from foreign competitors. To maintain this technological superiority U.S. firms, led by IBM Corporation with its $1.14 billion expenditure in 1977, are spending large sums of money on research and development. The spectacular success achieved in this area is underscored by the projection that U.S. firms are expected to account for an estimated 60 percent or more of all transistors, integrated circuits (IC) and other solid state electronic components sold in world markets in 1977.

However, in spite of U.S. industry leadership in overall production, development and sales, its spokesmen have increasingly raised the spectre of an impending competitive threat from Japanese semiconductor manufacturers in the North American market. A realistic appraisal of the Japanese "impact" on the U.S. semiconductor industry raises serious doubt as to the validity of such fears.

The U.S. semiconductor manufacturers have consistently captured a large share of the Japanese market. Japanese Government statistics indicate that IC imports account for an estimated 24 percent of the Japanese non-captive market. U.S.-based multinational corporations through direct exports and third country offshore facilities account for about 80 percent of all ICs imported by Japan.

In contrast, Japanese exports to the U.S. in 1976 totaled $40 million or less than two percent of the U.S. IC market. Moreover, more than an estimated 90 percent of U.S. imports are accounted for by U.S. offshore facilities.

U.S. industry spokesmen also state that the Japanese Government subsidizes exports of ICs by making available special low-interest, long-term loans from the Exim Bank of Japan. This again is untrue. Among the more frequently voiced claims of unfairness centers on the financing of the Japanese VLSI program to develop new integrated circuits for the 1980's using very large scale integration technology. The project was started to develop Japanese technological independence in the computer field presently dominated worldwide by IBM Corporation and other U.S. firms.

The Japanese Government does fund, in part, research and development of basic VLSI technology used for computers. However, such government assistance, which involves a rather modest amount of money rather than the exaggerated sums suggested by one witness at the San Francisco hearings, in our opinion does not contravene the provisions of the U.S. countervailing duty statute.

In light of the fact that the U.S. computer technology as well as semiconductor technology was initially developed largely under U.S. Government R&D and procurement funding, and the further fact that Canadian, French, and West German governments also subsidize semiconductor R&D, the claim of unfairness suggests a double standard of fairness, one which applies to Japan, and another which applies to all non-Japanese countries.

Finally, another factor often cited as a barrier to sales in Japan is the 12 percent duty on semiconductor components as compared with the U.S. duty of six percent. While the figures are correct, this tariff has not proved to be a major hindrance to U.S. sales in Japan. First, the tariff issue is irrelevant to multinational U.S. producers of semiconductors with production facilities in Japan. Secondly, in spite of the traiff, U.S. semiconductor exports to Japan have exceeded and continue to exceed Japanese exports to the U.S. Thirdly, the contention that the higher tariff paid by the U.S. manufacturers is an effective barrier to sales is refuted by U.S. industry experience in Europe. Despite the Common Market import duty rates of about 17 percent, U.S. manufacturers have still captured an estimated 80 percent of the European market. This makes suspect the claim that the lower Japanese import duty of 12 percent effectively restricts U.S. export sales. In any event, these duties are expected to be equalized as between the U.S. and Japan.

In the main, the dominance of U.S. firms, national and multinational, over the world IC and computer markets is expected to continue in the foreseeable future, although market shares currently accounted for by U.S. firms and U.S.-based multinational corporations are expected to decline moderately with the development and growth of production by Japanese and other foreign firms. This conclusion is positioned on the assumption that U.S. firms will maintain private R&D funding in IC and computer technology, at least, at current levels, and the Federal Government will continue to fund a substantial portion of the research and development in military equipment and aerospace IC applications. In addition, the United States market offers the largest growth potential for new IC and computer applications, and, to the extent U.S. manufacturers take full advantage of these newly developing markets, the U.S. manufacturers will maintain their competitive edge by cost efficiencies realized from learning economies and scale economies.

Statement of Thomas J. Buckholtz, Director, Corporate Systems, Teknekron, Inc., Berkeley, Calif.

POLICY ISSUES REGARDING THE COMPUTER INDUSTRY

Introduction

The United States computer industry and supporting semiconductor technology continue to grow in importance in the domestic and international economic scenes. While various industries, such as defense, energy, aerospace, transportation, and communications, that have sponsored computer development are influenced by government controls, computing has grown dynamically in an environment of relative license. There are many issues of increasing importance within the computer industry. These issues can prove a fertile field for future national policy decisions. The time is ripe for devising a comprehensive plan to provide an optimal mix of freedom, guidance, aid, and control for computing in particular, and the information industry in general.

Issues and Policy Areas

There are many intertwined issues important to American computing. I would like to catalogue some of the key policy areas:

1. Domestic.
   A. Innovation—Research and Development.
      1. Productivity from the full spectrum of sources.
      2. Selection and stimulation of research fields.
      3. Mix of effort and cooperation among industry, academia, and government.
      4. Relative impetus from defense and civilian sources.
   B. Investment.
      1. Incentives for domestic venture capital.
      2. Foreign investment in domestic enterprise.
   C. Industry-wide Standards.
      1. Hardware systems and interfaces.
      2. Software protocol, systems, and interfaces.
      3. Benchmarking.
   D. Societal Implications.
      1. Employment patterns.
      2. Educational emphases.
      3. Data security and individual privacy.
      4. Inter-personal and man-machine relationships.
2. International.
   A. Exports and Balance of Payments.
      1. Guidance and support for producers and distributors.
      2. Non-exportable "strategic" items.
      3. Trade missions: structure and effectiveness.
      4. Taxation of foreign-based American employees of American organizations.
      5. Inter-governmental cooperation.
      6. Foreign tariffs.
   B. Imports.
      1. Domestic tariffs.
      2. Foreign capital.
   C. U.S. Technological Superiority.
      1. Foreign manufacture of components and systems for, or by, domestic companies.
      2. Software.
      3. Foreign acquisition of domestic talent.
   D. Data Processing Services and Data Communications.
      1. International transmission of data.
      2. International data processing services.

Conclusion

Many issue areas should be considered in formulating a comprehensive national computer policy. Much can be said about any of the issues; I would like to discuss the problems behind these issues and possible remedial policies. I think it appropriate to concentrate first on the main question of a unified strategy, as current policy has evolved sporadically.

Statement of Leonard R. Weisberg

DOD PROGRAM ON VERY HIGH SPEED INTEGRATED CIRCUITS (VHSIC)

Introduction

In the 1960s the Department of Defense (DoD) funded the early R&D work on integrated circuits (ICs), and established an early market. The DoD market for ICs through 1965 exceeded 70 percent of the total IC market. These early DoD actions have been credited to be a major factor in initiating the IC industry.

Although early work was focused in only a few companies, the next step that occurred was a rapid diffusion of technology to many companies. This diffusion occurred through government reports, publications, meetings, workshops, transfer of personnel among companies, establishment of second sources and licensing. the formation of breakaway companies, etc. In many cases demonstration of feasibility was half the battle. Frequently within months after the announcement of a new process or product, the same result was repeated in other companies.

Over the past several years we had maintained a deliberate policy of minimizing DoD funding on advancing the state-of-the-art of integrated circuits (ICs). This policy had been based on two main assumptions: that industry would develop the ICs suitable for DoD use, and that our lead over potential adversaries was substantial.

It now appears that neither of these assumptions is presently justified. The DoD market for ICs is now about 7 percent of the total, and industry is reluctant to qualify ICs for the military, or produce low volume customized ICs. Additionally, industry is not focussed on DoD's needs for real time high speed signal processing. Another factor is that recent evidence has indicated that our lead over potential adversaries in *military* ICs may have eroded.

Yet another factor is that largre scale integration (LSI) and very large scale integration (VLSI) have brought us into a new era, the era of "integrated systems". Because of this, builders of DoD systems have already encountered difficulties in incorporating LSI technology into military systems because it demands customization. Such customization will create future problems in supply and logistics. Of even greater importance, the era of integrated systems is an era of complexity, and the problem that confronts us is the management of this complexity. We believe that if we do not start to handle this problem now, it will be even more difficult to introduce ICs into future military systems. The problem is getting worse, not better. We must learn how to reduce the need for and the cost of customization. We must introduce on-chip test circuits to meet DoD's needs for testability. We must learn how to introduce fault tolerance to meet DoD's needs for reliability.

Rationale for the Program

There are three main reasons for initiating the VHSIC program:

The DoD technological lead is a precious resource. This program will increase our lead in military integrated circuits (ICs) over the Soviets by at least five years.

ICs will not only provide highly advanced military capabilities, but will also provide a high return on investment in life cycle costs.

The program will get advanced ICs into future military systems in a timely and affordable manner, minimizing customization.

Each IC will replace at least 50 percent ICs, allowing new and improved capabilities to be achieved in satellites, cruise missiles, fire and forget missiles, radar, command and control systems, wideband data communications, undersea search, electronic warfare, signal intelligence, etc. Additionally, major savings in weight, size, power consumption, and reliability will accrue.

Main Features of the VHSI Program

The VHSI program is being initiated in Fiscal Year 1979, and willl extend through Fiscal Year 1984. Total funding is planned to exceed $150M. The VHSI program is constrained to silicon ICs since silicon is still the mainstay of the IC industry. Efforts on GaAs will continue to be pursued under the ongoing Service and DARPA efforts.

The program is divided into two main parts, roughly equally funded, VHSIC–I and VHSIC–II. VHSIC–I is oriented to getting future ICs into DoD systems in a timely and affordable manner. It will have as a major goal the delivery of several selected systems after about 4 years, with the fabrication of the required ICs as a key milestone after about 3 years. These ICs will have a minimum feature size of 1.3 microns, will operate over MILSPEC temperature ranges, and will operate under mansurvivable radiation dosages. This goal was chosen to coincide with the projected rate of industry development, and have devices available to DoD at the same time they are available to industry rather than 3 years later.

If particular importance, to minimize customization and customization costs, chip sets will be partitioned into primitives, wherever possible, micro and macrocells will be used wherever possible together with universal gate arrays or programmable logic arrays and their layouts and interconnections will be determined by CAD-E tools.

VHSIC–II will be oriented to advancing the IC technology to submicron dimensions (0.5 to 0.8 microns). It will include providing new tools for industry such as submicron lithography equipment, improved resists, and equipment for dry resist removal. It will also include university and industry efforts on design, architecture, software and testing (DAST) and related tools such as CAD–E. In this respect, we are considering establishing a centralized control office and library for CAD–E tools. A barrier is presently seen by industry to going below 1 micron. This program should provide the tools to industry to help them go past this barrier.

In both parts of the program, wherever possible, the statement of work will be written as a functional description aimed at end needs rather than as specific goals so as to allow the maximum flexibility by the responder with the associated maximum possible introduction of innovation.

Cooperative Aspects

The program is tri-Service in nature and is guided by tri-Service Steering Groups and a tri-Service Overview Committee. To insure maximum coordination, the Overview Committee is chaired by the Office of the Under Secretary of Defense for Research and Engineering (OUSDRE).

To insure coordination with other agencies, the Steering Committees have representatives from the Department of Energy (Sandia), NASA, and NBS. To provide additional coordination within the DoD community, there are also representatives from DARPA, NSA, IDA and Lincoln Laboratories.

Innovations and Fallout Expected

Virtually every advance in the IC industry has been based on continual innovation. For contractors to meet the end goals of this program, improvements must be made in areas such as materials perfection, low temperature epitaxy, high pressure oxidation, resist removal, resist sensitivity, electron beam control multi-level metallization, uniformity of ion implanation, methods of examining and testing the IC chips, etc.

While the main attention to achieving submicron ICs has typically been directed towards the materials and processing problems, actually the major innovations might be related to chip/architecture. The problems of complexity and customization have yet to be resolved, and new approaches might have the most dramatic effects. For example, software-programmable logic, signal processing microprocessors, and procedures for parallel and pipeline processing could provide greater overall gains for both DoD and the IC industry than just the shrinking of size and the placement of more gates on a chip.

We judge that over ¾ of the program will provide both direct and indirect fallout to industry. Direct fallout will result from improved CAD–E tools, new and improved concepts to simplify and standardize design/architecture and development of equipment for lithography, dry resist removal, and automatic chip test.

Although the present situation differs from that of the early 1960s since DoD has only a small market share, many of the advantages of a DoD effort should still accrue to industry as an indirect fallout. As in the 1960s, the VHSIC program will help catalyze advances by providing feasibility demonstration of advanced ICs and establishing a small but viable market. Then the traditional effect of technology diffusion should again occur except possibly for the formation of new companies as occurred in the 1960s. To help technology diffusion, DoD will encourage the dissemination of reports and the holding of workshops and meetings.

Some Issues

Many issues have been raised concerning the possible effects and direction of the VHSIC program. Basically industry is in an era of excellent prosperity with demands exceeding the industry capacity, and is concerned that the DoD program might be disruptive.

Statements from industry have been quite sweeping with little or no data offered to support them. Also some of the statements have been contradictory. For example, in contrast to some claims that the VHSIC program will be disruptive, other claims are that the "DoD's efforts are just a drop in the bucket" (Electronic Warfare/Defense Electronics, December 1978, p. 49). Some industry representatives have stated that the program must emphasize standardization of design for the program to be successful while other industry representatives have claimed that any standardization would stifle competition and innovation and should be avoided.

It should be recognized that the funding of the VHSIC program will be about $30 million annually, which is less than 10% of the IC industry expenditures of over $300 million in R&D annually. Additionally VHSIC funds will utilize present industry resources in those companies that choose to enter the program so that the program will actually result in only a few percent increment in new industry resources.

The effect of the VHSIC program can be fruitfully compared to the much larger effect of the demands of the automotive industry; however, the profit motive to supply DoD is less.

The configuration of the program should also be noted. The program will take nearly two years to build up, allowing adjustments to be made in industry. Contracts will be spread over a variety of IC companies, military system houses, equipment suppliers, and universities. The goals of VHSIC–I of 1.3 micron features sizes in about three years are commensurate with present industry trends.

With respect to basic research in universities, the VHSIC program has already served to further catalyze actions to strengthen university research. Since the VHSIC program was briefed to the Services and other governmental agencies about 8 months ago, the research (6.1) programs on ICs funded by the Services are starting to be built up. DARPA is proceeding with a program complementary to the VHSIC program aimed at research to further advance ICs. NSF is considering a major effort in submicron research expanding upon its initial program started two years ago. NBS has defined a new thrust in ICs. Universities are considering major IC research centers.

Summary

The VHSIC program will have a significant payoff to DoD by focusing on those aspects of IC technology of particular interest for military systems. It will stimulate innovation by establishing ambitious but sensible goals. It will result in significant direct and indirect fallout to industry by providing the needed tools, advanced concepts and identification of problems to help industry go beyond the one micron feature size barrier, and thus will strengthen the long term future of the industry. Fears that the program might be disruptive to the IC industry are not justified, and the program is configured to minimize any such adverse effects.

President's Reorganization Project—the Federal Data Processing Reorganization Study, Section B: Special Report of the Science and Technology Team

WHAT SHOULD BE THE FEDERAL GOVERNMENT'S ROLE, IF ANY, IN ADVANCING THE STATE-OF-THE-ART IN COMPUTER TECHNOLOGY?

(By Louis W. Haire, Team Leader, Lockheed Corp. and Charles W. Cross, Office of the Chief of Naval Operations, Department of the Navy)

THE PROBLEM

A special request was made by the Office of Management and Budget for the Science and Technology Team to investigate certain issues involving several of the Agencies' long range computer plans related to technology requirements. These issues primarily concerned the various approaches being taken by different Agencies to satisfy their long range state-of-the-art computer needs. For example, a number of the Agencies indicate current or future requirements for larger mass memory than is currently available. Other Agencies indicate a need for faster, more sophisticated peripherals to augment advanced main frame computers now being delivered. Most of the requirements cited by the specific Agencies involved small quantities, generally considered inadequate to attract interest because of the low volume. In other words, the research and development cost, to produce these items is not warranted when the market is confined to a single Agency's needs.

Investigation into this problem was undertaken by the Science and Technology Team in conjunction with its other Information Systems and computer efforts. As a result of discussions held with many groups within the Federal Government, with trade associations and with the computer industry, four major focal points began to emerge. These four points relate to:

1. The need for and the Government's role in sponsoring, either directly or indirectly, basic (sometimes called blue-sky) research in computer technology.

2. Defining requirements for hardware/software/firmware not currently available, and subsequently sponsoring applied research and development efforts to satisfy those requirements. These requirements will generally be found where current capabilities need to be extended or augmented. The same or related needs will generally be recognized concurrently in a number of Agencies.

3. Identifying and defining those internal computer operations which are widespread in nature and which can be improved by sponsoring applied research and development efforts best performed by those outside the Government. Frequently, joint problem solving with industry will be called for, as the solutions will be used by both. For instance, operating systems improvements, computer/communications interface problems, packaged application programs, language standards, etc., will fall into this category.

4. Identifying and defining those internal computer operations which are wide-spread in nature and which can be improved by sponsoring applied research and development efforts best performed by those within the Government. Generally, such efforts will be supportive of the computer operating centers, Agency Headquarters planning and possibly Government-wide planning. Operational activities in this category to be supported by internal R&D efforts are better nomenclature, data dictionaries, operating standards, training standards, etc.

The Government has many diverse requirements in these four areas. The appropriate fulfillment of these requirements will represent a significant driving force in the advancement of computer technology. This force, coupled with similar forces from U.S. business and industry in general, has helped the U.S. computer industry to achieve an unparalleled world-wide dominance in computer sales. In turn, this dominance has proved to be a boon in U.S. balance of trade payments. Countering this historical trend, however, is another pervasive concern which the Team frequently encountered. This concern is related to a growing recognition that the current dominance by the U.S. in the development, manufacture and sale of computers and computer services is seriously threatened by overseas activities now currently underway.

In consideration of all of the problems, opportunities, and concerns implied in the foregoing, it was concluded that the scope of this special report by the Science and Technology Team should encompass the question of: "What Should Be The Federal Government's Role, If Any, In Advancing The State-of-The-Art In Computer Technology?"

BACKGROUND

In the Basic Report by the Science and Technology Team of the Data Processing Reorganization Study, it was pointed out that the computer obsolescence trend in the Federal inventory is cause for grave concern. The Report also predicts that unless the obsolescence trend in the Federal inventory is soon reversed, that the trend will accelerate in the future. Other future trends which also influenced our efforts in addressing the question at hand are embodied in a report entitled, "Information Processing in the U.S.: A quantitive Summary," sponsored by the American Federation of Information Processing Societies, Inc. (AFIPS).

1. "The data processing industry will continue to double in dollar volume every five years worldwide from 1970 to 1990."

2. "Total user spending on data processing in the United States will rise from 2.1 percent of the Gross National Product (GNP) in 1970 to 13 percent in 1990, and from $101 per capita to $1,253."

3. "By 1990, as many as one in five of the U.S. labor force will require some knowledge of data processing. In addition, by that year more than six out of ten in the U.S. labor force will depend in some way on data processing. Finally, by 1990, more than 90 percent of the cost of DP will be attributable to personnel costs, perhaps making data processing the nation's most labor-intensive field."

In initiating this study, the Science and Technology Team accepted as a basic premise that the Federal Government has two fundamental reasons for critically examining its role in advancing the state-of-the-art in the computer industry. The first of these reasons relates to the Government's use of computers in the conduct of its business. In this role, the primary emphasis is upon greater efficiency and productivity, improved service to the public, etc., all resulting in lower overall cost to the taxpayer. In its second role the Government fulfills its obligation to help maintain a strong economy by encouraging and stimulating, where appropriate, the free enterprise system in this country.

With regard to the Government's role in helping to maintain a strong economy, the significance of the computer industry in helping to achieve this goal can be implied from figures contained in the AFIPS report cited above.

Year	World revenues for U.S. computer firms	Dollar increase from 1971 (percent)
1971 [1]	$14,395,000	
1976 [2]	31,860,000	121
1981 [2]	64,000,000	344

[1] In 1971 dollars.
[2] In 1976 dollars.

The overseas growth factor in the above amounts is larger than the U.S. growth factor and represents a significant and positive trade balance. Consequently, any loss of these overseas sales by U.S. firms would proportionately affect the U.S. balanec of trade problems currently existing.

Insidiously pervading the Science and Technology Team's effort were two obvious trends which should be noted.

One of these trends related to what Daniel S. Greenberg referred to as "Our Indolent Pursuit of Foreign Technology" in his syndicated column in the Washington Post of April 11, 1978. The major thrust of this article concerns the aggressive pursuit of American technology by foriegn firms who ". . . are scooping up the results of vast quantities of our taxpayer-financed research and using it to innovate products that outsell domestic goods." Greenberg then goes on to point out that ". . . there is scarcerly an organized American effort to keep abreast of foreign research, which despite our ethnocentric notions of American scientific supremacy, actually accounts for well over half of the world's scientific and technological output." Protectionism would not appear to be the answer. Instead we must overcome U.S. indolence in matching the organized, serious efforts that many other nations are exploiting as related to their own as well as U.S. research.

While the first area of concern is related to the on-going, total scientific and technology drain from the U.S., the second area of concern is more closely related to the current U.S. dominance of the computer industry itself. For example, the following recent headlines state the area of concern in a concise manner:

1. Computer Weekly, December 1, 1977: "Predicting the Decline of U.S. Dominance." An article based upon developments by Frederick G. Withington, Head of Data Processing Industry Forecasting for Arthur D. Little, Inc., a leading market research company of Cambridge, Massachusetts, predicts that "Over the next five years the U.S. can expect diminution in its dominance of the worldwide installed base of computer systems and an even greater decline in its superiority of the mini and dedicated application computer systems markets. Contributing to this gradual erosion of the U.S. stranglehold will be the aggressive Japanese computer manufacturers."

2. From the Japanese Economic Journal, February 7, 1978, headline: "Nippon Telegraph and Telephone Corporation plans computer to compete with IBM's FS (future system)."

3. From the Japanese Economic Journal, January 24, 1978, headline: "Fujitsu announces development of what it says is the fastest computer."

4. From the Washington Post, February 27, 1978, headline: HIGH STAKES RACE-Japanese Search For Breakthrough In Field Of Giant Computer." The major thrust of this article concerned the formation of a consortium by five of Japan's major computer manufacturers and the establishment of a $125 million interest-free loan by the Japanese Government. Objective—a determined search for a technology breakthrough which would allow a large penetration into the world computer market.

These and many other sources indicate to the Science and Technology Team that the cause for concern is real, not imagined, and that the Team should attempt to address the problem in its totality rather than a narrow segment only. This was deemed essential since the Government's past and future actions, both as a major user of computers and as a major sponsor of computer R&D, has and will continue to be a significant influence in advancing (or not advancing) computer technology.

FINDINGS AND CONCLUSIONS

Related to the state-of-the-art in industry

1. Following World War II many large computer Research and Development grants were made by or through the Federal Government, particularly during the 1960's. Today the consensus seems to be that far too little is being done. Complaints were heard that the National Science Foundation grants were too low and were oriented unduly towards basic (blue sky) research. As an indicated level of the inadequacy of the current funding levels, it was stated that the research funding by industry for technology related to Large Scale Integrated (LSI) circuitry is greater than the National Science Foundation's total budget. In this regard, the NSF role in the advancement of computer technology appears to have settled into a routine of highly theoretical studies thinly spread over many researchers. Whether this approach to NSF's investment in computer research is caused by meager funding or by more fundamental problems (lack of clarity of objectives, etc.) is unclear. In any event, recent contributions by NSF to computer technology advancement does not appear to have had a significant impact.

2. The fulfillment of applied R&D requirements sponsored by the Government do not appear to be handled well. This is partly because of (1) lack of focus as to the need, (2) lack of prioritization of requirements, and (3) the fact that each agency pushes its own R&D under the aegis of its own infra-structure.

3. The ARPA network is considered by many to be an illustration of a good job well done, pushing the state-of-the-art and significantly advancing the technology. Also, the DOD and NASA space programs are repeatedly cited as examples of Government at its best in stimulating technology. The Government needs many more cases like these.

4. The need to encourage small business and to spawn new entrepreneural type enterprises is urgent since a very large number of innovations in this Country are created in such an environment. The major reason for the current unfavorable environment is related to the shrinking of the high risk capital pools available to the small "silicon valley" innovators.

5. As to maintaining U.S. dominance in information/computer technology, our seeming inability to establish strategic goals between Industry and Government, and then push hard to accomplish them, appears to be a major obstacle. On the other hand, Japan seems to have developed this approach very successfully.

6. The present Government science and technology structure related to information management and computers does not appear to provide a focal point as it should. The many and varied groups which exist today within the Government appear to have little cohesiveness as to objective or to have a common unity of purpose.

7. The premature development and imposition of standards, by the very nature of their being, tend to slow down the pace of technology.

8. It appears probable that U.S. dominance in computer technology in the immediate future will be dependent on currently known or perceived technology, and will not be paced by major technological breakthroughs. If this should be the case, then the emphasis in the computer industry will shift to technology improvements related to manufacturing processes, quality control, logistics, etc.

9. Super computer developments currently in progress in the U.S. are few and far between. Expressed needs currently recognized are for huge scientific problem solving systems to support research in the weather/atmospheric/oceanographic sciences, in wind tunnel aircraft simulations, etc. Such systems could be built to be as powerful as 50 to 100 times the size of todays largest, fastest computer. Development costs to achieve such advances are huge, however. For example, the development cost to increase performance of the large Cray computer system by a factor of 2.5 to 5 (or 5 to 10 over the CDC 7600) has been estimated to be in the range of $100 million. If the U.S. expects to maintain its world lead in scientific computation, however, then such development costs are required.

10. It is now possible to completely simulate new computer architectural design at the circuit level. Consequently, it may now be possible to fully, or at least substantially, test new computer designs prior to actual production.

11. Little or no new computer architectural design or development of general purpose computers is currently going on in the industry.

12. A significant amount of computer research is performed by industry in the Government-sponsored Independent Research and Development (IR&D) programs. In general, there does not appear to be a focal point within the Government to help guide this effort in a fruitful and/or meaningful way.

Many of the above findings and conclusions are influenced in varying degrees by three recurring themes which the Sciences and Technology Team repeatedly encountered:

1. The Government is in a self-defeating role with its off-the-shelf, fully tested, procurement policies as currently applied to the procurement of advanced state-of-the-art computer hardware.

2. Many groups within the U.S. appear to believe through their actions that the Federal Government is a large segment of the computer market. A careful analyses of the shipments currently being made does not prove this to be the case.

3. It is widely believed that great benefits could be achieved by industry in general and by the Government Agencies if the current Government-funded research and development expenditures, both direct and indirect, were better coordinated, more intelligently prioritized, and more fruitfully deployed. Even without an increase in current funding levels, the potential for improvement within the current process could have a positive impact on the computer industry as well as in the Government's own operations.

Related To State-Of-The-Art In Government

The following major technical problems internal to (but not necessarily peculiar to) Government Agencies were frequently encountered. These problems need to be addressed in a formal and systematic way. These problems were raised often enough as to indicate that they significantly impact the agencies effective use of computer technology:

1. Computer security (especially multi-level) related to classified, privacy and proprietary information.

2. Mass memory technology requirements.

3. Software operating systems relating to Very Large Data Base Technology.

4. Methodology related to the development of specifications for system requirements (e.g., front-end system definition) particularly as related to application systems. In this regard, the widespread reluctance or inability to concentrate on front-end system definition preceding formal system design seems to be pervasive.

5. Improvement in software maintenance methodology, with the most crucial need related to accounting for systems maintenance activities.

6. The transferability of software programs.

7. A need for improved technology forecasting and improved ability to effect transfer of technology.

8. The actual or potential impact of computer technology on doctrine (e.g., especially military doctrine or tactical strategy which may need to be re-evaluated in light of current or forecasted change in computer technology.)

9. Needs related to insuring the quality of software.

10. Distributed computing and the related networks currently evolving. Particularly important are the communications interfaces.

RECOMMENDATIONS

Recommendations by the Science and Technology Team on the question of "What Should Be The Federal Government's Role, If Any, In Advancing The State-Of-The-Art In The Computer Technology?" are based upon one of the two primary options offered by the question itself. (For example, should the Government have a role or not?) The option selected by the Team is that "yes!" the Federal Government *does* have a role in advancing the state-of-the-art in the computer industry. Reasons for this role, we believe are those set forth earlier in this report, and are related to (1) productivity improvement needs within Government operations and (2) the maintenance of a strong U.S. economy.

Time constraints have been such that the five recommendations which are made here are necessarily of a basic policy nature. We believe them to be fundamentally sound and that significant benefits would accrue in several segments of our society if they were adopted.

Recommendation No. 1

Provide a focal point for the many and varied computer-related R&D efforts currently being funded, directly or indirectly, by Government grants, contracts, awards, purchase orders, IR&D programs, etc. From this effort, it is conceivable that broad, national objectives could be derived which would be supported by both industry and Government. Impetus for the development of this focal point should come from the Executive Office of the President, Office of Science and Technology Policy (OFTP).

Recommendation No. 2

The Government should become a more sophisticated, more intelligent buyer of both off-the-shelf as well as advanced state-of-the-art hardware and services.

The structural change which could help achieve this goal is the same as the recommendation made in the Basic Report (see page 23 of the Science and Technology Team.)

Recommendation No. 3

It is recommended that procurement techniques developed by DOD (e.g., Phase 1—Definition Contracts; Phase 2—Design Contracts; Phase 3—Construction Contracts) in acquiring advanced weapon systems be adapted to the acquisition of large scale developments involving computer technology.

The Government should recognize the self-defeating nature of some of its current procurement policies related to acquiring advanced state-of-the-art technology (e.g., requirement for competitive bids resulting in fixed price, no risk to buyer conditions in acquiring undeveloped technology.)

Recommendation No. 4

Aggregate the requirements, where appropriate, for advanced technology developments. This should be done in a manner designed to improve competition, bring into better focus the need for two or more operational requirements to share in the same or related technological development, to more effectively prioritize the variety stated (but uncoordinated requirements with the ever-limited resources available, to provide better guidance to on-going or contemplated applied research and development, etc.

Policy guidelines to accomplish this activity should be issued by the Office of Science and Technology Policy (OFTP) and by the Office of Management and Budget (OMB), as appropriate.

Recommendation No. 5

Provide one or more vehicles within the Federal Government which will offer sufficient management and technological expertise to define and take action on Government-wide computer technology problems such as those enumerated on Pages 8 and 9 of this report. A strong focal point for management guidance in solving these problems, and management impetus in obtaining action, is needed.

Of all the recommendations made by the Science and Technology Team, this one would provide the most direct, most widely needed and most immediate benefits to a majority of the Federal Agencies who use computers in their daily operations. We strongly recommend against the use of inter-agency coordinating groups to achieve this objective. While such groups may be effective in helping to define the problems, to isolate the causes, and to react to proposed solutions, nevertheless it is believed that such groups cannot take the action needed, nor effectively implement and enforce the final judgments.

This recommendation is related to the structural change inherent in the Science and Technology Team's Recommendation contained in the Basic Report (Page 23).

Submicron Digital Technology

(By Robert E. Kahn, Defense Advanced Research Projects Agency, Arlington, Va.)

1. INTRODUCTION

This paper presents a view of the DOD needs for substantial and timely advances in high speed digital technology for critical defense applications in which cost, size, weight and power are limiting constraints. A decade or more is typically encountered between the initial demonstration of a new technology and its earliest application in operational defense systems. According to the best technical estimates, initial systems that contain submicron-feature digital devices are achievable within the next 5–7 years but it is unlikely that industry alone will take an aggressive lead in developing the technology base to support such applications in the 1980's.

Industry will continue to provide advances in circuit design and manufacturing capability, but in the absense of a significant DOD investment, these will most likely be focussed in high volume custom chips (e.g., TV games) and low/medium performance "massive application" chips (e.g. RAMS). Unique military requirements such as MILSPEC operation or subnanosecond speed chips would not normally be addressed by industry without DOD funding.

There has been a trend in the past toward fewer, but more sophisticated military systems. This trend is exemplified by our increasing reliance on space based systems employing only a few satellites. The cost of custom LSI for such DOD systems is larger since there is no opportunity to take advantage of the learning curve associated with larger production runs.

Recently, efforts have started to develop alternative military concepts based on a large number of lower cost systems, but these concepts have not yet been proven. with the existing LSI technology base since they must meet specifications for which the entire production may consist of a few dozen chips most of which are for testing or spares. These devices cannot be fabricated cheaply and fast enough with the existing LSI technology base since they must meet specifications for reliability and performance that impose unique materials and architecture requirements which cannot currently be justified for commercial devices. With VLSI, this situation could conceivably be reversed. In most cases, low cost "special purpose" devices could be obtained from a standard family of restructurable chips for use either with a few sophisticated systems or with many unsophisticated ones. If, as expected, a submicron technology base emerges with industry support in the 1990's, it will be well into the 21st century before it affects military systems to any appreciable extent.

A basic problem with LSI technology has been the high cost and fabrication time of custom LSI. Utilization of existing 3–5 um LSI fabrication technology in DOD systems is poor; the reasons are several, but frequently cited are the custom nature of the DOD circuit requirements and early design freezes in service programs. A major objective of a VLSI program must be to overcome the high cost of using LSI in military systems and to ensure that the investments in VLSI technology result in higher utilization in DOD systems than is currently the case with custom LSI.

Due to the high levels of integration achievable in VLSI, it may be possible to develop a fairly small (e.g., 10–50) set of "meta-level" structures which can be used to dynamically generate a powerful class of microsequenced or "data-flow" architectures that can be used to meet most high speed processing implementation requirements. A custom VLSI chip would be capable of being configured quickly (micro-planned) into one or more of these architectures and a small set of such chips should provide an entire range of functions and architectural alternatives. We should aim to determine if such a goal is feasible and if so strive to achieve it.

Demonstrated laboratory integrated circuit fabrication techniques suggest the possibility of forming the entire central processing unit (CPU) of a computer (that is large by 1978 standards) on a single, small chip of semi-conductor material, including memory and other logic functions. Realization of this suggestion in the form of packaged, militarily qualified integrated circuits would provide the capability to place the computational power of today's very largest computer within the volume, power, and weight constraints of tactical and strategic missiles, as well as in surveillance and communication satellites. Continuing innovations in circuit fabrication techniques, materials, and system organization indicate a potential for surpassing this level of computational capability on a chip by a factor of at least one or two orders of magnitude within the next 5–7 years. However, a substantial technical effort must be mounted in order for the DOD to capitalize on this significant increase in computational capability in a timely an affordable manner.

There is also substantial evidence that foreign efforts are progressing rapidly in this scientific field. Compound semiconductor technology, electron beam lithography and projection optics lithography are at a more advanced state of development in the UK, France, and Japan than in the U.S. In fact, the U.S. technology in silicon crystal growth appears to have slowed rather than progressed. A major U.S. manufacturer is currently achieving a factor of two yield improvement with foreign supplied silicon over the domestic supply. This situation is more indicative of an inability on our part to achieve vertical integration in the industry, than a comment on what others have achieved.

A coordinated program that accelerates the development of the technology base for submicron digital technology and achieves an operational capability for fabrication and for use in actual systems with the next decade should incorporate the following elements: 1) application requirements from a few selected military systems, 2) materials research, device design, and processing development to integrate the individual fabrication techniques into a total fabrication process with 3) the development and reduction to practice of new VLSI architectural concepts (including Software Design techniques) which capitalize on the unique attributes of submicron technology. The integration of these technologies into one or more prototype systems is necessary to provide firm evidence that the technology is ready for system implementation within the DoD. Each of the above areas must be pursued in a coordinated fashion with the other areas.

This document addresses this critical subject and discusses both the opportunities and problems which face us in achieving a submicron technology base.

2. BACKGROUND AND TECHNICAL NEED

In this section we discuss the DoD problem, the current state-of-the-art in high speed digital logic, the opportunity that is posed by submicron technology and the problems we must solve in achieving our stated goals.

a. The DoD Problem

A large and growing number of DoD applications require very high speed processing of information. The most critical requirements to date have arisen in ballistic missile defense, in weather modeling and prediction, in surveillance systems of almost every kind, and in numerical analysis. The ultimate capability of such systems is usually determined principally by the available computational power. For space or airborne applications the limits on available energy, volume, and cost are very tight and the resulting overall performance of an on-board system is usually constrained by these limitations.

If high speed communication with a ground based system is acceptable (despite the transmission delay, vulnerability and added communications equipment), the task still remains to provide maximum ground based processing power subject to possibly relaxed (but not unbounded) constraints on cost, power and volume. In either case, the opportunities for achieving increased processing power appear to be two fold. First, a faster device technology can be sought. This can lead to increased computational power via machines whose cycle times are simply much faster. There is a limit imposed by physics and chemistry on how much speed-up we can expect with any given material. Second, a more powerful set of system architectures can be fabricated using a given device technology. Or both options may be pursued. Other things being equal, these two approaches can yield in combination, practical increases in processing power of two or four orders of magnitude over state-of-the-art systems within the next 5–7 years.

However, for many applications, a means must be found to provide sufficient on-board processing power within the constraints of the particular platform. If the information cannot be processed onboard, it must then be relayed to some less constraining environment as, for example, via a high speed telemetry link to the ground. This latter step may not always be a feasible option. For example, an intelligent "fire and forget" missile may not have time to relay "raw" data to a ground based system or wait for its reply; further, its mission may also be directly and adversely impacted by electronic interference with uplink or downlink transmissions. In general, the effectiveness of a space based system may be compromised by active radiation to and/or from the ground.

Advances in high speed digital technology would also make it possible to carry out for the first time sophisticated information processing applications such as real-time image understanding. A critical technical trade-off issue in this area will be system partitioning among sophisticated analog and digital devices.

Even with combined analog and digital operation, image processing requirements on the order of 100 billion operations per second may be envisioned where an operation is viewed as one complete instruction in a suitable high level language. For example, a typical landsat satellite image consists of about 10**7 picture elements or "pixels". Approximately 10**3–10**4 operations are required to process each pixel. For display applications, what we now achieve rather slowly and in non real-time with conventional comuuters, we can do on the fly with VLSI. Moving faster images, zooming and other real-time filtering applications would all become feasible. Even for very simple image processing applications where perhaps only 100 operations are required per pixel, a one billion operations per second processor is required, a level of capability which exceeds the current state-of-the-art even for unconstrained systems located on the ground.

b. Current State-of-the-art

1. High Speed Computer Technology

The current generation of high speed computers implement instruction sets which operate on the order of 20–50 ns per machine cycle. (e.g., IBM 370/195, CDC Star, CDC 7600, Amdahl 470 V/6 and Cray-1) or the equivalent of 5–50 million instructions per second (MIPS) on the average. The Cray-1 is the fastest of the commercial machines. The ILLIAC IV parallel processor currently in operation at NASA/AMES can provide up to about 100 MIPS equivalent for a carefully tailored application. Each of these machines is very large and very costly. They all depend upon the fast cycle times provided by current high performance digital logic and by minimizing the equivalent number of machine cycles per instruction.

Generally, the high performance logic comes from improvements in the materials, device design and processing area while more equivalent computation per machine cycle comes from architectural improvements such as parallel processing, pipelining, look-ahead techniques, and data flow concepts.

The estimated number of gates required to implement a typical state-of-the-art very large processor has grown from about 25,000 to 50,000 about a decade ago to about 250,000 today. At the current rate of progress, very large processors will contain upwards of a million gates in the early 1980's and will provide on the order of a few hundred MIPS as the state-of-the-art in machine capacity.

If we are able to achieve a two or three order of magnitude increase in gate density with an equivalent increase in size (and to some extent in complexity) of the resulting logic functions, we will also have to contend with a far more significant interconnection problem in the design and layout of integrated circuits than currently exists. Unless innovative interconnection techniques are developed for both on-chip and off-chip communications, we can easily envision most of the resulting chip being devoted to wires instead of logic elements.

High density memories can now be implemented on the same substrate as processor logic and on-chip interconnections of high-speed processors and memory are now possible. It is also apparent that certain materials like GaAs may serve as photoemitters and photodetectors. This observation suggests an interesting set of options based on packet broadcasting to supplement the use of on-chip wires. In particular, packet processing logic totaling perhaps 10% or less of the total number of gates can be implemented in a number of locations on the substrate alongside implanted photodetectors and photoreceptors. A reflecting seal over the chip would allow optical broadcasting from one point to another.

The semi conductor industry has progressed from a silicon wafer size of about an inch in diameter almost two decades ago to the 4 inch wafer range today and 6 inch wafers in a few years. Each wafer typically contains a few dozen chips (today's microprocessor chips are limited to a few thousand gates not including memory) and we can expect that individual chips as large as today's wafers will be technologically possible within the next decade. Assuming a current capability of about 10,000 gates/chip, the largest of today's processors could be implemented, in principle, with a few tens of chips; provided the packaging constraints were obliging. In practice, a few hundreds of LSI chips might actually be required.

If large single chips could be reliably implemented in practice at a 4 inch wafer size, on the order of ten large chips would be required, in practice, for the same machine. If a tenfold increase in linear circuit density could then be achieved with acceptable yield, at most a few chips would be required. Assuming this program of developments was carried out successfully, we would obtain, in essence, a single chip version of todays largest processors with room to spare. Although it is unlikely that we shall arrive at (or even need to arrive at) single chip implementations of the very largest processors (interconnections alone may be difficult to multiplex onto the limited number of available pins), we can nevertheless anticipate a radical reduction in the size and hence the cost of these processors. With carefully designed building block processor components, we can then build large, more powerful systems out of collections of these functional elements; or conversely, we can embed some lower power variant of these multi-component architectures within a single chip.

2. Semiconductor Technology

Silicon is still the most widely used semiconductor material and state-of-the-art feature size on a silicon substrate is in the 3–5 um range although some products with 2 um dimensions are on the market. Photolithographic techniques are used to "write" on the wafer and a sequence of chemical and thermal processes are used to develop it. The limiting dimension of the optical writing process is about 1 um (or 10,000 A) and other masking techniques based on electron beams, X-rays or focussed ion beams will be needed to achieve further reductions to submicron feature sizes. With a further reduction in size, the device speeds will increase due to the smaller geometries. Less power will be required for operation. Lower power, in turn, may lead to increased reliability. The best technical estimates are that with carefully processed silicon, feature sizes on the order of 0.1 um can be approached and that practical systems with about .25 um line widths can be achieved.

At these submicron dimensions, device physics limitations such as leakage currents, statistical variation of threshold voltage and subthreshold current lead to an inability to achieve adequate linearity and gain for logic to be functional. These limitations are common to all semiconductor materials and will not change appreciably by going to another semiconductor. Taking into account a number of projected materials and device processing improvements, we can reasonably expect a several thousand fold overall increase in number of gates on a chip due to increases in chip size (10x) increases in circuit density (500x) and logical advances in circuit design (5x) at the reduced linewidths.

Silicon is the material of choice in the semiconductor industry for many reasons such as the fact that it is cheap, readily available, an excellent insulator and incredibly stable. However, other materials such as GaAs can be used at any given scale to reach a higher speed of operation (e.g., 5x). The critical step for the DoD is in leapfrogging the limits of photolithography and quickly entering the realm of submicron-feature size digital electronics.

A major R&D program in materials, device design and processing is required to achieve a quantum jump to microelectronic fabrication at the submicron level. This is a technology intensive high risk effort which will require the dedicated efforts of the nation's best materials scientists, device physicists and engineers. Many aspects of this effort will undoubtedly be completely new and unexpected and unknown phenomena may be uncovered.

The ability to achieve 0.1 um lithography does not by itself achieve a VLSI capability. Equally important, if not more important, will be the development of compatible fabrication and information processing techniques to realize the advantages of submicron VLSI. The major limitation is less likely to be the generation of submicron lines per se, than the related integrated processing technology to turn the latent images into finished circuits. This is expected to be a major area for research.

Optical lithography with 1 um features is available now and will probably be in production by 1980 and chips in excess of 100,000 logic gates will be possible technically if we know how to design them. E-beam or X-ray lithography will be essential for smaller feature siz. It is quite possible that ultraviolet exposure techniques could be perfected within the next few years to extend optical lithography to 0.5 um. If so, industry will probably adopt it for both throughput and familiarity reasons (although with masks prepared by E-beams or X-rays).

3. The Problem and the Opportunity

In many ways, life in the 0.1 um region is expected to be quite a bit different than life at the 3–5 um region. For the supplier of bulk silicon, it will mean more meticulous preparation of bulk materials and the preparer of raw silicon wafers will find even more exacting demands for precision in fabrication. We must strive to get the "targets" for lithography right.

There is no accepted design methodology at the 0.1 um linewidth and circuit designers may have to develop radically new approaches to realize digital logic. What new circuit families might be appropriate at that dimensionality? Lithographic techniques based on the use of ultra high resolution writing devices will have to be perfected for production run environments; alternatives to chemical/thermal processing (e.g., plasma etching or maskless etching) may become necessary to reduce defects, achieve high yield, high reliability and high throughput. Also, ultra clean furnaces and ultra pure chemical process will have to be developed. Many of the VLSI problems will be similar to those encountered in the fabrication of conventional high speed digital logic.

Some very basic questions arise. For example, if transistor logic is retained as the essential digital element, then as the geometry decreases in size, how big ultimately must a flip flop be and how fast must signals flow for it to retain its bistable characteristic? What are the physics of such devices at submicron dimensions and how should we accurately model them? What circuit design techniques can be used to approach the limits of performance quite closely?

While we are primarily concerned in this program with certain pragmatic limits of materials due to physics and chemistry, some interesting theoretical questions arise as to the ultimate limitations on computational capability per unit of volume and power. How "big" or "powerful" a computer can one make with a given volume based on fundamental limits of heat disipation, speed of light propagation, chemical stability, etc.

A complex LSI chip containing several thousand gates is about the design limit for one individual. With VLSI, a million gate circuit can no longer be designed the same way since the current design methodology is totally inadequate to handle the enormous quantity of high density logic that results from the effective utilization of a large chip with submicron-feature sizes. The current approach is inadequate primarily because it deals only with the "syntax" of circuit design rather than its "semantics", it requires the circuit designer to specify the chip layout in detail.

A new design methodology is required that allows the circuit designer to operate at a functional level where hierarchical design techniques can be used to supply and successively refine global block diagrams and data flow structures. The designer wants to say this is a "multiplexer", that is a "correlator", this is a "heap", and that is a "stack."

Computers play a critical role in the circuit design process. First, they will insulate the design team from the detailed design and layout of each gate on the substrate yet retaining control of the overall high level design. This will require the development of higher level models for computer-aided process and device design which can be used in conjunction with computer based design systems. This effort would include test structures representative of the "best guess" VLSI technologies and heuristics for process modeling and development using submicron feature sizes.

Computers will manage the space layout on a chip, which is a major design problem today. By the use of knowledge engineering (e.g., A.I. heuristics, knowledge bases) it will be possible to utilize a far more powerful set of design rules than is currently achievable.

Formal definitions of chip functions will be required for the computer to "understand" and then to carry out the hierarchical design process. Hopefully, this will also lead the invocation of verification techniques both during the design process as well as afterwards.

Functional testing of VLSI circuits is required since brute force methods are impractical to test each gate or transistor individually. Given a set of functions and data paths, we would like to use a minimal number of tests optimally chosen by objective function in place of individual device testing. A formal definition of each function (e.g., multiplier) is required for a computer to determine automatically if the function is implemented properly and/or operating properly. A formal definition of each individual function and a formal representation of the layout is required to carry out composite tests of functionality. In general, adequate testing can be accomplished only if provisions for it have been included in the design.

One difference between LSI and VLSI design is that VLSI design will be done normally by teams of people rather than by an individual. Effective design support and configuration control techniques are essential to enable them to work together cooperatively. Design support includes multiple-terminal design systems that can be used by teams of workers for interactive broadcasting, large scale high resolution output devices (e.g., Calcomp "wallpaper" or large displays) and easy to use graphic input devices. Color output is extremely important in this application to distinguish different devices, identify paths, denote layers, etc.

Configuration control of the VLSI design process is closely coupled wtih the formal definition of logic functions, standard interfaces between functions, subsystems design status, verification and test status, modification controls, etc.

A key design issue is the development of techniques for partitioning functions into subfunctions within a single chip and between chips. Packaging and physical restriction (e.g., pin limitations) will become increasingly important here. With increased on-chip complexity, self-timed circuits may become practical. These circuits are characterized by asynchronous event timing determined by individual "events" and are advantageous in developing large or otherwise complex systems. They should be easier to use in the design process than conventional synchronously clocked circuits, self-timed circuits are probably more difficult to debug, but VLSI systems will require totally new approaches to debugging and functional testing anyway, and a solution to the latter problem may require a solution to the former problem along the way.

We end this section with mention of three innovative technical areas of opportunity. The first area is that of self diagnosis technology (which may or may not lead to a self repair capability) where each chip would have some percentage of its real estate devoted to built-in test and monitoring capabilities. This is an area of considerable commercial activity at the present time. It appears that IBM currently devotes perhaps a quarter of its chip area to test circuitry. This capability could be integrated into a "working system" to automatically test idle (or even non-idle) components by the same circuitry used by the manufacturer initially.

The second area, which is intimately connected with self diagnosis (and repair), is that of restructurable logic. Since logic and memory are nominally interchangeable at the gate level, one might seek out "meta-level" structures that could be dynamically organized by changing the architectural counterpart to "microcode". We call this capability "microplanning". A programmable digital "map" embodied in the chip would be used as a template to redefine the architecture and data paths on the chip. Different microprogrammable architectures could therefore be produced dynamically on the given chip. Radically new techniques for organizing on-chip communication would also be required. One possibility would be the use of optical packet broadcasting using the basic semiconductor material as a photoemitter and photodetector. The packet processing logic would be located at several different places on the chip.

Third, partitioning of functions on a single chip can lead to a single chip multiprocessor organization which may achieve higher yield than a uni-processor system on an equivalent sized chip. Each chip could self-repair itself by selecting only those portions of the multiprocessor that are working correctly and deselecting the remainder. In this case, the self repair might occur through the normal functioning of the chip without an overt repair action being taken.

The resulting high yield process would produce working chips with variable performance (e.g., speed, power) depending on the exact nature of its internal defects. These chips could be sorted and utilized based on performance category (e.g. speed quantile). Alternatively, a system composed of many such chips selected at random could reach a performance level determined by that of the average chip. These systems must be designed such that failures and replacements only affect the relative system performance but not its functionality.

PROPOSED PROGRAM ELEMENTS

a. Basic Materials, Device Physics and Processing Research:
   Analytical Characterization.
   Exploration of Fundamental Limitations.
   Stable, Defect Free Ultrathin Insulators.
   Novel Ion/Electron/Photon Beam Processes.
   Feasibility of Mixed Technology Chips.
   Novel Interconnect Technologies.
   Anisotrophic Processing.

b. Submicron Technology Development:
   Statistical Process Limitations.
   Technology Dependent Process Validation.
   Technology Dependent Models for Submicron Computer Design.
   Technology Demonstrations.

c. Architectural and Design Methodology:
   Hierarchical Circuit Design Techniques.
   Silicon Compiler Technology.
   Functional Testing Methodology.
   Meta-level Architecture Development.
   Interconnection Strategies.
   High Yield/Variable Performance Structures.

d. Applications Development:
   This portion of the program will be developed in greater detail during the first and second years of the program.

Additional Data Supplied for the Record

A. SEMICONDUCTOR INDUSTRY

1. Major Product and Process Innovations in the Semiconductor Industry 1951–71
2. U.S. Semiconductor Companies Founded 1966–76
3. R&D Expenditures of Leading Independent U.S. Semiconductor Manufacturers, 1972–78
4. Semiconductor Industry Value of Shipments to the Federal Government, 1963, 1965–73
5. Estimated World Sales of Semiconductors by Major International Firms, 1972, 1974 and 1976
6. Estimated Consumption of Semiconductor Components, 1973–78
7. Estimated Trade in Semiconductor Components, 1973–78
8. Japanese Semiconductor Production, 1976–78
9. Japanese Semiconductor Production and Exports, 1976–78
10. Total Integrated Circuit Market Share Estimates, 1970–77
11. Total Semiconductor Market Share Estimates, 1970–77
12. U.S. Electronics Components Trade, 1970–77
13. (a) Foreign Acquisitions in and Mergers with U.S. Semiconductor Manufacturers, 1975 to Present; (b) U.S. Semiconductor Industry Acquisitions and Mergers with Foreign Participation, 1975 to Present

B. COMPUTER INDUSTRY

1. R&D Expenditures of Leading U.S. Computer Manufacturers, 1976–77
2. Cumulative Number of Computers in Federal Government and United States 1967–75
3. Distribution of General-Purpose Computers and Minicomputers by Industry and Government, 1975
4. Worldwide Revenues of Leading U.S. Data Processing Companies, 1974–76
5. U.S. Exports of Electronic Computing Equipment to Principal Foreign Markets, 1970–78
6. U.S. Imports of Electronic Computing Equipment and Principal Suppliers, 1970–78
7. U.S. Foreign Trade in Computers and Related Equipment, 1967–78

MAJOR PRODUCT AND PROCESS INNOVATIONS IN THE SEMICONDUCTOR INDUSTRY, 1951–71

Innovation	Principal company responsible	Date
Point contact transistor [1]	Bell Telephone Laboratories	1951
Grown junction transistor [1]	Bell Telephone Laboratories	1951
Alloy junction transistor [1]	General Electric Co., RCA Corp	1952
Surface barrier transistor [1]	Philco Corp	1954
Silicon junction transistor [1]	Texas Instruments, Inc	1954
Diffused transistor [1]	Bell Telephone Laboratories, Texas Instruments, Inc	1956
Silicon controlled rectifier [1]	General Electric Co	1956
Tunnel diode [1]	Sony (Japan)	1957
Planar transistor [1]	Fairchild Camera & Instrument Corp	1960
Epitaxial transistor [1]	Bell Telephone Laboratories	1960
Integrated circuit [1]	Texas Instruments, Inc., Fairchild Camera & Instrument Corp.	1961
MOS transistor [1]	Fairchild Camera & Instrument Corp	1962
DTL integrated circuit [2]	Signetics Corp	1962
ECL integrated circuit	Pacific (TRW)	1962
Gunn diode [1]	International Business Machines Corp	1963
Beam lead [2]	Bell Telephone Laboratories	1964
TTL integrated circuit [3]	Pacific (TRW)	1964
Light-emitting diode [3]	Texas Instruments, Inc	1964
MOSFET (MOS field effect transistor) [3]	Bell Telephone Laboratories, Philips	1968
Collector diffusion isolation [3]	Bell Telephone Laboratories	1969
Schottky TTL [3]	Texas Instruments Co	1969
Charge-coupled device [4]	Bell Telephone Laboratories, Fairchild Camera	1969
Complementary MOS [3]	RCA Corp	1969
Silicon-on-sapphire [3]	RCB Corp	1970
Ion implementation [4]	Bell Telephone Laboratories	1971

[1] John E. Tilton, International Diffusion of Technology: The Case of Semiconductors, (Washington, D.C.: The Brookings Institution, 1971), pp. 16, 17.

[2] Anthony M. Golding, "The Semiconductor Industry in Britain and the United States: A Case Study in Innovation, Growth and the Diffusion of Technology," unpublished D. Phil. Thesis (Sussex, England: University of Sussex, 1971), p. 81.

[3] William F. Finan, "The International Transfer of Technology Through U.S.-Based Firms," unpublished study (New York: National Bureau of Economic Research, October 1975), pp. 35, 36.

[4] U.S. Department of Commerce, Bureau of Domestic Commerce, Office of Business Research and Analysis, Science and Electronics Division, unpublished semiconductor study.

Source: Webbink, Douglas. "The Semiconductor Industry: A Survey of Structure, Conduct, and Performance." Bureau of Economics Staff Report to the Federal Trade Commission, January 1977.

U.S. SEMICONDUCTOR COMPANIES FOUNDED 1966–76

Company name (date founded)	City	Previous employment of founders (number of founders)	Calendar 1977 sales (millions)	Comments
American Microsystems (1966)	Cupertino	Philco-Ford (4)	$71	
National Semiconductor (1967)	Santa Clara	Fairchild (3)	426	Founded 1959, reorganized 1967.
Electronic Arrays (1967)	Mt. View	Philco-Ford (4), Bunker-Ramo (2)	14	Purchased by NEC (1978).
Intersil 1968 (1976)	Sunnyvale	Union Carbide (3)	85	Combined with AMS (1976) to form new Intersil.
Avantek (1968)	Santa Clara	Applied Technology (4)	10	
Integrated Systems Technology (1968)		Philco-Ford (3)		Purchased (1970), sold again (1972). Now part of Nitron.
Nortec Electronics Corp. (1968)	Santa Clara	Philco-Ford (2)	(1)	
Intel (1968)	do	Fairchild (3)	283	
Precision Monolithic (1969)	do	do	12	Parent Company is Bourns, Inc.
Computer Microtechnology (1968)		Fairchild (3), ITT (1)		Sold to AMS (1972).
Qualidyne (1968)	Sunnyvale	Intersil (1), Fairchild (2), Lehrer (1)		Sold to Standard Microsystems (1972).
Advanced Memory Systems (1968)	do	Fairchild (1), IBM (2), Motorola (1), Collins (1)		Merged with Intersil (1976).
Communications Transistor Corp. (1969)	San Carlos	National Semiconductor (3)	12	Affiliate of Eimac-Varian.
Monolithic Memories (1969)	Santa Clara	IBM (1)	25	
Advanced LSI Systems (1969)		Nortec (1)		Acquired by Integrated Technology Corp. (1976).
Mostek (1969)	Carrollton, Tex	TI	86	
Signetics Memory Systems (1969)	Sunnyvale	Signetics (2), IBM (2), HP (1)		Renamed Scientific Microsystems (1974).
Advanced Micro Devices (1969)	do	Fairchild (8)	82	
Four Phase (1969)	Cupertino	Fairchild (6), General Instruments (2), Mellonics (1), other (1).	89	
Litronix (1970)	do	Monsanto (1)	15	Bought by Siemens (1978).
Integrated Electronics (1970)	Mountain View, Calif	Fairchild (2)	(2)	Renamed Integrated Microsystems (1972).
Varadyne (1970)			(2)	Sold to McDonnell-Douglas. Renamed Nitron.
Caltex (1971)		TI (2), Nortec (4)		Sold to Fairchild (1975) renamed Exetron.
Exar (1971)	Sunnyvale	Signetics (3)	(2)	Private company.
Micropower (1971)	Santa Clara	Intersil (2)	(2)	Do.
Standard Microsystems (1971)	Hauppauge, N.Y	Four Phase (1)	8	
Antex (1971)		Electro-Nuclear Labs (1)		Assets sold to Litronix (1975).
LSI Systems (1972)		Nitron (1)		Purchased by Litronix.
Nitron (1972)	Cupertino			Purchased by McDonnell-Douglas.
Frontier (1972)	Newport Beach, Calif	Caltex (1)		Purchased by Commodore Ltd. (1977).
Spectronics (1969)	Richardson, Tex	TI	10	
Interdesign (1972)	Sunnyvale	Signetics (1)	(2)	Purchased by Ferranti (1977).
Synertek (1974)	Santa Clara	CMI (3), AMI (4), Fairchild (1)	19	Purchased by Honeywell (1978).
Zilog (1974)	Cupertino	Intel (2)	(2)	Owned by Exxon Enterprises.
Maruman (1975)	Sunnyvale	National Semiconductor (2)	(2)	
Supertex (1976)	do	Fairchild (1)	(2)	Private company, major holdings by Hong Kong interests.

[1] Chapter XI.
[2] Not available.

Source: Hoeffler Chart, Dataquest, Inc., WEMA 1977 Directory, annual reports

R. & D. EXPENDITURES OF LEADING INDEPENDENT U.S. SEMICONDUCTOR MANUFACTURERS, 1972–78

[Dollar amounts in millions; fiscal years]

Company	1972	1973	1974	1975	1976	1977	1978 [1]
Texas Instrument: [2]							
Dollars	154.00	185.00	198.00	183.00	187.00	195.00	
Percent of sales	16.32	14.37	12.59	13.38	11.27	9.53	
FCI: [2]							
Dollars	29.29	38.25	40.29	38.00	47.00	49.70	[3] 54.00
Percent of sales	13.08	10.89	10.47	13.03	10.60	10.80	
NSC:							
Dollars	9.80	11.70	18.70	20.72	24.85	30.71	41.83
Percent of sales	16.39	11.81	8.76	8.80	7.64	7.93	8.46
Motorola:							
Dollars	76.00	95.00	100.26	98.48	96.41	109.73	
Percent of sales	6.53	6.61	7.22	7.51	66.28	5.94	
Intel:							
Dollars	3.44	4.56	10.50	14.54	20.71	27.92	41.40
Percent of sales	14.70	6.90	7.81	10.63	9.16	9.88	10.83
Signetics:							
Dollars	3.50	6.41	7.24	(4)	(4)	(4)	(4)
Percent of sales	7.23	6.52	5.99				
AMD:							
Dollars	0.25	0.75	1.49	1.72	2.13	5.53	6.96
Percent of sales	5.39	6.71	5.62	6.64	6.20	8.90	7.54
AMI:							
Dollars	2.37	3.41	6.03	5.79	6.45	6.68	6.82
Percent of sales	8.31	5.87	8.01	8.76	9.60	9.39	8.48
Mostek:							
Dollars	1.10	2.58	4.27	4.14	3.91	4.79	
Percent of sales	6.21	6.16	7.14	8.79	6.78	5.60	
Intersil:							
Dollars	1.39	1.70	2.51	1.99	6.81	6.61	7.86
Percent of sales	10.81	5.40	4.10	3.46	9.37	8.04	7.21

[1] 1978 data is not available until annual reports are received by us.

[2] Some R. & D. is Government funded—for Texas Instruments, about 50 percent 10 percent for the period| covered in this table. For Fairchild, approximately $6,000,000 (1977) $4,000,000 (1976) and $3,000,000 (1975) was funded by outside firms or U.S. Government.

[3] Estimated.

[4] Not available. In 1975, Signetics became a part of N. A. Philips Corp.

Source: Dataquest, Inc., Company 10-K and annual reports, January 1979.

SEMICONDUCTOR INDUSTRY VALUE OF SHIPMENTS TO THE FEDERAL GOVERNMENT, 1963, 1965–73

Year	Total Industry value of shipments and receipts (millions)	Total Federal Government contracts (millions)	Federal Government contracts as a percent of total industry shipments
1963	600.3	213.1	35.5
1965	879.2	193.6	22.0
1966	1,054.6	254.4	24.1
1967	1,073.6	296.8	27.6
1968	1,189.0	273.9	23.0
1969	1,457.3	246.5	16.9
1970	1,336.7	274.9	20.6
1971	1,519.2	192.9	12.7
1972	1,912.4	228.1	11.9
1973	3,457.8	201.4	5.8

Source: Webbink, Douglas. ''The Semiconductor Industry: A Survey of Structure, Conduct and Performance,'' F.T.C. 1977 (base on U.S. Bureau of the Census, ''Current Industrial Report, Series MA–175, Shipments of Defense-Oriented Industries,'' various years).

ESTIMATED WORLD SALES OF SEMICONDUCTORS BY MAJOR INTERNATIONAL SEMICONDUCTOR FIRMS, 1972, 1974, AND 1976

Company	Country	Estimated world sales (millions)			Percent of total		
		1972 [1]	1974 [2]	1976 [2]	1972	1974	1976
Texas Instruments	United States	$405	$652	$655	11.8	13.7	11.4
Motorola	do	310	482	462	9.0	10.1	8.0
IBM	do	275	(3)	(3)	8.0		
Western Electric	do	195	(3)	(3)	5.7		
Philipps	Netherlands	175	2.77	260	5.1	5.8	4.5
Fairchild	United States	165	324	307	4.8	6.8	5.3
Toshiba	Japan	145	170	233	4.2	3.6	4.0
Hitachi	do	135	195	240	3.9	4.1	4.2
ITT	United States	95	160	144	2.8	3.4	2.5
RCA	do	80	(3)	182	2.3		3.2
Siemens	Germany	80	142	(3)	2.3	3.0	
SGS-ATES	Italy	75	78	(3)	2.2	1.6	
National Semiconductor	United States	75	204	263	2.1	4.3	4.6
Mitsubishi	Japan	70	80	94	2.0	1.7	1.6
Matsushita	do	70	150	254	2.0	3.2	4.4
General Electric	Uni ed States	60	114	113	1.7	2.1	2.0
Secosem	France	50	48	(3)	1.5	1.0	
Signetics	United States	50	121	125	1.4	2.5	2.2
Intel	do	45	115	147	1.2	2.4	2.6
Fugitsu	Japan	40	(3)	(3)	1.2		
NEC	do		120	343		2.5	6.0
Telefunken	Germany		37	(3)		.8	
General Instruments	United States		63	106		1.2	1.8
Other companies		855	1,841	1,834	24.0	34.3	31.8
Total		3,450	5,373	5,762	100.0	100.0	100.0

[1] U.S. Department of Commerce.
[2] Dataquest, Inc.
[3] Not available.

ES IMATED CONSUMPTION OF SEMICONDUCTOR COMPONENTS

[Millions]

	1973	1974	1975	1976	1977	1978
United States	$1,964	$2,266	$1,810	$2,353	$2,712	$3,262
Japan	1,156	1,276	996	1,531	1,623	1,708
Europe	1,336	1,591	1,333	1,592	1,773	2,078

Source: Dataquest, Inc., appendix A, February 1978.

ESTIMATED TRADE IN SEMICONDUCTOR COMPONENTS

[Millions]

Countries	Source	1973	1974	1975	1976	1977	1978
United States to Europe	SIA	$591	$795	$630	$756	$885	$1,149
United States to Japan	SIA	122	130	102	168	164	230
Japan to United States	MITI/DQ	20	38	56	54	85	[1] 174
Japan to Europe	MITI/DQ	[2] NA	NA	NA	NA	54	[1] 70
Europe to United States		NA	NA	NA	NA	NA	NA
Europe to Japan	MITI	NA	NA	NA	NA	44	[1] 38
United States to Japan	MITI	92	115	90	134	142	193

[1] Preminary.
[2] Not available.
Note: Semiconductor Industry Association (SIA) data is sales by U.S. firms to applicable destination, not necessarily exports. Much of U.S. sales to Europe, and some U.S. sales to Japan are produced by U.S. companies in region of buyer. Japanese exports calculated from MITI data with 47 percent adder. MITI data translated from yen at 300 yen equals $1, 1970–76; 265 yen equals $1, 1977; and 195 yen equals $1, 1978.

Source: SIA, MITI, Dataquest, Inc

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JAPANESE SEMICONDUCTOR PRODUCTION

	Value (million yen)	Percent change from previous quarter	Value (million) ($=300¥)	Percent change from previous quarter	Approximate current exchange rate [2] (yen per dollar)	Value (million) using current exchange rate	Percent change from previous quarter
1976:							
1st quarter	95, 690		$319. 0	(Same as yen)	300	$317. 9	
2d quarter	108, 651	13. 8	362. 1		298	364. 6	14. 7
3d quarter	124, 434	14. 4	414. 8		292	426. 1	16. 9
4th quarter	125, 476	. 9	418. 3		290	432. 7	1. 5
1977:							
1st quarter	123, 624	(1. 5)	412. 1		284	435. 3	. 6
2d quarter	118, 330	(4. 3)	394. 4		272	435	(. 1)
3d quarter	122, 711	3. 7	409		265	463. 1	6. 5
4th quarter	118, 177	(3. 7)	393. 9		251	470. 8	1. 7
1978:							
1st quarter	124, 334	5. 2	414. 4		230	540. 6	14. 8
2d quarter	125, 910	1. 3	419. 7		205	614. 2	13. 6
3d quarter	141, 809	12. 6	472. 7		190	764. 4	21. 5
Net change, 1st quarter 1976 to 3d quarter 1978		48. 2					134. 8

Source: MITI Dataquest, Inc., January 1978.

JAPANESE SEMICONDUCTOR PRODUCTION AND EXPORTS—1976 TO 2D QUARTER OF 1978

[All values in billion yen]

	Production	Total exports	Percent of production	Exports to United States	Percent of production
1976:					
1st quarter	95. 7	[1]	[1]	[1]	[1]
2d quarter	108. 7	[1]	[1]	[1]	[1]
3d quarter	124. 4	15. 1	12. 1	2. 7	2. 2
4th quarter	125. 5	17. 2	13. 7	3. 6	2. 9
1977:					
1st quarter	123. 6	17. 5	14. 2	3. 2	2. 6
2d quarter	118. 3	18. 7	15. 9	4. 6	3. 9
3d quarter	122. 7	18. 0	14. 7	4. 4	3. 6
4th quarter	118. 2	18. 5	15. 7	5. 2	4. 4
1978:					
1st quarter	124. 3	18. 4	14. 8	5. 3	4. 3
2d quarter	125. 9	21. 9	17. 4	5. 8	4. 6
3d quarter	141. 8	22. 2	15. 7	5. 9	4. 2

[1] Not available.

Source: MITI, Dataquest, Inc., January 1978.

TOTAL INTEGRATED CIRCUIT MARKET SHARE ESTIMATES

[Dollar amounts in millions]

Sector	1970	1971	1972	1973	1974	1975	1976	1977
U.S. companies	$625	$663	$883	$1, 459	$18. 75	$1, 559	$2, 083	$2, 577
Percent of total market	75. 6	72. 6	70. 9	73. 5	75. 2	73. 7	70. 6	72. 9
Japanese companies	$143	$153	$241	$343	$372	$343	$599	$661
Percent of total market	17. 3	16. 8	19. 9	17. 3	14. 9	16. 2	20. 3	18. 7
European companies	$53	$87	$107	$161	$210	$204	$260	$288
Percent of total market	6. 4	9. 5	8. 6	8. 1	8. 4	9. 6	8. 8	8. 1
Rest of world	$6	$10	$14	$23	$38	$10	$8	$10
Percent of total market	0. 7	1. 1	1. 1	1. 1	1. 5	0. 5	0. 3	0. 3
Total market	$827	$913	$1, 245	$1, 986	$2, 495	$2, 116	$2, 950	$3, 536

TOTAL SEMICONDUCTOR MARKET SHARE ESTIMATES

U.S. companies	$1,283	$1,373	$1,865	$2,812	$3,358	$2,783	$3,502	$4,040
Percent of total market	56.5	58.0	59.3	60.9	62.5	63.8	60.3	61.9
Japanese companies	$712	$625	$788	$1,089	$1,092	$842	$1,420	$1,538
Percent of total market	27.1	24.6	25.0	20.3	19.3	24.5	24.5	23.6
European companies	$424	$432	$481	$609	$881	$729	$873	$93.4
Percent of total market	16.1	17.0	15.3	15.0	16.4	16.7	15.0	14.3
Rest of world	$6	$10	$14	$23	$38	$10	$12	$14
Percent of total market	0.3	0.4	0.4	0.5	0.8	0.2	0.2	0.2
Total market	$2,626	$2,540	$3,148	$4,614	$5,369	$4,364	$5,807	$6,526

Source: Dataquest, Inc., February 1979.

U.S. ELECTRONIC COMPONENTS TRADE, 1970–77

[In millions of dollars]

Year	Total components	Total semiconductors	Semiconductor imports 806/807	Integrated circuits	Parts of semiconductors
1970:					
Imports	296	157	139	69	
Exports	817	417		100	167
Balance	+548	+260		+31	
1971:					
Imports	348	179	152	94	
Exports	747	370		91	152
Balance	+399	+191		−3	
1972:					
Imports	520	330	250	180	14
Exports	957	470		103	236
Balance	+437	+140		−77	+222
1973:					
Imports	877	619	410	357	8
Exports	1,670	848		218	425
Balance	+783	+229		−139	+417
1974:					
Imports	1,304	961	682	601	41
Exports	2,267	1,247		313	691
Balance	+963	+286		−288	+650
1975:					
Imports	1,160	803	617	579	31
Exports	1,987	1,053		262	622
Balance	+827	+250		−317	+631
1976:					
Imports	1,645	1,107	877	809	52
Exports	2,532	1,400		320	896
Balance	+887	+293		−489	+844
1977:					
Imports	2,018	1,352	1,120	1,020	63
Exports	2,683	1,503		348	959
Balance	+655	+151		−672	+896

Source: U.S. Bureau of the Census.

FOREIGN ACQUISITIONS IN AND MERGERS WITH U.S. SEMICONDUCTOR MANUFACTURERS, 1975 TO PRESENT

Year	U.S. company	Foreign company/country	Foreign ownership
1969	Monolithic Memories	Northern Telecom Ltd./Canada	12.4 percent.
1971	Micropower	Daima Seikosha (Seiko)/Japan	77 percent.
1972	Exar	Toyo Electronics/Japan	53 percent.
1975	Maruman	Mansei Kogyo Kabushiki Kaishi/Japan	100 percent (since reduced to 60 percent).
	Signetics	N.V. Philips/Netherlands	Merger.
1976	Supertex	Hong Kong interests	Not available.
	MOS Technology	Commodore !nternational Ltd./Bahamas.	86 percent (since increased to 100 percent).
1977	Frontier	Commodore International/Bahamas	100 percent.
	Intersil	Northern Telecom Ltd./Canada	7.5 percent (since increased to 24 percent).
	Interdesign	Ferranti Ltd./ United Kingdom	100 percent.
	American Microsystems, Inc.	Bosch/Germany	25 percent (half of interest since acquired by Borg-Warner).
	Litronix	Siemens/Germany	80 percent (since offered to. acquire remaining 20 percent)
	Advanced Micro Devices.	Siemens/Germany	20 percent.
	Solid State Scientific	VDO/Germany	25 percent.
	Siliconix	Lucas/United Kingdom	24 percent.
1978	Electronic Arrays	NEC/Japan	100 percent.
(ND)	Amperex	N.V. Philips/Netherlands	100 percent.

Source: Dataquest, Inc.

U.S. Semiconductor Industry Acquisitions and Mergers With Foreign Participation 1975 to Present

Siemens Capital Corporation, a wholly-owned subsidiary of Siemens (Germany), purchased 500,000 new shares of AMD stock for $45 each in October 1977, for an initial 17% ownership of AMD. The agreement further allowed that Siemens could increase holdings up to 20% through open market purchases. As of March 26, 1978, Capital owned 609,000 shares and a further 75,000 shares subject to a warrant held by W. J. Sanders. The 184,000 shares were purchased on the open market for $4,223,087, or $22.95 each. Total investment to date: $26,723,087.

Siemens (*Germany*) purchased 9.7M shares of newly issued Litronix stock for $0.77 each in November, 1977. The money was used to pay Litronix bank debt ($4.2M) and unsecured creditors ($3.3M) at 35¢/dollar of indebtedness. After this original acquisition of 80% of Litronix stock, in September 1978, Siemens announced plans to offer $3.625 for each of the remaining 2.4M shares, bringing Siemens total investment to $16.2M. Offer officially tendered 12/20/78 to run through 1/22/79.

NEC America, a subsidiary of NEC Japan, purchased all 1.78M shares of Electronic Arrays stock for $5.00 per share, subject to approval of shareholders. It was approved 11/29, effective 12/6/78. Total investment, $8.905M.

Robert Bosch GmbH (*Germany*) purchased 749,000 shares of authorized, but previously unissued, shares of AMI stock for $19 each in June 1977. Proceeds were used to pay bank debt and establish a cash excess. The total investment was $14.23M, or 25% ownership. Borg-Warner later acquired half of Bosch's shares.

Commodore International Ltd. (*Bahamas*) acquired 86% of MOS Technology in a stock exchange, November 1976. The traded 64,462 shares of Commodore stock plus $143,000 in notes in November 1976. In 1977, MOS Technology purchased the balance of the stock from shareholders for $66,000. Presently, MOS Technology is a subsidiary of Commodore Business Machines, Inc. (U.S. firm) which, in turn, is a subsidiary of Commodore International Ltd. (Bahama).

Sign Development Corp., a subsidiary of N.V. Philips Corporation through the U.S. Philips Corp., merged with Signetics. Each Signetics shareholder received $8.00 per share, or a total of $43.85M for 5.48M shares outstanding. Merger occurred June 1975.

Ferranti Ltd. (*Great Britain*) purchased all shares of Interdesign for about $3.5M, or greater than $4.66 per share in November 1977.

Commodore International, Ltd. (*Bahamas*) paid approximately $10M for Frontier, Inc. a Costa Mesa, CA, MOS manufacturer, shareholders and creditors, in September 1977.

Northern Telecom, Inc. Subsidiary of Northern Telecom, Ltd. (Canada) purchased 605,940 shares of Intersil for $3,973,770 from RCA (400K shares), Hales Bros. (76K shares), and approximately 130K on the open market. To this they added 20K shares of preferred stock, Series B, each convertible to 20 shares of common stock, and 30K shares at $120 each of private issue, Preferred Stock Series D, each of which was convertible to 10 shares of common stock. Total investment to date: $10,865,629 for 1,314,493 common share equivalents, or 24% of voting shares.

N.V. Philips (Netherlands) is sole owner of Amperex, Inc.

Maruman. Mansei Kogyo Kabushiki Kaishi (Japan), single investor, 1975. Total investment to date, estimated at $2.7M with eventual dilution to about 60% of ownership.

Micropower. Daima Seikosha (Japan), otherwise known as Seiko; $3,135,000, plus loan guarantees, plus an unknown amount of about $250,000; for 1,947,000 shares, or 77% ownership; July 1, 1971, initial investment ($2.1M converted to stock in 1976).

Supertex. Major holdings, percent unknown, are by Hong Kong interests. Founded in May 1976.

EXAR. 53 percent owned by Toyo Electronics (Japan). Formed in 1972. Initial Toyo investment was in loans, loan guarantees and stock with approximately $1,073,000.

Solid State Scientific. VDO (Germany), purchased in (1977) 264,200 shares at $8.50 and $2,301,800, 7 years, 7½, convertibles (at $8.50). (Total $4.5M and 25% ownership.)

Siliconix. Lucas (GB) purchased 465,898 shares (24%) for an estimated $13 share, or $6.1M.

Monolithic Memories. Founded 1969 with Northern Telecom owning 12.4% interest. Investment believed to be about $285,000.

Amdahl. Fujitsu owns 29.4%, plus manufacturing agreements, joint ownership, plus short-term loans, maintenance guarantees, etc. 1,768,750 totals·

1972—10,000 shares, at $0.06/share, or $600.00 total.
1972—Convertibles, $5,000,000 at $16.67.
1972—310,000 shares, $6,200,000.
1974—$7,100,000 loans.
1975—$11,487,500, 9 percent convertibles.
1976—1,448,750 shares at $27.50; or $39,840,625.

Nixdorf (Germany) also purchased 300,000 shares (1972) for $6,000,000; this currently constitutes about 5% of total shares outstanding.

Source: DATAQUEST, Inc. January, 1979.

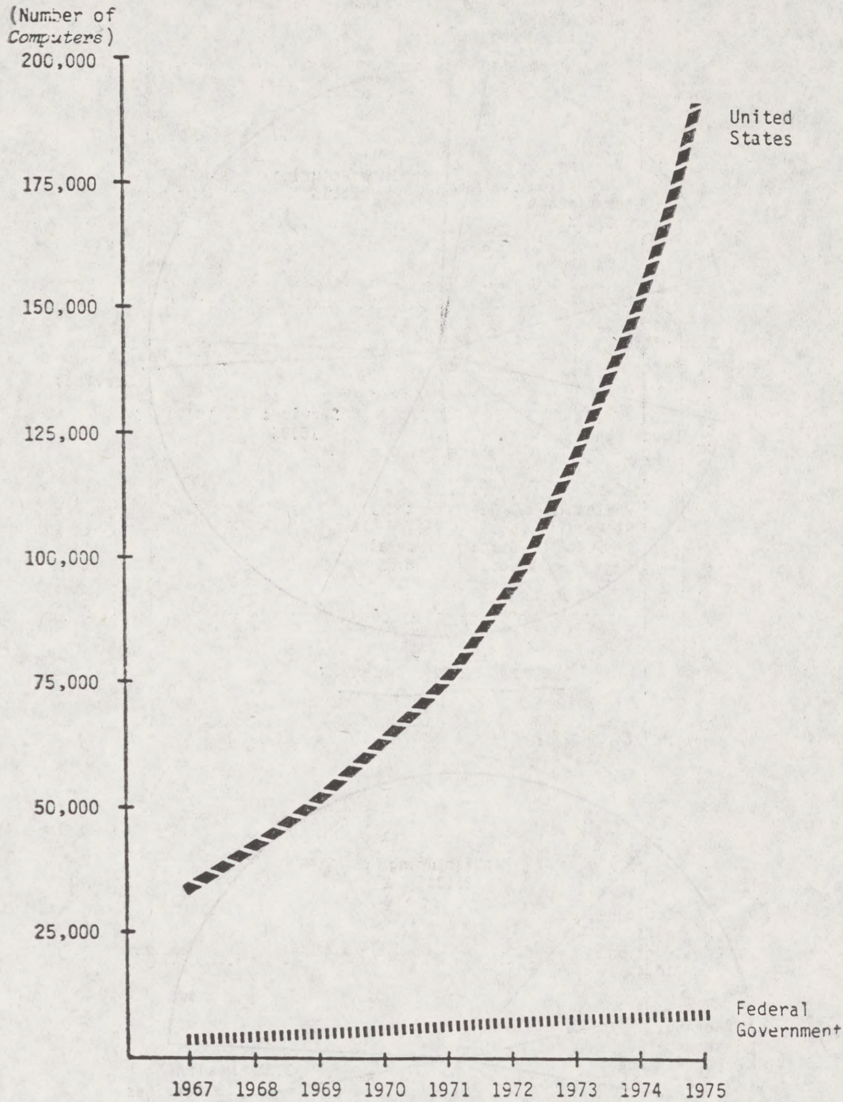
R. & D. EXPENDITURES OF LEADING U.S. COMPUTER MANUFACTURERS, 1976–77

Company	Sales			Profits		Research and development expense				
	1977 millions of dollars	Percent change from 1976	Percent average annual change	1977 millions of dollars	Percent average annual change	1977 millions of dollars	Percent change from 1976	Percent of sales	Percent of profits	Dollars per employee
Amdahl	189	103.4	(1)	27	(1)	16.7	78.9	8.8	62.6	8,679
Applied Digital Data Systems	32	35.5	67.4	5	91.2	.6	37.7	1.8	10.7	1,180
Applied Magnetics	67	5.7	6.1	−4	(1)	2.8	17.9	4.2	−78.9	1,013
Burroughs	2,091	11.8	13.0	215	18.7	122.4	13.4	5.9	56.9	2,386
California Computer Products	117	3.2	7.2	−2	(1)	8.6	−15.0	7.3	−451.9	3,512
Centronics Data Computer	57	10.4	21.4	13	23.1	3.6	27.8	6.4	29.0	2,703
Control Data	1,493	12.2	12.1	62	1.4	73.1	24.3	4.9	117.2	1,592
Data General	255	42.5	42.8	29	43.0	26.1	41.8	10.2	91.2	3,033
Datapoint	103	43.0	51.7	8	62.4	6.4	58.6	6.2	75.8	2,325
Dataproducts	115	35.5	18.5	12	51.1	7.9	68.1	6.9	64.8	2,394
Digital Equipment	1,059	43.8	39.4	109	42.8	79.7	36.5	7.5	73.5	2,218
Electronic Associates	26	11.6	−8.6	0	−65.1	.9	−56.4	3.4	6,471.4	1,262
Electronic Memories & Magnetics	109	19.0	−1.3	5	10.5	6.8	45.0	6.3	145.3	1,668
General Automation	84	19.4	24.4	1	(1)	5.1	7.1	6.1	353.9	2,584
Honeywell	2,911	16.7	8.3	134	12.6	152.3	21.3	5.2	113.4	2,009
IBM	18,133	11.2	13.3	2,719	14.5	1,142.0	12.8	6.3	42.0	3,682
Memorex	450	30.6	26.2	34	(1)	19.2	37.8	4.3	56.4	2,178
Mohawk Data Sciences	146	−9.7	0	3	(1)	5.1	16.3	3.5	191.4	1,365
NCR	2,522	9.0	8.5	144	15.2	118.1	25.3	4.7	82.2	1,845
Pertec Computer	95	96.9	40.5	5	21.2	7.3	121.3	7.7	156.0	3,487
Sperry Rand	3,270	2.1	10.2	157	16.0	168.3	5.9	5.1	107.3	1,965
Storage Technology	162	33.3	28.0	11	25.6	9.2	17.0	5.6	80.1	2,296
Systems Engineering Laboratories	31	53.8	15.8	1	(1)	3.7	64.0	12.1	550.4	4,917
Telex	112	10.3	12.5	3	(1)	2.8	31.1	2.5	86.2	891
Wang Laboratories	134	38.7	28.4	9	25.6	6.6	53.6	4.9	71.8	2,047
Industry composite	33,764	12.5	12.9	03,70	15.5	1,995.4	16.3	5.9	53.9	2,752

[1] Not available.

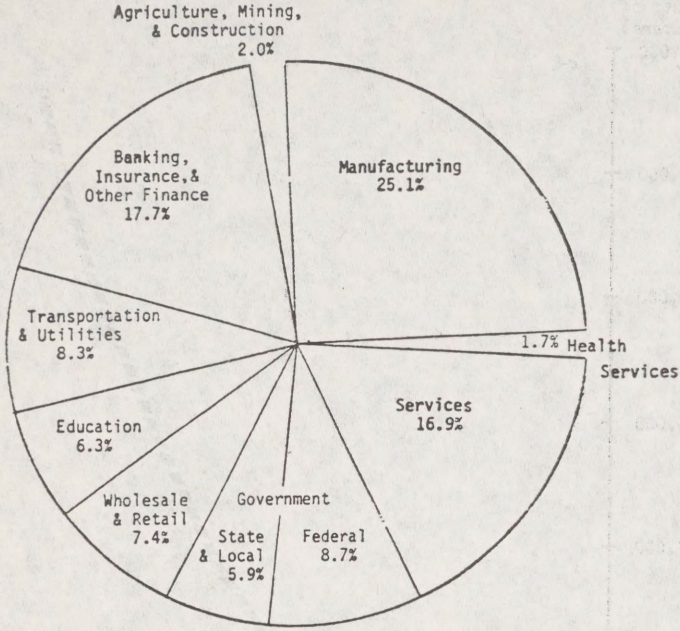
Source: McGraw-Hill, Inc., Business Week, July 3, 1978, p. 63.

Cumulative Number of Computers in Federal Government and United States (Installed Base Number); 1967–75

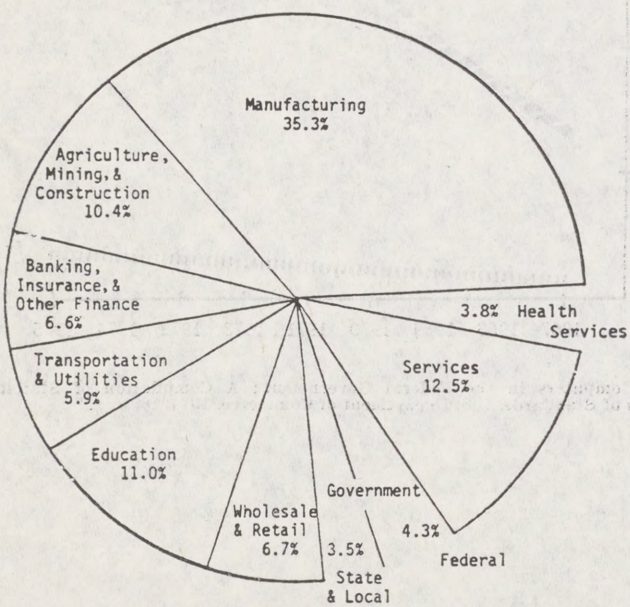


Source: "Computers in the Federal Government: A Compilation of Statistics," National Bureau of Standards, U.S. Department of Commerce, 1977.

Distribution of General-Purpose Computers and Minicomputers by Industry and Government (Percent Installed Base Value); United States, 1975



GENERAL-PURPOSE COMPUTERS



MINICOMPUTERS

Source: American Federation of Information Processing Societies, Inc. (Based on data supplied by International Data Corp., 1977.)

WORLDWIDE REVENUES OF LEADING U.S. DATA PROCESSING COMPANIES, 1974–76

[Dollar amounts in millions]

		Estimates for 1976			Reported data				
Rank	Company	DP revenues	DP revenues (percent of total revenues)	U.S. DP revenues (percent of total DP revenues)	1974 total revenues	1975 total revenues	1976 total revenues	1976 net income or (loss)	Number of employees
1	International Business Machines	$12,717	78.0	50	$12,675	$14,437	$16,304	$2,398	291,977
2	Burroughs	1,630	86.0	57	1,533	1,702	1,902	186	49,884
3	Sperry Rand	1,430	45.0	58	2,613	3,041	3,202	145	87,090
4	Honeywell	[1] 1,428	[1] 47.0	[1] 45	2,626	2,760	[1] 3,009	113	70,775
5	Control Data	1,331	98.0	66	1,101	1,246	1,358	13	41,553
6	NCR	1,100	48.0	51	1,979	2,166	2,313	96	67,000
7	Digital Equipment	736	100.0	62	422	534	736	73	25,000
8	Hewlett-Packard	335	30.0	52	884	981	1,112	91	32,200
9	Memorex	310	90.0	58	218	264	345	40	6,800
10	TRW	295	10.0	90	2,486	2,586	2,929	133	87,625
11	3M	211	6.0	80	2,937	3,127	3,514	339	78,500
12	Itel	189	73.0	90	144	204	260	16	2,800
13	General Electric	185	1.0	80	13,918	14,105	15,697	931	380,000
14	Automatic Data Processing	178	95.0	90	112	155	188	18	6,500
15	Computer Sciences	165	75.0	81	147	177	220	7	7,200
16	Mohawk Data Sciences	162	100.0	43	168	170	162	14	3,800
17	Data General	161	100.0	59	83	108	161	19	5,780
18	Electronic Data Systems	133	100.0	95	114	119	133	14	3,942
19	Management Assistance	123	100.0	60	77	94	123	13	2,600
20	Storage Technology	122	100.0	75	75	99	122	8	2,161
21	Data 100	120	98.0	67	70	96	122	6	2,873
22	Xerox	120	3.0	100	3,505	4,054	4,404	359	97,336
23	California Computer Products	116	96.0	76	130	123	121	(4)	2,800
24	Ampex	115	45.0	53	272	242	255	8	10,000
25	Bunker Ramo	107	34.0	90	314	289	316	8	9,448
26	Amdahl	93	100.0	75	(2)	14	93	23	777
27	Harris	92	18.0	90	437	479	514	27	12,600

28	Teletype	90	50.0	90	[2]	[3] 157	[3] 180	[2]	[3] 3,300
29	System Development	85	77.0	95	90	109	110	2	3,600
30	General Instrument	84	22.0	80	404	401	376	7	22,800
31	Tymshare	82	100.0	85	46	56	82	7	1,600
32	Wang Laboratories	82	85.0	55	64	76	97	6	2,600
33	McDonnell Douglas	77	2.0	100	3,075	3,255	3,543	109	63,000
34	Dataproducts	75	88.0	75	69	86	85	7	2,928
35	Telex	75	71.0	74	90	106	106	4	2,350
36	Raytheon	74	3.0	80	1,929	2,245	2,463	85	52,600
37	Perkin-Elmer	73	21.0	75	272	297	349	20	9,600
38	General Automation	71	100.0	70	61	56	71	(1)	1,500
39	Datapoint	68	94.0	54	34	47	72	6	1,921
40	Sycor	67	100.0	56	40	55	67	5	1,508
41	Texas Instruments	66	4.0	90	1,572	1,368	1,659	97	66,162
42	GTE	65	1.0	95	5,661	5,948	6,751	453	187,000
43	Four-Phase Systems	63	100.0	80	36	50	63	7	1,158
44	Inforex	63	100.0	44	52	57	63	3	1,400
45	Tektronix	62	17.0	59	271	337	367	30	12,970
46	Wyly	62	97.0	47	88	65	64	(71)	1,700
47	Recognition Equipment	60	92.0	75	43	59	65	6	1,967
48	Informatics	59	100.0	93	33	39	59	[2]	1,900
49	Electronic Memories & Magnetics	58	63.0	90	111	92	92	9	3,600
50	Boeing	55	1.4	95	3,731	3,719	3,918	103	62,600

[1] Includes CII–HB; other figures do not.
[2] Not available.
[3] Estimate.

Source: Oscar H. Rothenbuecher, Arthur D. Little, Inc., in Datamation, June 1977

U.S. EXPORTS OF ELECTRONIC COMPUTING EQUIPMENT [1] TO PRINCIPAL FOREIGN MARKETS, 1970–78

[In thousands of dollars]

	1970	1971	1972	1972	1974	1975	1976	1977	1978 [2]
Total exports	1, 236, 519. 5	1, 262, 473. 8	1, 340, 651. 5	1, 716, 613. 2	2, 198, 261	2, 228, 454	2, 587, 513	3, 263, 884	3, 973, 631
By countries:									
Canada	149, 048	191, 063	225, 818	253, 608	309, 641	320, 447	407, 621	475, 354	519, 138
West Germany	189, 642	202, 219	196, 622	215, 307	264, 642	275, 072	292, 587	353, 756	493, 625
United Kingdom	183, 634	148, 271	133, 485	216, 063	286, 801	271, 216	305, 335	408, 355	536, 780
France	130, 816	147, 080	161, 173	195, 342	235, 641	223, 723	273, 255	317, 320	371, 812
Japan	168, 417	140, 154	148, 692	208, 546	244, 085	189, 310	239, 457	279, 464	307, 059
Australia	30, 422	29, 458	33, 192	50, 109	84, 065	88, 953	102, 870	140, 914	166, 665

[1] Includes parts and accessories for electronic computers, not elsewhere classified.
[2] Annual estimate based on 10 month's data.

Source: U.S. Bureau of the Census, FT 410, Schedule B, U.S. Exports, Commodity by Country (SIC 3573).

U.S. IMPORTS OF ELECTRONIC COMPUTING EQUIPMENT [1] AND PRINCIPAL SUPPLIERS, 1970–78

	1970		1971		1972		1973		1974		1975		1976		1977		1978 [2]	
	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)	Value	U.S. import share (percent)
Total Imports	$60, 408	100	$118, 634	100	$173, 786	100	$110, 128	100	$115, 073	100	$128, 552	100	$234, 729	100	$252, 911	100	$353, 486	100
By country:																		
1. Canada	38, 558	64	86, 956	73	134, 142	77	67, 015	61	53, 181	46	62, 215	48	112, 497	48	77, 301	31	116, 380	33
2. France	1, 528	3	4, 864	4	7, 153	4	12, 989	12	17, 538	15	21, 881	17	24, 114	10	61, 716	24	67, 830	19
3. West Germany	3, 014	5	1, 309	1	4, 291	2	5, 654	5	26, 122	23	19, 397	15	25, 569	11	9, 304	4	16, 267	5
4. Italy	4, 775	8	6, 174	5	12, 479	7	6, 499	6	6, 877	6	10, 857	8	18, 943	8	18, 756	7	18, 472	5
5. United Kingdom	3, 822	6	5, 242	4	5, 283	3	4, 266	4	3, 452	3	6, 213	5	5, 483	2	10, 546	4	11, 955	3
6. Japan	1, 449	2	1, 044	1	1, 418	1	3, 148	3	1, 783	2	3, 225	3	41, 732	18	57, 971	23	101, 500	29

Source: U.S. Bureau of the Census, FT 246, TSUSA, U.S. Imports, Commodity by Country. (SIC 3573).

[1] Does not include parts for electronic computers which are contained in the aggregate parts category, TSUSA No. 676.5200, other parts for office machines, except typewriters.
[2] Annual estimate based on 10 month's data.

U.S. FOREIGN TRADE IN COMPUTERS AND RELATED EQUIPMENT, 1967–78

[Dollars in millions]

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978(E)
Exports: Indcluding parts	$475	$530	$786	$1, 237	$1, 262	$1, 341	$1, 717	$2, 198	$2, 228	$2, 588	$3, 264	$3, 974
Imports:												
Excluding parts	20	18	37	60	119	174	110	115	129	235	253	353
Including parts												710
Balance of trade	455	512	749	1, 177	1, 144	1, 167	1, 606	2, 083	2, 100	2, 353	3, 011	[1] 3, 620 [2] 3, 262
Domestic shipments	4, 049	4, 278	5, 213	5, 671	5, 169	6, 108	7, 085	8, 668	8, 443	10, 134	12, 550	15, 100
Apparent consumption	3, 594	3, 767	4, 464	4, 495	4, 025	4, 941	5, 478	6, 585	6, 343	7, 781	9, 539	[1] 11, 479 [2] 11, 836
Exports as percent of shipments	12	12	15	22	24	22	24	25	26	26	26	26
Imports as percent of apparent consumption	1	1	1	1	3	4	2	2	2	3	3	[1] 3 [2] 6

[1] Excluding parts imports.
[2] Including parts imports.

E = Estimate by Bureau of Domestic Business Development, Department of Commerce.

Source: U.S. Bureau of the Census.

SUMMARY OF PREVIOUS HEARINGS

[From the Congressional Research Service, Library of Congress, Report No. 78-204 SPR-Oct. 13, 1978]

INDUSTRIAL INNOVATION AND ITS RELATION TO THE U.S. DOMESTIC ECONOMY AND INTERNATIONAL TRADE COMPETITIVENESS

(By Mary Ellen Mogee, Analyst in Science and Technology, Science Policy Research Division)

SUMMARY

This report summarizes and analyses testimony and submissions made during hearings on the subject of industrial innovation and its relation to the U.S. domestic economy and international trade competitiveness. It reviews problems, explanations, and recommendations with respect to the subject, as well as Government policies that may inhibit industrial innovation.

PREFACE

This report on industrial innovation and its relation to the U.S. domestic economy and international trade competitiveness was prepared at the request of the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation. It summarizes and analyzes hearings held by subcommittees of the Committee on Commerce, Science, and Transportation; the Committee on Banking, Housing, and Urban Affairs; and the House Committee on Science and Technology, on February 14, April 26, and May 16, 1978. The report reviews problems, explanations, and recommendations with respect to the subject, as well as Government policies that may inhibit industrial innovation.

Because of the broad scope and complexity of the issues and the uncertainties expressed by witnesses concerning remedial actions, the Senate Committee on Commerce, Science, and Transportation has decided to hold additional hearings on a narrower range of innovation-related issues. Since it was considered to be useful in preparation for the forthcoming hearings, this report has been reproduced by CRS; subsequent publication by the requesting committee is planned after the hearings.

The report was prepared by Mary Ellen Mogee, Analyst in Science and Technology. It was reviewed by Dorothy M. Bates, Specialist in Science and Technology, and Walter A. Hahn, Senior Specialist in Science, Technology, and Futures Research.

CHARLES S. SHELDON, II,
Chief, Science Policy Research Division.

INTRODUCTION

The Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation held three days of hearings on industrial innovation and its bearing on the domestic economy and U.S. international trade competitiveness on February 14,[1] April 26,[2] and May 16,[3] 1978. The February 14 and May 16 hearings were held jointly, the former with the Subcommittee on Science, Research and Technology of the House Committee on Science and Technology, and the latter with the Subcommittee on International Finance of the Senate Committee on Banking, Housing and Urban Affairs. Senator Stevenson opened the hearings by reviewing statistics from "Science Indicators 1976" that have been cited as evidence that the innovative capability of United States indus-

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[1] U.S. Congress. Senate. Committee on Commerce. Science, and Transportation. Subcommittee on Science, Technology, and Space, and U.S. Congress. House. Committee on Science and Technology. Subcommittee on Science. Research, and Technology. Oversight of Science and Technology Policy, Part 1. Joint Hearings, 95th Congress, 2d session on oversight of the National Sience and Technology Policy, Organization, and Priorities Act of 1976. February 14, 1978. Washington, U.S. Govt. Print. Off., 1978.

[2] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. Oversight of science and technology policy, Part 2. Hearings on oversight of the National Science and Technology Policy, Organization, and Priorities Act of 1976. February 10 and April 26, 1978. Washington, U.S. Govt. Print. Off., 1978.

[3] U.S. Congress. Senate. Committee on Banking, Housing, and Urban Affairs. Subcommittee on International Finance, and Committee on Commerce, Sciece and Transportation. Subcommittee on Science, Technology, and Space. Export Policy, Part 7. Joint Hearings. 95th Congress, 2d session on oversight on U.S. high technology exports. May 16, 1978. Washington, U.S. Govt. Print. Off., 1978.

try is declining with potentially unfavorable effects on U.S. economic growth and its international trade position. The statistics cited were the following:

> * * * Since 1963 the United States has spent a steadily declining percentage of its GNP on research and development, down from nearly 3 percent to 2.2 percent. Japan, West Germany, and the Soviet Union recorded significant growth in the proportion of their GNP devoted to R&D.
>
> Foreign patents in the United States increased 91 percent between 1966 and 1976 to the point where patents of foreign origin represent 35 percent of all U.S. patents and are distributed across a wide range of subjects. The United States now has a negative patent balance with both Germany and Japan.
>
> The United States' share of major technological innovations fell from 80 percent in the mid 1950's to 60 percent in the mid 1970's. In output per manhour, the U.S. productivity gain between 1960 and 1976 was smaller than that of Japan, Germany, Canada, France, and Britain.[4]

The purpose of the hearings was to define more clearly the nature of the problems existing with regard to industrial innovation, economic growth and international trade, and to explore the role of the Federal Government if Federal action appears to be warranted.

In the course of the hearings, the Subcommittee heard from Commerce and Treasury Department officials, industrial research and development (R&D) directors, academics, economic consultants, a former Office of Technology Assessment (OTA) assistant director, and officers of scientific and engineering professional associations. The witnesses whose testimony is analyzed in this report are listed below:

February 14, 1978. Oversight of Science and Technology Policy, Part I.

- Dr. Jordan J. Baruch, Assistant Secretary of Commerce for Science and Technology, Department of Commerce.
- Dr. N. Bruce Hannay, Vice President for Research and Patents, Bell Telephone Laboratories.
- Stanley Ruttenberg, Ruttenberg, Friedman, Kilgallon, Gutchess & Associates, Inc.
- Dr. Bela Gold, Professor of Industrial Economics, Case Western Reserve University.
- Dr. Lewis M. Branscomb, Chief Scientist and Vice President, IBM Corporation.

April 26, 1978. Federal R&D Budget.

- William D. Carey, Executive Officer, American Association for the Advancement of Science.
- Dr. Richard L. Garwin, IBM Thomas J. Watson Research Center.
- Ellis R. Mottur, 6500 Tall Tree Terrace, Rockville, Md.
- Dr. Bruce L. R. Smith, Department of Political Science, Columbia University.
- Charles F. Horn, Mayor, Kettering, Ohio.

May 16, 1978. Oversight on U.S. High-Technology Exports.

- Dr. Jack Baranson, President, Developing World Industry and Technology, Inc.
- Dr. Lawrence G. Franko, Director, Project on American Policy and European Economic Interests, Carnegie Endowment for International Peace, and Adjunct Professor of International Business Diplomacy, Georgetown University.
- H. Eugene Douglas, Memorex Corporation.
- Dr. Klaus P. Heiss, President, ECON, Inc.
- Dr. Gary Hufbauer, Deputy Assistant Secretary of the Department of Treasury.
- Dr. Edwin Mansfield, University of Pennsylvania.
- Dr. Lowell W. Steele, Manager of Research and Development Planning, Corporate Research and Development, the General Electric Company.
- Dr. Bruno O. Weinschell, Vice President, Professional Activities, The Institute of Electrical and Electronics Engineers, Inc.

This report is intended to facilitate further consideration of the issues by summarizing and analyzing testimony and submissions made to the hearings. The materials are presented in a manner that brings out the areas of both consensus and disagreement and points out areas where our understanding of the

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[4] Oversight of Science and Technology Policy, Part I, p. 3.

problem is weak. The report is limited to materials presented during the hearings and hence is not a comprehensive treatise on the subject of U.S. R&D and industrial innovation, although a broad range of innovation-related problems and a variety of viewpoints are covered. Heavy reliance is placed on quotations from the witnesses in order to capture the flavor of the hearings and to document the ideas expressed.

The problems discussed by the witnesses fell into three broad categories:

1. U.S. Research and Development (R&D) and Industrial Innovation;
2. U.S. Economic Growth and Productivity; and
3. U.S. Competitiveness in International Trade.

Each major subject area is treated uniformly by addressing the following questions:

1. What is the nature of the problems?
2. What are the causes or explanations for the problems?
3. What are the areas of conflicting or inconsistent knowledge or opinion?

In addition one section of the report covers Government policies that witnesses said may inhibit industrial innovation. Another section reviews recommendations for Federal action made by the witnesses.

To the extent possible, a distinction is made between R&D and industrial innovation. Research and development activities are parts of the larger process of innovation whereby ideas are brought into reality and introduced into the market in the form of new or improved products, processes, or services. However, R&D funding is often used as an indicator of the level of innovative activity, in the absence of better measures, and much of the discussion at the hearings was in terms of R&D statistics.

U.S. R&D AND INDUSTRIAL INNOVATION

In a sense R&D and industrial innovation may be said to be a root problem of the three problem areas—R&D and industrial innovation, economic growth and productivity, and international trade competitiveness. Although many witnesses acknowledged that there is probably some circularity of causation among the three problems, most of them emphasized R&D and innovation as keys to the solution of economic problems. In their view, the United States is experiencing a slow-down in the rate of R&D spending and innovative activity and an increasing emphasis on short-term, incremental improvements, as opposed to major innovations, that may have serious consequences for the U.S. domestic economy and its international trade position.

Some witnesses, such as Jack Baranson and Klaus Heiss, were primarily concerned with the U.S. international trade position and the pressures the Nation is beginning to feel from some of its primary trade competitors, such as Japan and West Germany. The concerns of others were closer to home. Bela Gold stated:

> We . . . have a real problem in terms of developing our technological capabilities. I think the real problem is to understand that it arises not from the limited pressures which we still feel from overseas. Rather, it arises from some of the very real needs we have in this country: to more effectively utilize resources that we are running short of; to keep raising standards of living; to reduce the threats to health and safety; and to improve our achievement of other major social goals. (I, 31)[5]

In a similar vein, Ellis Mottur stated:

> A particularly telling indicator is our failure as a nation to develop and adopt successful innovations in areas of maximum public need such as energy conservation, water purification, solid waste disposal, air pollution control, mass transit, health care delivery, public safety, and urban and rural community development. (II, 223)

R&D spending level

The Problem.—There was agreement among the witnesses that total funding for industrial R&D has barely kept up with inflation for the last ten years. Increases in private industry funding of R&D have largely been offset by decreases in Federal funding of industrial R&D. The problem thus appears to be the decrease in Federal funding for industrial R&D and the resulting slow growth of total industrial R&D.

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[5] Reference to quoted material are in the form (I, 1) where Roman numerals I, II, III refer to the hearings on February 14, April 26, and May 16, respectively, and the Arabic numeral refers to page number.

Jordan Baruch stated:

> We see some signs of our decline in that the average constant dollar investment in R&D by industry has increased by less than two-tenths of a percent per year from 1967 to 1977. (I, 5)

William Carey stated:

> In current dollars, [Federal] R&D spending appears to be rising rapidly. But in the more realistic constant dollars, adjusted for inflation, R&D budget authority in 1979 is only 1 percent over 1978, only 6 percent over 1972, and 16 percent below 1967. . . . In the 1979 budget as a whole, R&D is only 5.7 percent of total outlays. . . . (II, 186)

In Gary Hufbauer's view:

> Total industrial R&D spending, that is, spending by both the Federal Government and business on R&D performed within industry, has barely kept up with inflation. Measured in constant 1972 dollars, this spending has hovered within the range of $19 to $21 billion during the last ten years.
>
> Much of this stagnation in total real industrial R&D has been accounted for by a shrinkage in federally-funded R&D, which declined in every year but one between 1966 and 1975, averaging a 5.5 percent yearly drop. However, industry's own funding for R&D, which now accounts for two-thirds of total industrial research, increased in real terms in every year except two since 1966, averaging a 3.8 percent annual real gain over that period. Preliminary figures suggest that real increases accelerated in 1976 and 1977, averaging a 5.3 percent annual rise.
>
> I find the solid gains in industry-funded R&D encouraging, and I would contrast them with the generally somber pronouncements made about R&D trends in the United States. (III, 7–8)

Lawrence Franko described a "dramatic decline in the U.S. Government-funded R&D from its heights in the late 1960's to current levels." (III, 250) He pointed out that R&D expenditures by the private sector had remained relatively constant as a proportion of U.S. Gross National Product. Thus, he said, the overall U.S. decline was caused by a change in Government policy.

Klaus Heiss testified that Federal funding for defense and space R&D declined in the 1970s, in constant 1972 dollars, while it increased in civilian R&D, and that the total (defense, space, and civilian R&D) also declined. He argued that the changes in relative priority were in the wrong direction.

Some witnesses referred to declines in the ratio of R&D spending to the Gross National Product (GNP) since the late 1960s, using this as a measure of relative emphasis on R&D. Stanley Ruttenberg said that the percent of GNP spent on R&D has declined in the last decade from 3 percent to about 2 percent. Gary Hufbauer noted that industrial R&D spending as a percentage of GNP declined from 2 percent in 1967 to 1.6 percent in 1977. William Carey said that R&D as a percent of Federal outlays and GNP is down some 45 percent since 1967. Klaus Heiss noted that in terms of R&D/GNP there has been a 50 percent cutback in defense, a threefold cutback in space, and a 50 percent increase in civilian R&D.

On the other hand, Gary Hufbauer contended that the ratio of R&D spending to GNP is misleading as an indicator of U.S. performance in industrial growth and productivity. The composition of GNP has shifted over the last twenty years away from the manufacturing sector, where a major portion of federally-funded and enterprise-funded R&D is performed, toward the service sector, where relatively little R&D is undertaken.

Richard Garwin pointed out that increases have occurred in manpower and research costs since the late 1960s. For basic research, he estimated that we would have the same level of effective work per person only with a budget about three times as large as we have now.

Recent concern about U.S. R&D and industrial innovation has been based largely on the belief that R&D and innovation contribute significantly to economic growth and international trade competitiveness. The relationship between R&D innovation and economic growth and international trade competitiveness will be discussed in more detail in a later section of this report. It is important to note in the present context, however, that the relationship is not a simple one. William Carey noted the difficulty of tracing the benefits of R&D spending:

> We are exceedingly weak . . . in any accounting of the benefits of the R&D, of what has happened, of what has been yielded from this effort year after year, now at a very impressive level of about $30 billion annually. (II, 201)

Gary Hufbauer stated:

> Taken as a whole, then, the various measures do suggest that in the past decade overall R&D effort in industry for the United States has been

sluggish, except for industry's own R&D financing, and that governments and firms abroad have raised their own levels of R&D activity. Yet these developments on their own do not automatically support a conclusion that the U.S. economy is weakening or that our trade position will deteriorate. (III, 10)

Explanations.—Some of the witnesses offered general explanations for why, at any time, private investment in R&D is likely to be less than optimum, from the point of view of society as a whole. Gary Hufbauer said that the private entrepreneur can ordinarily expect to recapture less than half of the benefits of his research, which leads to underfunding by the private sector of R&D and particularly of high-risk projects. Richard Garwin pointed out that development which results in a specific product can usually be protected by a patent for a period of seventeen years—often long enough to repay the investment and to provide a spur to innovation. Exploratory development, applied research, and basic research are less attractive because their fruits can benefit competitors almost as well as the firm which supports the research.

Other explanations were given for the changes occurring in R&D funding and direction at the present time. These explanations hinged on four variables: 1) a slowed rate of economic expansion, 2) increased economic uncertainty, 3) changing Government priorities, and 4) Government policies that create a net disincentive to industrial R&D and innovation.

Bela Gold stressed the effects of a slowing economy. He said that in the United States steel industry not enough expansion or new plant construction is going on to allow the installation of new technology that has already been developed. Eventually this inability to use the new technology seeps down and inhibits R&D.

Lawrence Franko said that the lack of a clear, deterministic link between R&D expenditures and new products or processes, makes R&D one of the first things to be sacrified by management in times of economic downturns or uncertainty.

Bruce Hannay testified that there are increasing uncertainties in industrial research and that many companies feel there are decreasing incentives for innovation. According to him, reasons for this include, "not only the economic climate, but also all the incentives and the barriers that are intentionally or unintentionally supplied by a range of government activities and interventions in the process of translating science into application." (I, 19)

Klaus Heiss and Gary Hufbauer mentioned the change in Government R&D priorities since the late 1960s. The decline in Federal R&D funding coincides with the phase-down of the large defense and space efforts associated with the Viet Nam war and the Apollo Project. Federal priorities have shifted toward civilian R&D, but the increases in civilian R&D funding have not made up for the large decreases in defense and space.

Decline in the U.S. Rate of Industrial Innovation

The Problem.—R&D is only one part of the process of industrial innovation which, when conditions are right, results in the introduction of new and improved products, processes and services into commercial markets. The use of R&D funding as a measure of technological innovation is unsatisfactory for a number of reasons, including the fact that R&D is an input measure rather than an output measure. Not all R&D results in successful new products; in fact, most R&D projects are dropped before they reach the market. The financial returns to R&D come from the few projects that do succeed. Moreover, not all new or improved products and processes arise from laboratory R&D. Some result from relative minor design changes or routine engineering improvements.

In terms of impact on the economy and international trade, it would be desirable to measure the rate of innovation or the number and significance of new products and processes. However, the concept of industrial innovation is not well defined and widely accepted measures are not available. Some witnesses at the hearings referred to a decline in the U.S. rate of industrial innovation, but were able to offer few statistics to support their statements due to these difficulties. Jordan Baruch referred to "the apparent decline of our innovation rate in the private sector." (I, 5)

Bruce Hannay testified:

> "In my view—and many share this—there has been a serious decline in our capacity for innovation. . . . There are increasing uncertainties in industrial research, and many companies feel that there are decreasing incentives for innovation. And I believe that it is a matter of national necessity to strengthen the U.S. innovative capacity." (I, 14)

Ellis Mottur stated:

"The problem . . . is that this complex process of innovation is not currently occurring as effectively as it could in our country. Some infer this from our relative decline in patents, our low increase in productivity in recent years, or our worsening competitive position with countries such as Japan or West Germany." (II, 223)

Explanations.—The explanations given for the posited declining rate of U.S. industrial innovation were very similar to those given for the perceived decline in R&D spending.

Jordan Baruch said that economic theory predicts that industry will tend to underinvest in innovation in terms of the benefits to society as a whole. Lowell Steele argued that inflation has undesirable effects on innovation. He said:

Innovation is inherently risky and the addition of uncertainties regarding future costs resulting from inflation adds further critical dimensions to business planning that leads to shorter time horizons, heavier discounts on the future, and a focus on lower risk projects. (III, 119)

On the other hand, Richard Garwin thought that inflation should not necessarily deter investment in R&D or innovation. He reasoned that:

The fruits of R&D will be worth more in money in future years than they would have in the absence of inflation. Thus, the inflation-free discount rate is appropriate for comparing present costs and products with the ones that could flow from the R&D under consideration. (II, 189)

William Carey pointed to Government policy as a primary cause of the decline in innovation. In his opinion, U.S. industry still has the capacity to innovate, but the capacity is being constrained. If the constraints can be removed the capacity will begin to exercise itself again. He said part of the problem "is that nobody has been in charge of the question of technology and its vitality." (II, 242)

An example of Government constraints on innovation was provided by Bruce Hannay, who referred to new drug applications, which have declined by a factor of four in the last twenty years. He said the decline was not due to a shortage of ideas in the drug industry for new pharmacologically active substances, but rather to increased governmental regulation in that industry.

Change in the Quality of Innovation

The Problem.—In addition to the problems of funding of R&D and the rate of innovation, witnesses warned that the quality of innovations coming out of U.S. industry is deteriorating. R&D and innovation are being turned in the direction of short-term, incremental changes and away from long-term, major changes. This may have serious effects on future economic growth.

Bruce Hannay discussed this problem in detail. He distinguished incremental or "nuts and bolts" innovation from more "fundamental" innovation. According to Hannay, "nuts and bolts" innovation is valuable, but largely aimed at process improvements to reduce costs. "Fundamental" innovation, which results from major technological advances, is the source of major economic and social benefits. As examples of fundamental innovation, Hannay cited the transistor, synthetic fibers, antibiotics, Xerography, the digital computer, the Polaroid process, and the laser. He stated:

The central issue is the decline of the U.S. industrial research capacity for this sort of fundamental innovation. Important innovations for the civilian sector often come as the result of a commitment of R&D in which the reward comes in the long-term. But only a few companies in a few industries are willing to take the long-term view. I am happy to say that my own company is probably the leading example of that today. But in much of the industry, the R&D is directed to short-term goals.

Thus, even though the figures show that industry funding of R&D is substantial and growing, the commitment to fundamental innovation is absent or has declined in broad segments of industry. . . .

Not many of our industrial contemporaries are talking about exciting, new major discoveries that they think will change the world. The outlook has become more focused on defensive activities. (I, 15)

Other witnesses made similar comments. Jordan Baruch stated:

There has been an increased private-sector R&D emphasis in recent years on low-risk, short-term projects directed at incremental product changes, and a decreased emphasis on the longer term research that could lead to radically improved products and processes. (I, 10)

Jack Baranson said that, in the consumer electronics area, U.S. firms have cut back on basic research and that spending is largely on maintenance of existing product lines and less on developing new generations of products.

Bela Gold said that in the steel industry, the emphasis on short-term profitability leads companies to favor investments that are less risky and more quickly rewarding. This means marketing innovations or minor product improvements. Projects seeking advances in technology are curtailed, as well as construction of new plants which would make possible the installation of new technology leading to gains in efficiency and capacity.

On the other hand, Gary Hufbauer, while not arguing that the shift to short-term, incremental innovation is desirable, maintained that such activity is valuable to the economy. He said that from an overall economic standpoint a lot of gain comes from quite small, non-sensational improvements in products and processes.

Explanations.—Explanations given for the change in the quality of innovation were very similar to the explanations given for the posited declines in R&D funding and the rate of innovation, i.e., economic uncertainty, Government policy (especially regulation), and the difficulty of appropriating benefits of innovation.

Stanley Ruttenberg articulated the appropriability argument, saying:

> The primary motivation of industry is, understandably, to maintain or increase profits. This means that they are more apt to support research which has an immediate payoff by improving the efficiency of their operations in producing and marketing of present products than they are to support basic research which might lead to the development of entirely new and different fields of commercial endeavor.[6]

Jordan Baruch said that expenses associated with regulations—for example, the capital requirements for pollution control—divert some of industry's funds from longer-range R&D projects. He also stated that high interest rates, inflation, and uncertainty about future regulations increase the rate at which industrial decisionmakers discount future earnings on current investments, biasing their decisions to shorter-range activities.

Problems of Small, High-Technology Firms

Many witnesses commented on the special problems of small, high-technology firms in obtaining capital and meeting Government requirements. Gary Hufbauer reviewed studies that suggest that such small firms are of special importance because they are more efficient in their use of R&D funds than large firms. Moreover, small companies have been the source of many major innovations.

Lowell Steele said that, according to the New York Stock Exchange, risk capital has been going down by $6 billion per year and that the 1971–1975 period was the poorest of the prior 20 years. Eugene Douglas mentioned the danger of small firms turning to foreign sources for financing.

Another indicator of the problems of small technical companies in obtaining capital is the decreasing number of small technical firms with successful public issues. Hannay stated that in 1972 there were over 100 such technical companies going into the market with new issue underwritings each year. By 1974 there were only 4, and in the first 6 months of 1975 there were none. Lowell Steele said that the annual number of successful public issues for small technical companies fell from 200 to none between 1969 and 1975.

Another problem of small companies that was raised by witnesses was their difficulty in meeting government reporting and regulatory requirements. Charles Horn stated that many of his small business clients were giving up because they lack the ability to cope with complex Federal policies and regulations. He felt it was dangerous to let such complexities divert the small businessman with a new technical idea from the development of his business.

U.S. ECONOMIC GROWTH AND PRODUCTIVITY

The Problem.—Concern has grown in recent years that the performance of the U.S. economy is slipipng compared to past performance and relative to other nations. One of the causes that has been cited for this phenomenon is a decline in the level and quality of U.S. industrial R&D and innovation activities. At the same time the slow growth of the economy has been cited as one of the reasons

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[6] Ruttenberg, Stanley H. Prepared statement for a Joint Hearing of the Senate Subcommittee on Science, Technology, and Space and the House Subcommittee on Science, Research, and Technology. February 14, 1978, p. 4.

for "low" investment in R&D and innovation. In the hearings witnesses commented on the low levels of U.S. industrial investment, GNP growth, and productivity gains.

Jack Baranson stated:

> Capital expenditures in the U.S. are about 15 percent of GNP as compared to 35 percent in Japan and even 22 percent in the United Kingdom. (III, 33)

Lawrence Franko noted:

> It has been cogently argued that the current level of U.S. inflation combined with a non-indexed tax system is in reality obtaining increases in current consumption by "de-capitalizing" U.S. industry. Be that as it may, this state of affairs is surely discouraging new private capital investment and therefore the domestic diffusion of whatever new technologies are embodied in new machinery. (III, 266)

Bruce Hannay said:

> * * * There are many signs of a decline in our innovative capacity. The growth rate of the GNP has been lower than that of other industrialized countries. The rate of increase in productivity is the lowest for any of the major industrialized countries. It is at its lowest level in 100 years. Business investments and trade figures also reflect the lower growth rate. (I, 14)

Explanations

R&D/Innovation and Economic Growth.—The primary reason given for the decline in the rate of U.S. economic growth and productivity was the decline in R&D and innovation. Bruce Hannay spelled out the relationship between inovation and economic growth:

> Innovation in new products and services is central to the process by which an economy grows and renews itself. . . . Innovation and productivity are closely linked because cost reductions and efficiency gains arise mainly through innovations in methods for production and distribution. . . . The health of our economy and all of the attendant consequences of increased employment and improved standard of living and progress in social areas unquestionably depend upon this innovation. (I, 14, 18)

Other witnesses voiced their faith in the ability of R&D and innovation to improve U.S. economic performance. William Carey said:

> R&D has something important to bring to a new surge of technological innovation and the stumbling performance of American industrial productivity in a competitive global economy. (II, 187)

Bela Gold said:

> Advances in the technological capabilities of our industries represent probably the most powerful single means we have to promote the welfare of the United States. (I, 31)

Some witnesses cited the results of economic studies of the benefits of R&D and innovation to the economy. For instance, Klaus Heiss pointed out that benefits and costs may be measured at several levels—at the level of the individual R&D project, the industrial firm, the industry, the sector, and the national level. Our knowledge of benefits and costs varies across these levels. Heiss summarized:

> The findings at the sector, industry or project level generally are strong, and attribute anywhere from 20 to 50 percent of increased output levels to the effect of R&D and technology. . . . The general finding of a strong sector specific impact of R&D is generally more accepted in the economic community than any proven impact at the national, or macro, level. (III, 87)

Bruce Hannay said:

> What seems to be generally true is that those industries which are R&D-intensive are the ones with the most rapid growth. Rates of return on investment from specific product innovations are estimated to average between 10 and 50 percent per year, while returns on innovation leading to productivity are in the 30 to 50 percent per year range. (I, 23)

Stanley Ruttenberg cited a Data Resources study that showed that high-technology industries experience faster growth in productivity than low-technology industries. Between 1950 and 1974, output per employee in high-technology industries increased at twice the rate of productivity growth in the low-technology industries. The high-technology industries experienced 4.0 percent compound annual growth versus 2.0 percent for the low-technology industries.

Notwithstanding, the relationship between R&D and economic growth is not a simple one. It is not possible to increase economic growth merely by increasing R&D expenditures. Lawrence Franko pointed out that, "given unfavorable governmental, social, or business conditions, R&D expenditure per se can turn out to be quite unproductive of commercially useful innovation." (III, 247)

Federal R&D and Economic Growth.—The contribution of Federal R&D to the economy is becoming an issue of increasing concern. The Federal Government funded an estimated 53 percent of total national R&D in fiscal year 1977. It funded an estimated 38 percent of total industrial R&D that same year.[7]

Some witnesses, such as Gary Hufbauer, argued that, unlike industrially-funded R&D, federally-funded industrial R&D does not contribute directly to economic growth. One of the reasons given was the emphasis of Federal R&D on defense and space. About two-thirds of Federal R&D outlays in 1977 were for defense and space. This amounted to about 35 percent of total national R&D outlays. It is argued that defense and space R&D expenditures are aimed at national goals not directly related to economic growth, and therefore any contribution to economic growth is a secondary and presumably minor effect of such funding. This point is debated by those, such as Klaus Heiss, who argue that the economic benefits of defense and space R&D programs are substantial.

It was pointed out by witnesses that the Federal Government has been particularly successful in promoting innovations in the areas of defense and space. However, it has been much less successful in stimulating innovations for use in the commercial sector. Gary Hufbauer noted that in continental Europe and Japan, which are experiencing higher rates of economic growth than the United States, the "Government R&D efforts are considerably less devoted to space and defense programs than in the United States, and are much more heavily focused on industrial programs, university programs, and private non-profit research institutes." (III, 9)

Jack Baranson stated that:

> We need to distinguish between areas in which industry is encouraged to develop a military or space prototype and the eventual development of a commercial prototype. The funding of an exotic piece of industrial hardware is a long way from commercializing that product and competing with the Japanese. (III, 136)

Bruce Hannay noted the difficulties faced by the Government when it attempts to encourage innovation by funding the development of civilian technology. He explained that:

> Lacking the close coupling to the consumer that is provided by the marketplace, the Government has no feedback mechanism to tell it what is succeeding and what is failing, in choosing and managing R&D for commercial markets. . . . Another problem with Government R&D for commercial technologies is that there is some tendency for private industry to reduce its expenditures in areas where Government funding is increasing. To the extent that this occurs, it becomes merely the taxpayer paying for the R&D, instead of private industry. (I, 22)

Richard Garwin said that another problem in Government stimulation of civilian R&D and technology development has been the imposition of unrealistic time horizons. He pointed to the Great Society programs in which large amounts of money were given to localities. He said there was inadequate time to develop new products which might have resulted in greater benefits at lower costs, because the localities had to "start buying things right away." He indicated a similar situation in the deadlines mandated by the Clean Air Act Amendments of 1970. He said, "We could have done much better, had better research and development made those emission limits more economically, had a 1980 deadline been set immediately and firmly held to." (II, 234)

TECHNOLOGY AND INTERNATIONAL TRADE COMPETITIVENESS

One of the purposes of the hearings was to learn about the nature of the Nation's problems in international trade and the relationship of R. & D. and innovation to them. Witnesses testified that the United States competitive position is deteriorating relative to our foreign competitors. Jordan Baruch listed three factors that he felt contributed to the "declining international competitiveness of some segments of U.S. industry":

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[7] U.S. National Science Foundation. National Patterns of R. & D. Resources, Funds and Manpower in the United States 1953–1977. Washington, 1977. (NSF77–310), pp. 9–10.

> A growth rate for productivity in manufacturing industries that is lagging behind that of some nations; the increasing penetration of domestic markets by foreign producers of intermediate technology and basic industrial goods; and a level of production technology in certain important industries that lags behind that in other countries (for example, coal mining and steel production). (I, 10)

Jack Baranson said, "Fundamental and disturbing structural changes in the U.S. economy . . . have contributed to the declining competiveness of U.S.-based industry in the world economy." (III, 31)

Lawrence Franko and Lowell Steele commented upon trends in world market share. Lowell Steele noted:

> From a businessman's point of view, the best single measure of competitive performance and the most reliable indicator of future business success is the market share trend. The previously mentioned Commerce Department study found a U.S. share decrease from 28 percent to 23 percent between 1968 and 1974 for technology-intensive products . . . Our 1976 share levels in the R. & D. intensive industry sectors are well below those of 1968. (III, 107)

Decreasing Relative Technological Capability

The Problem.—Many witnesses were concerned that the United States is losing its position of technological superiority that contributed to its favorable trade position in the past. They echoed the assessment by Klaus Heiss that the United States no longer has a competition advantage in either capital or labor. Our one remaining competitive advantage is know-how and technology. And there "we are not running as fast as we ran in the 1960s." (III, 130)

Stanley Ruttenberg warned that the U.S. lead in major technological innovations is declining. He cited a Gellman Research Associates study showing that of 500 major technological innovations introduced in commercial markets from 1953 to 1973, the majority was introduced by the United States, but that the U.S. share declined from 82 percent in the mid 1950s to 55 percent in the mid 1960s.

Gary Hufbauer stated:

> I think of the erosion [of technological innovation and preeminence in the United States] has in a sense just begun. Given the normal course of events, unless there's some fundamental change, it will probably increase in the years to come. (III, 23)

Bela Gold sounded a note of caution against over-generalizing that the state of American industrial technology as a whole is deteriorating or has become second rate. He stated:

> I don't think you can talk about the state of American technology in general. We have industries which lead the world; computers, aircraft, a series of others. We have industries which are in a more vulnerable position: footwear, textiles, and a variety of others. . . . But the problem is well illustrated by the weird confusion in the public discussion about the technological capabilities of our steel industry. People keep referring to its terrible backwardness. It's true, we don't have the best steel industry technologically in the world, but we certainly have the second best. And that isn't the impression one gets from hearing the criticisms of, and the lamentations about the industry efforts to deal with foreign competition. (I, 30)

Gold also pointed out the difficulty of measuring the technological capability of an industry, in order to compare it to other industries or the same industry in other nations. The concept of technological capability is not a simple one. Gold said of the concept:

> At the very least, it would seem to cover the maximum level of output capability, the quality and mix of products involved, the so-called 'efficiency' of production and perhaps even resulting cost levels. But the superiority or inferiority of technological capabilities in any industrial sector might also be appraised by evaluating such of its basic determinants as: the level of advancement of its basic and applied technical knowledge; the size and quality of its technical manpower; the modernity of its production facilities; the skills and productivity of its labor; the supply and quality of its raw materials and fuels; the usefulness and attractiveness of its product designs; and the attractiveness of its market prospects. (I, 39)

Explanations.—Many of the witnesses blamed our nation's decreasing relative technological capability on declining U.S. R&D funding, relative to our trade competitors. Lawrence Franko cited statistics from the Harvard/CEI Multinational Enterprise Project showing that continental European firms were spending an average of 3.2 percent of their sales revenue for R&D while U.S. multinational firms averaged only 2.4 to 2.6 percent of sales. He also pointed out that the percentage of U.S. patents granted to foreign persons and firms has risen from 21 percent in 1966 to 38 percent in 1973. It is possible that relatively higher funding of R&D and innovation in continental Europe could lead to new products and processes with a competitive advantage over U.S. products.

> A comparison of our R&D performance with the performance of other nations reveals that the United States still leads in absolute levels of gross expenditures on R&D, in concentration of R&D spending to industrial production, and in the ratio of R&D manpower to total population. But while the data for cross-country comparisons are weak, it appears that the United States lead is being slowly eroded, most notably by Japan and Germany. (III, 9)

Stanley Ruttenberg argued that the export of technology by U.S. multinational corporations hurts the U.S. technological capacity and international competitiveness. He reasoned that when a company has substantial overseas operations it is tempted to export technology. The existence of overseas operations removes the incentive to invest in R&D and to develop new technology in the United States because the firm can maintain profits by simply exporting the old technology.

On the other hand, Edwin Mansfield and Lowell Steele argued that technology exports can have a positive effect on U.S. R&D and innovation. Mansfield reasoned that the possibility of a firm's exporting, making foreign investments, or selling technology licenses might induce it to engage in certain R&D programs that would not be economical if the U.S. market were the only one considered. Thus, U.S. technological innovation would be increased. Mansfield's research showed that if firms' R&D decisions were based on expected domestic returns only, they would spend about 20 percent less on R&D than at present. About 30 percent of the anticipated returns from their R&D projects, on the average, was expected to come from foreign sources.

Lowell Steele confirmed that many U.S. firms rely on foreign sales to partially or totally justify investment in innovation, and many more depend on earnings from foreign trade to help support investment in the future. In the same vein, Lawrence Franko said, "The foreign R&D of U.S. firms—insofar as we know much about it—have by and large been either oriented to the kind of product modification which enhances U.S. export capabilities, *or* to R&D activity of a kind not going on in U.S. facilities." (III, 259—footnote deleted)

Technology and Balance of Trade

Witnesses testified that the United States balance of trade is favorable in products that are R&D-intensive, and generally unfavorable in products that are not, with one notable exception. The United States had a $3.6 billion trade deficit in 1977 with Japan in high-technology goods, mostly accounted for by imports of consumer electronics goods, according to Gary Hufbauer.

Total R&D Expenditures and International Trade.—The strong correlation between R&D expenditures and export success was noted. Klaus Heiss reported preliminary results from a study currently in progress:

> . . . By 1975 the significant contributors to the balance of trade are nearly exclusively research and development intensive industries, while industries with little research and development funding make hardly any contribution to U.S. exports and show a substantial import deficit. . . . (III, 91)

Gary Hufbauer said of the balance of trade situation:

> If we examine our trade balance in technology-intensive goods it appears that, prior to 1972, we had a fairly constant surplus of about $6 billion. In the past four years the average yearly surplus in this category of goods has doubled to over $13 billion. Thus, high technology goods trade has been a source of strength in our trade picture. By contrast, low-technology goods trade has largely caused the recent fluctions in our overall manufacturing balance. (III, 11)

Lowell Steele cited a study by the Office of Economic Research in the Department of Commerce showing: A growing percentage of high-technology products in our manufactures exports—42.5 percent in 1974 compared with 40.5 percent in 1968; faster growth of U.S. technology-intensive exports relative to nontechnology-intensive—10.7 percent annual average between 1968 and 1974 compared with 9.2 percent; and a generally increasing U.S. positive trade balance for the technology-intensive products groups—$5.7 billion in 1968 compared with $13.8 billion in 1977, compared with a negative balance for nontechnology-intensive products. (III, 107)

Steele concluded that "technologically intense products do better than average in international trade." But he felt they do not provide a direct answer to the technological leadership question, since the United States is losing market share even in its technology-intensive products, as noted earlier. (III, 107)

Gary Hufbauer summarized the state of our understanding of the relationship between R&D spending and exports, emphasizing the uncertainties. He asked:

> Is it possible to establish a connection between levels of R&D spending in the U.S. and a possible future worsening of our trade performance? The few statistical studies that have attempted to find a correlation between R&D intensity and exports show a positive and significant relationship. . . .
>
> What the studies do not show is how R&D affects trade performance independently from other important influences, such as skilled labor effects, industry-concentration effects, and scale economy effects. These other effects are frequently associated with just those industries which have high R&D levels. In addition, there are often long lag times between particular expenditures on R&D and observed effects on trade. Past studies have examined a cross-section of goods in a given time period, and have not attempted to quantify changes over time. Finally, there is an important circularity in causation. R&D stimulates trade, but trade also stimulates R&D. (III, 13)

Hufbauer said, "It is unlikely that larger R&D spending would improve our trade balance in the short-run, but it could well have a positive impact in five or ten years." (III, 13)

Lowell Steele's remarks on the subject also stressed the complexity of the relationship between R&D and exports. He argued that factors other than enhanced R&D expenditures may be responsible for increased exports. He stated:

> Since it appears that more R&D intense products do better in overall trade balance and growth of exports, one might be led to the conclusion that if we simply increase our R&D levels, we could grow our exports even more rapidly. But the argument might well be made that R&D intensity is simply a concomitant of growing markets and high exports—that these industries do more R&D because they are more successful in both domestic and international markets and have higher profit levels to plow back into R&D. Or, it might be claimed that the better performance is coming from relatively more sophisticated managements and work forces—or from higher levels of investment in more modern plants and equipment which permits higher quality, lower priced products. I am convinced that all these statements are true. Companies do more R&D when the competitive environment supports it, the industrial infrastructure facilitates it, the profit opportunity motivates it, and when they can afford to invest more. (III, 108)

Federal R&D Expenditures and International Trade.—With respect to the role of Federal R&D in technology exports, Lawrence Franko pointed out that it has played a significant role in the development of many innovations that were later successful in international commercial markets. He stated, "Often, successful U.S. innovations of a sort later commercialized abroad have been directly related to the U.S. Government's role as an early, large, and above all, constant and predictable customer for whatever it was that was being developed." (III, 249)

Klaus Heiss, referring to a study in progress, said, "Preliminary results indicate that the relationships between Federal R&D and the competitive world position of the United States is even stronger than the statistical correlations found between total R&D and these same product groups." (III, 95)

Klaus Heiss and Lowell Steele differed during the hearings over the relative importance of Federal R&D in the export success of the U.S. aerospace industry. Heiss stressed the importance of Federal R&D, while Steele played it down, pointing out that although many innovations in civil aviation benefited from technology early developed by the Federal Government, they were further developed with private money for civilian markets. He also identified other factors that contributed to their successful development: a healthy, growing economy; relatively profitable airlines that were expanding capacity for an expanding market; and a regulatory agency, the Civil Aeronautics Board, that was interested in nuturing the growth of the airline industry.

Industrial Innovation and International Trade.—Conceptually, industrial innovation, defined in terms of new and improved products and processes, should have a closer relationship to export success and international competitiveness than R&D expenditures. Therefore, it would be desirable to have a better understanding of this relationship. A few witnesses asserted the importance of industrial innovation to the international trade situation, but as seems typical when referring to innovation, as opposed to R&D, few statistics were offered to substantiate the statements. Jordan Baruch asserted that "the industrial innovation process . . . is a major determinant of the competitive advantage of U.S. industry," (I, 9) and Bruce Hannay observed that "technological innovation is an important element in international trade and the balance of payments." (I, 14)

Energy Crisis and International Trade.—Another explanation for the decreasing competitiveness of American industry was given by Lawrence Franko. He felt that the energy crisis had put the United States at a disadvantage. The quadrupling of oil prices had increased world demand for energy-saving products and processes and resource-short Europe and Japan had developed them first. U.S. innovations have traditionally been biased toward lavor-saving, convenience products and processes, which are energy and material intensive. Thus the energy crisis created more demand for the products of our competitors.

Technology Exports

An increasing tendency for U.S. industrial firms to "export" technology, through foreign direct investment, licensing of production technology, and other transfers of technological "know how" was noted. As Lawrence Franko stated:

> The fact that [big, multinational firms] transfers production technology abroad, or even develop some outside of the United States has given rise to fears that these activities substantially substitute for U.S. exports, or worse, lead to a relative gain in other countries' technological, and thence competitive abilities. (III, 258)

Jack Baranson testified that his work in the area of international technology transfer had uncovered a marked tendency for U.S. firms to export technology. For some firms technology export is part of a corporate strategy to maintain cost competitiveness and penetrate new markets. According to Baranson, the conventional wisdom has been that these technology exports were on balance beneficial to the United States and necessary if the firm were not to lose market share and suffer a net decline in earnings.

Stanley Ruttenberg stated:

> No problem, in my judgment, poses a more serious issue to us than the diffusion of technology around the world and the resulting dissipation of U.S. technological leadership. (I, 26)

He deplored the fact that transfers of U.S.-developed technology are occurring before production ever takes place in the United States. He warned that increased technology exports would reduce the rate of U.S. productivity growth and lead to higher unemployment.

"Another major source of erosion to U.S.-based production" according to Jack Baranson, "has been the massive movement offshore of production facilities to low-wage economies by U.S. corporations." This has occurred not only in low-technology industries such as clothing but also in "successive generations of consumer electronics products and their major components and . . . complete manufacturing of major automotive components such as engines and transmissions and eventually entire vehicles." (III, 32) Baranson saw this as an attempt to reduce labor costs, instead of improving the technology.

Jordon Baruch and Bruno Weinschell noted that R&D activity is also moving abroad. Baruch attributed the move to the increasing regulation of research in this country. Weinschell noted:

> R&D activity is indeed moving abroad, and the trend is likely to increase. Government actions could slow the process but would not stop it. The transfer is desirable from many points of view, and inevitable, but steps must be taken to minimize its neagtive effects on the U.S. economy. (III, 149)

Other witnesses argued that technology exports are not necessarily detrimental to the United States and in fact may have important economic benefits. For instance, Lawrence Franko pointed out that foreign direct investment in production facilities most often enhances exports, rather than substitutes for them.

In the same vein Gary Hufbauer said:

> While it is probably true that the increase in foreign skill levels arising from certain transfers of technology to other countries will create greater

competition for U.S. goods, it is equally true that the U.S. stands to gain from other transfers. New export markets for U.S. products may result from technology licensing agreements. Improvements in the technology may flow back to the United States. And foreign firms often locate production facilities in the United States in order to exploit their new technology here. In short, it is virtually impossible to determine the overall effect of the technology transfer process. (III, 19)

Lowell Steele argued that technology exports can actually help the U.S. economy. He stated:

> While some claim that U.S. companies with foreign affiliates are "exporting jobs" and manufacturing abroad to produce low-priced goods to sell in the United States, less than 7 percent of the output of foreign affiliates comes back to the United States, and half of that is from Canada under the automotive pact. In 93 percent of the cases, foreign affiliates are producing goods for foreign markets, and they are also pulling through exports and providing jobs in the United States. (III, 125)

Richard Garwin, applying the economic concept of comparative advantage, said that if a foreign country makes a better product using American technology, we should buy it because it is to our advantage to do so.

In addition, Gary Hufbauer pointed out that there are substantial difficulties in measuring international technology transfer. We really know very little about actual internattional transfers of technology, and whether they have net beneficial or detrimental effects on the U.S. economy. We are forced to rely on royalty and fee data, namely payments made for technology sales through license of patents, know-how, and other intangible property. These data tell very little about the nature of the technology being sold. They include payments for trademarks and other purposes unrelated to the transfer of technology and they do not measure the transfer of technology embodied in personnel.

Technology Imports

The Problem.—Much of the concern about technological lag is generated by the tremendous increase in U.S. imports of manufactured goods. Some witnesses were concerned that such imports can hurt American business and eventually contribute to the further deterioration of U.S. technological capability. Jack Baranson illustrated the problem:

> Not only have Japanese manufacturers taken over a substantial segment of the U.S. color television market (about 22 percent), they have also taken the lead in developing the new generations of consumer electronic products. The video tape recorder, originally invented and commercialized in the United States, has been completely taken over by Japanese firms who now manufacture this sophisticated equipment in Japan and license U.S. firms such as RCA and Zenith to market these products in the United States under their own brand names. (III, 33)

Unless the situation is remedied, Baranson predicted a scenario in which:

> * * * the U.S. economy will supply low-skill labor for assembly and the low-technology range of components (cabinets and glass for picture tubes). The sophisticated range of products will continue to be imported from Japan (electronic components for chassis, picture tube, and tuners.) Even more far-reaching, Japanese design engineering capabilities will be further enhanced, and U.S. capabilities will continue to decline. (III, 35)

Explanations.—The explanations given for the success of our trade competitors in penetrating U.S. and other world markets were generally in terms of their motivation and their growing economies. Lawrence Franko pointed out that foreign firms often feel that they have to keep aware of foreign markets in order to survive, and many foreign governments strongly urge their industries to export. Bruno Weinschell explained the attraction of the American market to foreign firms. Citing Business International S.A., he said, "The biggest reason for the greatly expanded and expanding European corporate investment in the United States lies in the attractiveness of the market—its size, its profitability, its research and development stream, its new products and industries, its process development and applications engineering." (III, 196)

In Bela Gold's opinion, lower price imports generally do not represent superior technology abroad, but rather are primarly due to differences in wage rates. They are also partly due to subsidies by governments abroad that are determined to invade the lucrative domestic U.S. market. In the few cases where our competitors do have superior technology, according to Gold, it is due to their high motivation for export success and their growing economies, which enable them to install new technology.

Gold gave the following four factors as instrumental in Japan's success at exporting steel: 1. Strong corporate support for major technological advances; 2. Speical commitments of the Japanese government to strengthen the steel industry; 3. Rapidly expanding output of the Japanese steel industry; and 4. Unique organizational relationships in large Japanese companies.

Lowell Steele noted that Japan's phenomenally effective export situation was achieved under conditions very stimulative of economic growth and productivity gains generally.

GOVERNMENT POLICIES THAT MAY INHIBIT INNOVATION

Prominent among explanations given for declining R&D and innovation, and the resulting domestic and international economic problems, were government policies. A wide variety of Federal policies were criticized by the witnesses. They included tax policy, regulation, securities regulations, import policies, price controls, antitrust, and Government patent policy.

Tax Policy

Richard Garwin said that inappropriate taxation is repressing our potential for innovation. Lowell Steele shared this view, stating:

Under some conditions, the maximum capital gains tax can approach the top tax rate on personal services. This combined with limitations on write-off losses critically alters the risk-reward ratio needed to motivate investment in innovation. (III, 119)

Regulation

Several witnesses commented on the effect of Government regulation on industrial innovation. Their testimony revealed that the effect is probably neither all negative nor all positive. On the one hand, some witnesses pointed out that regulation is commonly perceived as inhibiting innovation. Richard Garwin felt that excessive regulation is repressing industry's capability to innovate. Bruce Hannay noted that industry generally considers regulation to be one of the principal factors inhibiting innovation.

On the other hand, Hannay admitted that the effect of regulation on innovation can be either positive or negative. Ellis Mottur echoed this theme, citing a recent study by the MIT Center for Policy Alternatives which indicates that "environmental regulations in some instances have actually served to stimulate innovation." (II, 223)

Gary Hufbauer commented upon the difficulty of empirically determining the effect of regulation on R&D or innovation. He related his experience with a study of the steel industry:

> I was involved in some attempts at trying to get estimates of how much steel capital spending was connected with environmental controls. That seemed like a number that should be easy to come by, but it was a frustrating exercise. We finally came up with some estimates but they were by no means hard and fast. And my feeling is that in the research area the connections between regulatory push and research are, if anything, even weaker. (III, 24)

Securities Regulations

Lowell Steele commented upon the effects of securities regulations on the ability of small companies to obtain capital:

> The Securities Exchange Commission in promulgating rules to correct abuse in the sale of stock of young companies has severely impeded the opportunity to regain funds from a successful investment and invest them in another venture. These changes in the risk-reward ratio and reductions in liquidity and mobility of venture capital are a serious impediment to innovation. (III, 120)

Import Policies

Bela Gold faulted Government failure to protect industry from foreign "dumping" of imports, saying that a number of industries are curtailing technological advancement efforts because of a belief that any resulting price reductions will be met by reduced import prices, subsidized by foreign governments. The effect on industries is cumulative, he said:

> Bit by bit, such industries undergo a gradual regression in the state of their technological capabilities. Reliance on progressively older plants and older technologies ensures that at some point the foreign technology will in fact be better. (I, 38)

Gold pointed out that the U.S. steel industry cannot justify building large new plants, despite the continuing expansion of domestic demand for steel, because all of this increase has been absorbed by imports. This lack of new construction, in turn, discourages the development of new technology that cannot be easily retrofitted into existing plants, or that requires a much larger scale to be economic.

Price Controls

Two witnesses spoke of the adverse effect of government attempts to control prices. Bela Gold claimed that the Government has repeatedly objected to price increases for United States steel without ever proving that they were not justified. This lowered the profitability of the steel industry and made it difficult to raise capital for construction of new steel mills. Without capital for expansion it is difficult to install new technology.

Klaus Heiss also felt that price controls have a strongly adverse effect on industry's ability and willingness to innovate. He used the energy industry as an example, asking "How can one expect large innovative investments in energy R&D if at the same time one controls all types of fossil fuel prices at artificially low levels?" (III, 131)

Antitrust

Bruce Hannay said that antitrust threats inhibit activities that promote innovation, such as cooperative research. By altering the essential structures of innovative firms like AT&T, antitrust also inhibits innovation, in his view.

Bela Gold said that our Government's antitrust policy has hurt the competitiveness of the U.S. steel industry. The Japanese steel industry has been able to consolidate into fewer firms and larger plants to take advantage of the economies and new technology attuned to a much larger scale of operation. The United States steel industry has not been able to do this because our policy is very hostile to any increase in concentration in industry.

Government Patent Policy

William Carey spoke extensively about the inhibiting effect of Government patent policy on innovation. He called Government patent policy "the paramount flaw in our Federal R&D policy." (II, 188) Patent policies have been developed and instituted on an agency-by-agency basis. The Department of Defense has a relatively liberal policy of allowing inventors to hold title to the invention and to develop it. The rest of the Government, Carey said, operates on the principle that benefits from inventions resulting from federally-funded R&D should accrue to the Government. He said, "The effect is to preempt any market incentive for risk investment to bring the discoveries to commercialization and use. Industry is not going to touch inventions held by the Government without exclusive licensing." (II, 188) The result is that of 8000 new inventions being created every year out of Federal R&D, about three percent reach the market.

Richard Garwin agreed that much valuable information cannot be protected because of Government patent policy, and thus will not be worked on by individuals or industry operating on a profit motive. This inhibits our innovation potential.

RECOMMENDATIONS

This section of the report reviews recommendations made by the witnesses for Federal action to alleviate the problems identified in the hearings.

The Role of the Federal Government

All of the witnesses saw an important role for the Federal Government in the correction of the problems of declining R&D and innovation, economic growth and productivity, and international trade competitiveness. A wide variety of actions were suggested, as summarized by Ellis Mottur:

> Government certainly has an essential role to play throughout the innovative process involving: in-house Government R&D, support of private R&D, procurement of goods and services; setting standards; health, environment, and safety regulations; tax incentives and constraints; antitrust regulations; patent policy; scientific and technical information programs; international trade policy; and the like. (II, 223)

Some differences between the witnesses surfaced in the recommendations. One difference was in the relative importance placed upon Federal provision of financial support for private R&D as opposed to providing incentives for industry to invest its own funds in R&D. Mottur, for example, appeared to believe that both approaches are appropriate. Bruce Hannay, on the other hand, said:

> We should examine the question of what we could do to make investment attractive once again, by removing some of the disincentives, rather than by proposing that government action be taken to supplant the private sector and itself provide the capital. (I, 56)

Another difference was with respect to the relative importance placed on Federal support for basic research as opposed to the later phases of innovation, such as applied research, development, and pilot plant construction. Some witnesses felt that the most appropriate role for the Federal Government was in basic research, where it was less likely to simply substitute for industrial effort. Other witnesses warned, however, that simply funding more basic research without support or incentives for the latter phases of innovation would be unlikely to result in the introduction of significant new innovations.

Federal Support for Private Sector R&D

Klaus Heiss voiced strong support for Federal funding of private sector R&D. He said that the role of the Federal Government, in funding R&D ventures needs to be emphasized. Bruce Hannay suggested that "selective Federal support for R&D for civilian technologies can certainly be justified." (I, 18)

Most of the witnesses appeared to believe that, if the Government funds private-sector R&D, the most appropriate role is in the basic research end of the spectrum of innovation activities. Stanley Ruttenberg said, "Government support for basic and applied research efforts must be stepped up." (I, 29) Lewis Branscomb argued that Government must support most of the basic scientific research upon which the Nation's innovative capacity rests. He supported both institutional and project support for basic research at universities at a level adequate to meet the Nation's technological requirements.

Richard Garwin defined the proper role of the Federal Government as primarily in the basic research end of the spectrum. He said:

> It is clear that the direct expenditure of Federal dollars can have the greatest effect on productivity, innovation, and technological development if it is spent in the basic research, applied research, and exploratory development phases, where there are opportunities with very great returns on investment but which will, even so, not be supported by industry. . . . But to suggest that it should do demonstration instead of basic research, or concentrate its efforts on the laudable goal of creating a favorable climate for innovation (perhaps by adjustments in tax, regulatory, antitrust, and other policies) instead of demonstration or research implies the wrong model of the Federal Government. (II, 191)

Lowell Steele suggested two areas that should be given consideration for increased government support—basic research in industry and academic programs aimed at improving productivity. Among his recommendations were possible extension of the independent R&D allowance.

Bela Gold suggested that the Federal Government set up some "basic research centers", similar to the agricultural research centers, which would work to improve the technology of major industries.

Other witnesses called for research which is long-range in nature, but oriented toward a specific technological advance. Bruno Weinschell stated:

> A deliberate search seems to be indicated for areas of technology likely to become important, to establish long range missions where future requirements can be identified. This is not to be confused with basic research: it is concerned with mission-oriented research with a long lead-time, where the pay-off for private companies is too uncertain to justify the funding requirements. (III, 208)

Jordan Baruch described the Cooperative Technology Program being undertaken by the Commerce Department to develop the technological "infrastructure" of disaggregated industries. He said:

> This approach focuses upon developing and institutionalizing a partnership among Government, industry, academe, research institutes, et cetera, to develop the fundamental technologies—what I have called before the "infratechnologies"—from which industry develops its goods and processes. (I, 7)

Jack Baranson called for more joint government-industry ventures, referring to the historical example of RCA, which was founded in the 1920's by the U.S. Navy.

Incentives to Stimulate Private Sector R&D

The preponderant opinion of the witnesses that the appropriate Federal role is to stimulate private sector R&D was reflected in Bruce Hannay's statement, "The most useful thing the Federal Government could do is to stimulate the private sector to invest its own human and financial resources in innovation." (I, 17) Charles Horn spoke of the need for government to create a proper climate for industrial R&D:

> It is my feeling that in both government and in industry the government cannot mandate creativity. I think the government's role is one of creating a climate where this creativity and innovativeness can flourish and can bubble to the top. (II, 237)

In the same vein, Jack Baranson recommended that the Federal Government encourage industry to take risks in R&D and new industrial plant. He said:

> * * * What needs to be reinforced is private industry's incentive to commercialize the technology. * * * I do not think that Government spending * * * can take up the slack in this area. (III, 143)

There was disagreement on how specific the Federal programs should be. On the one hand, Stanley Ruttenberg believed that the Government must "pinpoint" its actions on specific programs in order to be effective. On the other hand, Lowell Steele recommended against a series of highly specialized programs, believing that general programs are needed to induce a stable and growing economic environment for the Nation. Steele said:

> I believe that the market pull-through of a strong growing economy that is being stimulated by healthy growth in investment is the key factor in stimulating innovation. Special attempts to stimulate R&D in an otherwise laggard or uncertain economy are unlikely to be effective. Many studies have demonstrated that market pull is a more powerful force in determining the success of innovation than technology push. (III, 119)

Steele also said, "I believe what we face is a sort of general malaise, and I think it would be a serious mistake to enact a series of highly specialized programs to attempt to deal with it." (III, 137)

Nevertheless, a variety of Federal actions were recommended to provide incentives. They are reviewed here, grouped by policy mechanism.

Tax Incentives.—About half of the witnesses were in favor of change in Federal tax policy to stimulate innovation, although it was recognized that there are problems in using tax incentives. Of these problems, Gary Hufbauer said:

> One problem with tax incentives is that it is quite difficult to construct a line between R&D and various kinds of market development and promotion activities. * * * As soon as the Government gives R&D a more favored tax status—and there are various devices one can think of—then this line drawing problem becomes immense. I don't think the problem is insuperable but I do think it is a difficult one; it's a problem that will lead to abuse as companies attempt to classify additional items into a tax-favored R&D status. (III, 25)

Despite the recognized difficulties, several witnesses recommended various changes in current tax laws. Bela Gold recommended more favorable tax treatment of capital gains and of long-delayed profits from long-term technological improvement projects. He suggested special allowances for losses on such projects. He also recommended accelerated depreciation in order to deal with the major new plant projects which would take a long period of time to build.

Stanley Ruttenberg argued that tax incentives given to technological development or selective support of R&D would produce more in the long run than the tax incentives for new equipment or new plant and equipment which are now part of our law.

Richard Garwin recommended a tax credit (not a tax deduction) for the support of university research by business.

Lowell Steele advocated that changes in tax law should make permanent and more liberal the investment tax credit, provide more rapid write-off of capital investment, and reduce the Federal corporation income tax rate. He felt these actions would increase capital investment, stimulate market pull, and help overcome the impediments of rapid obsolescence and inadequate capita cost recovrey. He recommended more favorable capital gains provisions—specifically a greater spread between capital gains and personal service tax rates, and larger write-off of losses.

Klaus Heiss suggested:

> A new initiative to create R&D venture corporations that after review and approval by Federal R&D institutions as to the significance of their pro-

posed research—would be allowed to depreciate a multiple (e.g. 3 times) the initial investment before being subject to Federal (corporate) income taxation. (III, 82)

In Jack Baranson's opinion:

> We need more finely tuned tax and credit mechanisms to encourage and fund the innovative firm that is designing and engineering for production in the U.S. economy and in product areas where there is neither or both growth and productivity gain potential. (III, 36)

Bruno Weinschell was in favor of investment credits to encourage the rapid introduction and integration of new product ideas into product lines.

Antitrust.—Several witnesses called for review of the antitrust laws or for change in the law. There were differences on whether increased concentration in industry should be allowed. Other themes stressed were the need for stability in enforcement of antitrust laws and the need to recognize that some collaborative efforts may be necessary in order to successfully compete with our trading partners. Bruce Hannay called for greater stability and wisdom in antitrust enforcement. Bruno Weinschell recommended a broad review and possible revision of current antitrust laws.

Bela Gold stated that, "we must learn how to take advantage of the economies of increasing scale technologies, and yet prevent any resulting collusion to reduce competition, instead of continuing to assume that one is impossible without the other." (I, 38)

Richard Garwin supported more specific antitrust legislation:

> I do believe that American commerce and industry would benefit exceedingly from having specific laws which provide a way to direct the competition among the companies in this country so that individuals managing such companies would know what was permitted and what was not permitted, rather than the present situation, where what is feasible and tolerable at one time may be the origin of a suit to destroy a company in the future. (II, 231)

Jack Baranson testified that, although he did not necessarily favor relaxation of the antitrust laws, there is a need to sanction some collaborative efforts. He said that "certain legitimate collaborative efforts within and among American industry may be not only useful, but indispensable in order to hold our own against trading adversaries." (III, 129)

Subsidies.—There was some discussion of Government subsidization of industrial R&D. Opinion was about evenly split on its desirability. Bruce Hannay thought that subsidies offer significant possibilities for the stimulation of private investment in innovation. Bela Gold suggested cost-sharing grants between the Government and industry on more risky technological development projects. On the other hand, Richard Garwin said that in his personal opinion, his firm, IBM, does not need subsidy for R&D. Lewis Branscomb also took a negative position, saying:

> Government subsidy is not required for such commercially-motivated industrial research, but adequate profitability and the environment for an optimistic attitude toward future economic opportunities are required. (I, 68)

Procurement.—Witnesses recommended more attention to Federal procurement as a means of stimulating innovation in the private sector. Bruce Hannay said, "One mechanism that has been proposed but seldom exercised in the civiilan sector is the use of Government procurement to stimulate private investment." (I, 18)

Richard Garwin said we should continue to follow the model of Government procuring for its own purpose, as in space and defense technology. The Government, he said, succeeded very well at that and "the usuable technology that came from those programs was then applied to make a profit by industry in the commercial world." (II, 233)

Lawrence Franko suggested considering multiyear procurement budgeting:

> Given the past role of government-as-customer in fostering innovation—in contrast to the recent tendency of government to become more fickle in its procurement habits—perhaps multi-year procurement budgeting might be worthy of consideration. (III, 267)

Regulation.—Greater stability and less uncertainty in government regulation were recommended. Bruce Hannay said, "the provision of a greater degree of stability and wisdom in regulation" is urgently needed. (I, 23)

Lawrence Franko said regulation must be more constant and predictable:

> * * * Who would invest in building up R&D skills and in assembling an R&D team to develop a product or process if there was a fear that its profits

might be regulated out of existence by the time the results got into production? (III, 267)

Lowell Steele advocated improvements in the regulatory process:

> The government simply must reduce regulatory delays and uncertainties. And in order to maximize the social benefit from our innovation process, a requirement to consider reasonable alternative approaches to and costs of achieving proposed regulatory objectives could help counteract the present single-minded focus on a narrow specific approach and objective. Better coordination of regulatory activities could help facilitate a more timely and effective process. (III, 124)

Government Patent Policy.—Changes recommended in Government patent policy related primarily to exclusive licensing. Bruce Hannay said, "Patents resulting from Federal R&D contracts could be a source of innovation, through provisions for exclusive licensing." (I, 24) William Carey, who called Government patent policy the "paramount flaw" in our R&D policy, recommended that the Government, legislate a clear intention to give the inventor the opportunity for a reasonable time to bring that invention into commercial use, while preserving rights to the government.

Richard Garwin saw two problems—stimulating invention and exploiting inventions. He made two suggestions:

> Giving the inventor right-to-exploit wouldn't necessarily help if we are trying to facilitate exploitation of Government-owned inventions. Exclusive licensing or sale to the highest bidder would presumably take care of that.
>
> In addition there is another problem of stimulating invention. . . . That would certainly be aided if the inventor received full rights. The Government could perhaps request 50 percent of the royalties or 20 percent. (II, 203)

Loans and Loan Guarantees.—Two witnesses recommended loans or loan guarantees to stimulate industrial investment in innovation. Bruce Hannay thought loans offered "significant possibilities" for stimulating investment. Ellis Mottur recommended establishing a National Venture Capital Bank, with the power of Federal loan guarantees, which "could help channel private capital into new, innovative ventures—if accompanied by appropriate tax and patent incentives." (II, 224)

Help for Small Firms

A variety of measures aimed at assisting small, high-technology firms with the special problems that face them was suggested. Jack Baranson said that if refinement of tax and credit instrumentalities is considered, special attention should be given to small or medium firms. He said efforts should be made to reinforce their ability and motivation to commercialize technology.

Bruce Hannay argued that there is a need to find mechanisms for extending the advanced technology that makes productivity gains possible to smaller or less technology-oriented firms and basic industries. He said:

> One way this might be done is through increased support of research and education in industrial engineering and manufacturing processes. A Federal program of information transfer to smaller companies would be useful; there is evidence that many of them do not know what is possible in manufacturing technology. Some of the most significant gains in productivity will undoubtedly arise from innovations in the application of computers to the management and control of manufacturing processes and industrial operations. (I, 24)

International Trade Policy

Many of the recommendations made during the hearings concerned international trade policy, primarily technology exports and imports. The main issue in both exports and imports was whether the proper approach should be by controls or stimulation. The argument in favor of controls is that we need to: 1) protect our technological base of superiority by controlling exports of technolgy to other countries where it may possibly be turned against us, and 2) protect our domestic industry against lower priced imports. The argument for stimulation is that controls will be counterproductive and only a program of stimulation will make U.S. industry competitive in international markets. Gary Hufbauer supported the latter:

> * * * a program of R&D stimulation broadly defined * * * makes far more sense than the quite diametrically opposed approach of attempting to put up barriers. First, attempting to put barriers would not work very well; and to the extent it did work, it would very probably be self-defeating. (III, 23)

Similarly, Bruno Weinschell said "Licensing and joint ventures abroad can be beneficial to the United States if we can maintain the two-way flow of technological innovation." (III, 150—emphasis added)

Technology Exports.—The recommendations in the area of technology exports can be grouped into those in favor of increased controls or coordination and those against. Stanley Ruttenberg strongly supported increased technology export controls. He said, "We must slow down the rate and pace of technological transfers by multinational corporations." (I, 29) He recommended that technology exporters be required to secure licenses and file an employment impact statement before exporting. He also called for the removal of the presently existing incentives for the export of technology, meaning the tax credits, the tax deferrals, the excess tax credits, the accounting rules and transfer pricing policies. Bruno Weinschell also recommended requiring an impact statement for technology exporters. His "technology impact statement" would facilitate an evaluation of whether the technology should be allowed to be exported or not. Eugene Douglas thought that most of the business community would welcome the creation of "a focus with muscle" inGovernment that would cordinate technology export policies that are currently handled by several different agencies.

Most of the witnesses however, opposed the strengthening of technology export controls. These included Lowell Steele, who said:

> Any effort to restrain the outflow of technology except for clear cut and specific national security reasons most certainly would be counterproductive. Technological protectionism is not the way to assure maintenance of technological leadership. It would serve to slow our own rate of industrial innovation and, in turn, our international competitiveness. (III, 122)

Moreover, Steele said, "Our policy should be to encourage—not discourage—expansion of U.S. companies abroad. (III, 125)

Lawrence Franko made a similar point, saying, "Even with a draconian secrecy apparatus, technological protectionism has never been successful for long in keeping skills and technology from diffusing." (III, 264)

Klaus Heiss recommended the abolition of current export control programs except for those necessary for defense strategy. Gary Hufbauer expressed the belief that "restrictions on the outflow of technology would not be in the national interest." He said, ". . . Our national interest lies not in the creation of new barriers but in exposing U.S. firms to the stiff breeze of competition and fresh ideas from abroad." (III, 19–20)

Richard Garwin said, "the best we can do would be to go in the direction of free competition and free trade." (II, 232) Finally, Jack Baranson said that a purposeful effort should be made to influence decisions in the marketplace because the path of administrative controls is probably a futile one.

Imports.—Both Bela Gold and Richard Garwin favored some form of restriction on imports. Gold stated:

> * * * the conclusion seems inescapable that the undermining of a considerable array of private industries in this country by uneconomically-priced or otherwise government-supported imports can be prevented only if the U.S. Government makes a determined effort to restore fair competition in our markets and access for our exports to foreign markets on fully comparable terms. [footnote omitted] This would require not only immediate measures to gradually curtail uneconomically—priced imports, but increasingly tough long run restrictions to assure American producers against a resurgence of such practices whenever overseas economic pressures are intensified. (I, 46)

Garwin said that the Federal Government should provide some "compensatory restrictions" on the access of foreign products to our markets in response to limitations on the free access of U.S. products to foreign markets. (II, 232)

On the other hand, Jack Baranson argued that "sustained movements in the direction of protectionism . . . will only exacerbate our difficulties." (III, 36)

National Policy for Innovation

Ellis Mottur recommended the formulation of a national innovation policy, saying:

> This policy must recognize the preeminent position of the private sector in producing innovations which work and which will be widely used. But this policy must also recognize the essential role of government in establishing coherence and continuity in the envronment of incentives and constraints within which the private sector must operate.

We must shape an innovation strategy involving a partnership of Federal, State, and local government, large and small business firms, academia, the nonprofit sector, and individual inventors and entrepreneurs. Government's role must be focused on key leverage points in the process at which there is maximum potential for beneficial impact from government action. (II, 224)

In a similar vein, Lewis Branscomb said that we need an "economic strategy that takes into account the strengths and weaknesses of American industry and the technology on which it rests. * * *"

William Carey, on the other hand, was doubtful about the utility of a national innovation policy. He said:

I have lived long enough in Washington to have a dismal view of great comprehensive national policies, from the top down. I think I would have to apply that to the problems of innovation. * * * (II, 241)

I think that I would rather see us tackle such problems as the patent policy problem one at a time, and try to deal with it, than to wait until we have an ideal formulation that will carry us for the indefinite future. I don't think the politics in Government work that way. (II, 244)

Lowell Steele presented an alternate idea to achieve strategic coordination in government. He suggested the equivalent of the production manager in industry, whose job, he said, was "to get the job done, not to represent any particular special interests." He went on to say, "That concept of a person not protecting a special interest but just insuring that you move rapidly and expeditiously to achieve an answer" is missing in government. (III, 135)

Government Reorganization for Innovation

William Carey supported reorganizing the Department of Commerce to put it in charge of innovation policy. The reorganization would transform the Department of Commerce into a Department of Industry, Economics, and Technology which would attempt to correct "our present policy muddle with regard to industrial innovation and technological movement." (II, 242)

Eugene Douglas supported a suggestion to reorganize the agencies involved in international trade. But he felt that Congress should continue to exercise diligent oversight in this area. (II, 134–135)

SUMMARY

The Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation held three days of hearings in 1978 to investigate claims that the innovative capability of U.S. industry is declining, with potentially unfavorable consequences for the U.S. economy. The problems discussed by the witnesses at the hearings fell into three categories: U.S. R&D and Industrial Innovation; U.S. Economic Growth and Productivity; and International Trade Competitiveness.

U.S. R&D and Industrial Innovation

R&D is only one part of the process of industrial innovation which, when conditions are right, results in the introduction of new and improved products, processes and services into commercial markets. In terms of impact on the economy and international trade, it would be desirable to measure the rate of innovation or the number and significance of new products and processes introduced. However, the concept of innovation is not well-defined and widely accepted measures are not available. For this reason, R&D expenditures are often used as a surrogate measure, although they are not completely satisfactory for a number of reasons. Some witnesses at the hearings referred to a decline in the U.S. rate of industrial innovation, but were able to offer few statistics to support their statements due to these difficulties.

There was agreement among the witnesses that total funding for industrial R&D has barely kept up with inflation for the last ten years. Increases in private industry funding for R&D have largely been offset by decreases in Federal funding of industrial R&D.

The reasons given by witnesses for stagnation in R&D funding hinged on four variables: 1) a slowed rate of economic expansion; 2) increased economic uncertainty; 3) changing Government priorities; and 4) Government policies that create a net disincentive to industrial R&D and innovation. A possible explanation that was refuted by most witnesses is a decrease in the inherent innovative capability of American industry.

Witnesses warned that U.S. R&D and innovation are being turned in the direction of short-term, incremental changes. The reasons given for this trend were very similar to those given for the low growth in R&D spending. Increased economic uncertainties bias R&D decisions toward projects with short-term payoffs and lower risk. Government regulations divert R&D funding and investment capital away from major new products and improvements to meet regulatory requirements.

Many witnesses also commented on the special problems of small, high-technology firms in obtaining capital and meeting government requirements.

U.S. Economic Growth and Productivity

Witnesses commented upon the low levels of U.S. industrial investment, GNP growth, and productivity growth, compared to other developed nations. This was attributed to the decline in U.S. R&D and innovation. Studies were cited showing a strong statistical coorelation between R&D and economic growth. These findings are more generally accepted at the industrial and sector levels than at the national level.

Despite these strong correlations, the relationship between R&D and economic growth is probably not one of simple cause-and-effect. For instance it is probably not possible to increase economic growth simply by increasing R&D expenditures. Governmental, social, and business conditions are very important to the success of R&D and, given unfavorable conditions in these areas, R&D expenditures may be unproductive.

Some witnesses argued that Federal R&D expenditures do not contribute directly to economic growth, although industrially-funded R&D does. One of the reasons given was the emphasis of Federal R&D on defense and space. Opposing testimony found that defense and space technology expenditures provide great direct and downstream stimulus to the economy and the trade balance. It was also pointed out that the Federal Government has experienced great difficulty in stimulating innovations for use in the commercial sector.

Technology and International Trade Competitiveness

Witnesses presented evidence that the United States competitive position in international trade is deteriorating relative to our foreign competitors. Increasing peneration of domestic markets by foreign producers and decreasing world market share were cited as indicators.

Many witnesses were concerned that the United States is losing its position of technological superiority that contributed to its favorable trade position in the past. However, it was pointed out that the state of American industrial technology as a whole is probably not deteriorating, but rather that a few U.S. industries are in a vulnerable position while other U.S. industries continue to lead the world.

Some witnesses blamed our nation's decreasing technological lead on declining R&D funding; others pointed to the decline in Federal R&D funding in particular. Statistics were cited showing that U.S. R&D funding is declining relative to our trade competitors.

One witness argued that the export of technology by U.S. multinational corporations hurts the U.S. technological position. Other witnesses, however, argued that the opportunity to export technology, make foreign investments, and sell licenses induces firms to engage in R&D programs that would not be justified otherwise, thus enhancing U.S. innovation.

Witnesses testified that the United States balance of trade is favorable in products that are R&D-intensive, and generally unfavorable in products that are not. One area of trade weakness in R&D-intensive products, however, is in our $3.6 billion trade deficit in 1977 with Japan in high-technology goods, mostly accounted for by imports of consumer electronics goods.

Witnesses cited studies that show a positive and significant relationship between R&D expenditures and trade performance. Although it is unlikely that larger R&D spending would improve our trade position in the short-run, it could have a positive effect in the long-run.

There was some debate about the relative importance of Federal R&D spending to trade performance. It was pointed out that Federal R&D has often played a significant role in the development of innovations that were later successful in international commercial markets. However, it was private industry that made use of that technology and adapted it for commercial markets. Results of a preliminary study show that Federal R&D spending may be more strongly related to trade competitiveness than total R&D spending.

Witnesses noted an increasing tendency for U.S. industrial firms to "export" technology, through foreign direct investment, licensing of production technology, and other transfers of technological "know how." In some this gave rise to fears that these activities substantially substitute for U.S. exports or lead to a relative gain in other countries' technological capabilities. Other witnesses argued that technology transfer is not necessarily detrimental to the United States and in fact may have important economic benefits by enhancing U.S. exports.

Much of the concern about technological lag is generated by the tremendous increase in imported manufactured goods. Some witnesses argued that such imports hurt American business and eventually contribute to the further deterioration of U.S. technological capability. The reasons given for the success of our trade competitors in penetrating the domestic U.S. market were primarily their high motivation and their growing economies. In the few cases where U.S. imports represent superior technology abroad, this has also been accomplished through their high motivations for export success and their growing economies which enable them to install new technology.

Government Policies that May Inhibit Innovation

A wide variety of Federal policies that may act to inhibit innovation were identified by the witnesses. The policies that were discussed were: tax policy, regulation, securities regulation, import policies, price controls, antitrust, and Government patent policy.

Recommendations

All of the witnesses believed that the Federal Government has an important role to play in correcting the problems of declining R&D and innovation, economic growth and productivity, and international trade. Most of the witnesses believed the most appropriate Federal role is to stimulate private industry funding for R&D instead of direct Federal R&D funding. Of those who preferred direct Federal funding, most believed it should be concentrated in the basic research end of the spectrum of innovation activities. Possible incentives for innovation that were discussed were: tax incentives, antitrust, subsidies, procurement, regulation, Government patent policy, and loans and loan guarantees. Some witnesses felt that small, high-technology firms deserved special assistance.

In the area of international trade policy, most of the witnesses opposed additional Government controls over exports and imports. They recommended, instead, programs to stimulate innovation in U.S. industry which would in turn increase its competitiveness in international markets.

Some witnesses recommended formulation of a national policy for innovation or massive governmental reorganization to put one department in charge of industrial innovation. These suggestions were greeted with skepticism by other witnesses who argued that such efforts would not be effective.

The wide range of problems identified and the variety of viewpoints expressed during these hearings should provide a useful base of informed opinion for further consideration of innovation-related issues.

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